BC HYDRO DAM IMPACT FOOTPRINT REVIEW – WHITEFISH, WESTSLOPE CUTTHROAT TROUT, COTTIDS, CYPRINIDS & CATOSTOMIDS

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EXECUTIVE SUMMARY

The Columbia River drainage in British Columbia has been significantly altered by dams built on the major rivers and some of their tributaries for hydroelectric power production and flood control. Eleven of the dams within the basin are under the jurisdiction of BC Hydro. The Fish and Wildlife Compensation Program – Columbia Basin (FWCP) was established in 1995 to offset impacts resulting from construction of BC Hydro dams. It delivers conservation and enhancement projects for fish and wildlife on behalf of its program partners with funding provided by BC Hydro.

To quantify the extent of the footprint impacts of construction of BC Hydro dams in the Columbia River watershed on fish and wildlife, the FWCP initiated a dam impacts project. Major components include: pre-impoundment mapping, a primary productivity assessment, quantification of physical habitat losses and gains, and evaluation of population impacts for specific fish species.

This report provides a summary, where possible, of the impacts to species of fish that were of lower importance to fisheries managers at the time of dam construction, and the compensation options that are available to limit these impacts. In general very little is known about the impacts on these relatively unstudied species. At the very least a significant amount of river and stream habitat was inundated with dam construction, and the loss of this habitat requires some level of compensation on the part of BC Hydro. Given that such limited data exists on these species, distribution, inventory, and life history work is a major compensation option that will allow for more informed decisions about future management of fish species, particularly those at risk.

Key Words: dam impacts, biodiversity, compensation, fish, lake, reservoir, stream, river.

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INTRODUCTION

The Columbia Basin is home to representatives of over half of British Columbia's freshwater fish species. This region contains a total of 43 fish species of which 27 are native to the area and 9 are endemic. There are many historic and contemporary pressures on these species including, but not limited to, habitat loss, the introduction of exotic species, eradication programs and impoundments.

Since the beginning of the twentieth century the Columbia Basin has seen dams built on the majority of its major water courses. These dams have blocked migration routes, altered flow regimes and facilitated other substantial anthropogenic effects on freshwater fish. Eleven of the dams within the basin are under the jurisdiction of BC Hydro (Table 1). The dam footprint area are those watersheds impacted by the dams within the Canadian portion of the Columbia River. The Fish and Wildlife Compensation Program – Columbia Basin (FWCP) was established in 1995 to offset impacts resulting from construction of BC Hydro dams. It delivers conservation and enhancement projects for fish and wildlife on behalf of its program partners with funding provided by BC Hydro.

This review describes, where possible, the impacts that impoundment has had upon 19 species of native freshwater fish in the Columbia Basin. The majority of these species are fish that have traditionally been known as non-sportfish types. Historically this has meant that they were generally ignored or in some cases eradicated, often systematically, from specific waterbodies. Therefore quality quantitative assessments of abundances, distributions and life histories are often missing for the pre-impoundment period.

Table 1. Dam units and dates of construction for dams in the Columbia River basin. Areas of reservoirs are during the growing season.

Dam Unit	Location	Dam	Year Completed	Lake/Reservoir Area (km^2)
C1	Columbia - Donald	-	-	-
C2	Spillimacheen River	Spillimacheen	1955	0.01
C3	Donald - Mica	Mica	1973	370
C4	Mica - Revelstoke	Revelstoke	1984	114.5
C6	Cranberry Creek	Walter Hardman	1959	-
C8	Whatshan Lake	Whatshan	1952	17.6
C9	Keeleyside - U.S.A.	-	-	-
C10	Pend d' Oreille	Seven Mile	1979	4.1
C11	Arrow Lakes	Keenleyside	1968	476
K1	Kootenay – Wardner	-	-	-
K2	Bull River	Aberfeldie	1922	0.12
K3[a]	Wardner – U.S.A.	Libby[a]	1972	60[a]
K4	Elk River	Elko	1924	0.18
K5	U.S.A. – Kootenay Lake	-	-	-
K6	Kootenay Lake	Corra Linn[b]	1939	394
K7	Duncan River	Duncan	1967	65
K8	Lower Duncan - Lardeau	-	-	-
K9	Corra Linn - Brilliant	Kootenay Canal and four non-BC Hydro dams	1976	0.5

[a] Libby Dam is operated by the Bonneville Power Administration (BPA); area is for Canada only.
[b] Corra Linn dam is owned by Fortis BC but forms the control structure for the Kootenay Canal power plant owned by BC Hydro.

WHITEFISH POPULATIONS IN THE BC HYDRO DAM FOOTPRINT IMPACTS AREA

Introduction

The whitefishes are in the family Salmonidae but belong to a separate subfamily, the Coregoninae. In the BC Hydro dam footprint area within the Columbia Basin we have two native species of whitefishes: the mountain whitefish (*Prosopium williamsoni*), and the pygmy whitefish (*Prosopium coulterii*). There is also a third species of introduced whitefish, lake whitefish (*Coregonus clupeaformis*), which will not be discussed in this review. There are several populations occurring in large lakes (Arrow, Kootenay) that were introduced from eastern Canadian populations. Like many salmonids, whitefish often exhibit morphological polymorphisms and plastic life histories that depend on environmental conditions.

Both our whitefish species occur as lacustrine and fluvial populations; however, in our area the mountain whitefish is primarily a fluvial species and lacustrine populations are relatively uncommon. In contrast, the pygmy whitefish is primarily a lacustrine species but there are fluvial populations in cold, glacier-fed rivers.

The pre-impoundment distributions and abundances of whitefish are poorly known; however, there are pre-impoundment records of both species in the UBC Fish Museum, and in general the species was abundant in most systems that were surveyed. Despite the general lack of pre-impoundment data, both of these species probably have been affected by the following footprint impacts (as defined in Appendix A): i) construction impacts related to sediment and water quality; ii) habitat loss; iii) nutrient and/or contaminant effects related to flows released from the reservoir; iv) reduction in natural turbidity levels due to interception of sediment in reservoirs; v) fragmentation and loss of habitat connectivity at the landscape level (barriers to fish movement and migration); and, vi) fish entrainment and loss of fish. These impacts are discussed further below.

Life History of Native Species

Mountain whitefish (Prosopium williamsoni)
Mountain whitefish occur in virtually every major reach of the Columbia and Kootenay rivers, and in many of the tributaries to these systems as well. They can be found both above and below natural barriers, and are highly adapted to the cold and turbid water that is found throughout the region. Adults live in both lakes and a wide variety of streams and rivers. In large lakes they are often mistaken for the lake whitefish (an introduced species). This is because in large lakes like Kootenay Lake, their body shape closely resembles the body shape of lake whitefish (e.g. they are deep bodied and slab-sided, while in contrast, fluvial populations are round in cross-section).

Additionally, fluvial populations of this species often exhibit striking polymorphism in head shape — one form has a normal snout, whereas the other form has an elongate snout. This polymorphism in snout size and shape are related to differences in diet and foraging behaviour

(Troffe 2000; Whiteley 2007). The two forms often occur together and both occur within the BC Hydro dam footprint area. Currently, there is little conservation concern for this species; it is not listed by either COSEWIC or the BCCDC; however, in British Columbia, it is a locally important recreational species.

Spawning

Most mountain whitefish spawn in riverine environments although some shore spawning occurs in large lakes (e.g. Kootenay Lake) (McPhail 2007). Falling water temperatures in the fall cue whitefish spawning. In the Columbia River spawning may not occur until January or February. Apparently, spawning occurs at dusk or at night. There is no site preparation and eggs and sperm are released over coarse gravel substrates. The eggs are demersal and lodge in interstices in the substrate. Average egg size is about 3.5 mm and they incubate over winter. The fry emerge in the early spring.

Rearing

Newly emerged mountain whitefish are typically found in shallow water over a substrate of sand or other small fines. Juveniles are associated with inshore habitats in lakes and glide or run habitats within rivers. As they grow, they move into faster, deeper water. Their biology in lakes is poorly known.

Overwintering

Similar to westslope cutthroat trout, mountain whitefish make extensive migrations to over-wintering sites. Such sites usually consist of deep pools with some ground water input. Dam construction has likely isolated populations of whitefish although no studies have elucidated their putative population structure within the Columbia Basin.

Feeding

In rivers, mountain whitefish forage primarily on drifting aquatic insects; however, in lakes they feed on both plankton and benthic organisms. The two trophic forms of this species (the longnosed "pinocchio" form and the shortnosed "normal" form often coexist and differ somewhat in their diet and behaviour (Troffe 2000).

Pygmy whitefish (Prosopium coulterii)

In most of this species' native range it occurs in large deep lake environments; however, in the upper Columbia system it is relatively common in cold, turbid rivers (e.g., the type locality, the Kicking Horse River). The life history and habitat use of these fluvial populations have never been studied, and apparently fluvial populations are rare elsewhere. Consequently, these upper Columbia fluvial populations may be of special interest. It is likely that the pre-impoundment ranges of these fluvial populations within the BC Hydro dam footprint area were fragmented by dams.

Although the pygmy whitefish is widely distributed throughout the Columbia Basin, there is little information on the status of these populations. Current and historical sources of information (especially on fluvial populations) are unavailable for British Columbia. The pygmy whitefish appears to be common in the lakes and rivers of the upper and lower Columbia River and

Kootenay River systems. Little is known of their specific habitat requirements although cold (<10°C) water temperatures probably are necessary for them to complete their life cycle and influence their distribution. In lakes, pygmy whitefish are generally found in deep water but seasonally may occupy shallower littoral habitats. Their depth distribution in lakes can be influenced by the presence of other *Prosopium* species (McCart 1965) most likely through competitive segregation.

Although, pygmy whitefish do not have any federal conservation listing, they are listed provincially as S4/S5 (apparently secure/demonstrably widespread, abundant, and secure). However, this listing was based on lacustrine populations. Over the species' entire distribution, fluvial populations are rare. Nonetheless, in our area fluvial populations are moderately common. Consequently, as more information becomes available on our fluvial populations, the BCCD listing could change.

Spawning
Spawning takes place sometime between September and January. Very little is known about the reproductive habitat use or requirements of adult pygmy whitefish spawning, however, lacustrine populations are known to spawn in inlet streams and they also may spawn along lake shores (Hallock and Mongillo 1998). Presumably pygmy whitefish scatter their eggs over coarse gravel similar to other species in the genus. The eggs are smaller than other *Prosopium* spp. and are about 2.5 mm in diameter. In all probability, the eggs incubate over winter and the fry emerge in the spring.

Rearing
The early life history of pygmy whitefish is still a mystery and there are no published observations on habitat use in fluvial populations. In northern BC, by midsummer they occur in large numbers in inshore shallow waters. Pygmy whitefish mature early; typically at age 1 to 2 for males and age 2 to 3 for females (Hallock and Mongillo 1998).

Overwintering
In lakes they probably move into deep water in the fall. Where the fluvial populations overwinter is unknown.

Feeding
In rivers they forage on the nymphs and larvae of aquatic insects but in lakes they include plankton in their diets.

Dam Footprint Impacts and Whitefish Populations

Habitat Loss
There were extensive losses of riverine habitats with the dam footprint area that have likely directly limited the amount of habitat available to whitefish. For a detailed summary of the estimated habitat lost overall and by dam unit see Thorley (2008). Basic summaries of habitat lost by dam unit are presented below.

Construction Impacts and/or Contaminant Effects
It is unknown what the construction impacts of dams in the study area may have been, but there is the possibility of contaminant effects.

Turbidity
As most whitefish (particularly mountain whitefish) live in water that is turbid from glacial runoff for at least some period of time during the year, it is likely that any short term increases in turbidity associated with dam construction had minimal immediate impacts on whitefish populations. It has been speculated however, that sediment slugs associated with dam construction may have filled in river and stream substrates below constructed dams. If this is the case there may be reproductive limitations in these areas due to habitat limitations (see Porto 2008).

Habitat Fragmentation
Fluvial populations of mountain whitefish may make extensive migrations for feeding spawning and overwintering. In all likelihood, the addition of impoundments in the Columbia Basin blocked movements of whitefish to feeding and spawning habitats for some of the large river populations.

Fish Entrainment and Loss of Fish
There are no quantitative studies on the entrainment of mountain whitefish through BC Hydro facilities, but it is likely that some significant amount of entrainment does occur where there are losses of fish (direct mortality) or displacement of fish downstream. These types of impacts on whitefish populations are being addressed through a entrainment group consisting of BC Hydro, BC Ministry of Environment, and Fisheries and Oceans Canada representatives. The issue also is largely an operational issue, and falls outside the scope of this footprint dam impacts study.

Water Quality (e.g. Temperature, TGP, DO)
There is no doubt that the construction of dams has altered the water quality characteristics of the rivers on which they were built. Water temperatures have generally become more stable, with cooler water temperatures in the summer, and warmer temperatures in the winter. There are also known impacts of hydroelectric operations and associated total gas pressure increases on whitefish, particularly in the Columbia River (Fidler and Miller 1997).

Status of Isolated Groups or Sub-Populations within the BC Hydro Dam Footprint Area

Spillimacheen - C2
Mountain whitefish occur above and below the dam on the Spillamacheen River however there appears to be no detailed information on the pre- or post-impoundment status of this population. In total 0.15 km (Thorley 2008) of this river was lost due to backflooding with the construction of the dam. There is the potential for entrainment through the dam turbines that would result in mountain whitefish mortality (but this would be considered an operational impact).

Donald-Mica - C3

Impoundment in this reach inundated several lakes (SA=24 km^2) as well as flooding 744 km of riverine habitat (Thorley 2008). Mountain whitefish appear to be well established within this reach and its associated tributaries. Petersen and Withler (1965) sampled all streams tributary to the Mica Reservoir footprint prior to the dam using rotenone, primacord explosive, seines and angling, and found large numbers of mountain whitefish in almost every stream sampled. A list of the streams supporting this species is provided in their report along with some information on how far upstream the species extended and their relative abundance. The species was/is an important component of the sport fishery (Ahrens and Korman 2004). Presence of pygmy whitefish in the samples is also recorded for some of the streams (Petersen and Withler 1965).

Pygmy whitefish were abundant in pre-impoundment collections from the Kinbasket River and associated lake. Surveys in 1998 confirmed their presence in the Canoe Reach area of the Kinbasket Reservoir (Westworth Associates Environmental Ltd. 1998).

Revelstoke Reservoir (Mica Dam to Revelstoke Dam) - C4

The Revelstoke Dam construction in 1984 flooded approximately 142 km of Columbia River mainstem and 128 km of tributary habitat (Thorley 2008). Mountain whitefish were very likely an abundant species within this reach prior to impoundment and were recorded at relatively high abundance in weir counts from several tributaries prior to the dam (Lindsay 1977). Early assessments of abundance showed declines of mountain whitefish in the reservoir by 1987 (Hirst 1991) most likely due to losses in spawning habitat availability.

Arrow Lakes - C11

The Arrow Lakes Reservoir which impounds over 110 km of the Columbia River between the Revelstoke and Hugh Keenleyside Dam currently provides habitat for a healthy population of mountain whitefish for the size of the reservoir. There was an additional loss of 181 km of tributary streams and river.

Intensive population studies in the short section of the Columbia River between the Revelstoke Dam and the town of Revelstoke found that mountain whitefish were the most abundant species sampled and estimated the population of adults in the area to be approximately 3,000 (Golder Associates Ltd. 2004**).**

Mountain whitefish comprise 2-3% of the total fish which are entrained through the HLK Dam (Hirst 1991).

Whatshan River - C8

Whatshan Lake, which has a natural upstream migration barrier preventing access from the Arrow Reservoir, has been impounded since 1951. Assessments from 1985 through 1987 show that mountain whitefish are present in gillnet surveys (Hirst 1991). A total of 7 km of riverine habtitat was lost due to construction of the dam.

Upper Columbia River (HLK Dam to Canada-U.S.A border) - C9

There was no habitat loss within this section of the Columbia River, although there were likely impacts to whitefish populations in this dam unit due to dam construction. This portion of the

Columbia River includes the confluences with the Kootenay River and the Pend d'Oreille River. Surveys conducted over a decade after the construction of the Hugh Keenleyside Dam show that mountain whitefish were the most abundant of the sport species encountered (Hirst 1991).

In 2001 BC Hydro began a Large River Fish Community Indexing Program in this dam footprint area. Mountain whitefish were identified to be suitable for use as index species in nearshore areas. Population estimates for mountain whitefish in the area between HLK Dam and the US border have declined from a 1991 estimate of 37,400 (95% CI: 33,200 to 42,300) to an assessment of 14,907 (95% CI: 7,043 to 34,400) made in 2001 (Golder Associates Ltd. 2002).

Pend d'Oreille (U.S.A. Border to Waneta Dam) - C10

The Canadian portion of the Pend d'Oreille River was impounded by the Waneta Dam near it's confluence with the Columbia River in 1954. Surveys conducted prior to the construction of the Seven Mile dam in 1974 show mountain whitefish presence within this reach. Surveys subsequent to the construction of Seven Mile Dam in 1979 show the continued presence of mountain whitefish within this reservoir (Hirst 1991). In total 16 km of stream were lost in this dam unit

Bull River - K2

Electrofishing, snorkelling and angling surveys in 1995 and 1996 found that mountain whitefish were the most prevalent sportfish in the lower Bull River (Ahrens and Korman 2004). They are also the most abundant salmonid in the upper Bull River as well. In total there was 3 km of the Bull River inundated with the construction of Aberfeldie Dam.

Koocanusa Reservoir - K3

Creel surveys undertaken in the Koocanusa (then called Libby) Reservoir in 1979 (June – August) report that mountain whitefish was the most abundant sportfish caught by anglers (Oliver 1980). Annual gillnet surveys by Montana agencies indicate, however, that the abundance of mountain whitefish has declined significantly since impoundment with consistently low catch rates since the late 1980s (Dunnigan et al. 2003). Construction of Libby Dam inundated 128 km of habitat in the Kootenay River.

Elk River - K4

Creel surveys in the Elk River upstream of the Elko Dam have consistently found that in excess of 74% of the total winter caught sportfish in this area were mountain whitefish (Martin 1983; Westover 1994; Heidt and Stalker 2007). The population appears stable, but there were habitat losses of 4 km of river habitat in the Elk River.

U.S.A. Border to Kootenay Lake - K5

No information is available as to the pre-impoundment status of mountain whitefish populations in this dam unit. Mountain whitefish accounted for a high proportion of catch in a 2001 survey of this section of the Kootenay River (Cope 2001). There was no river habitat lost in this dam unit, although there is likely some back flooding of this section of the Kootenay River with elevated Kootenay Lake levels and flow releases from Libby Dam.

Kootenay Lake and tributaries - K6
No pre-impoundment (Cora Lynn) assessments are available for this dam unit. Populations of mountain whitefish are extant in Kootenay Lake (Hirst 1991), and are likely fairly abundant.

Duncan Reservoir - K7
There is very little information on the pre-impoundment status of mountain whitefish in the Duncan Reservoir footprint area. Recent inventory surveys have found mountain whitefish in Duncan Lake tributaries nearly 30 years after impoundment (Timberland Consultants Ltd. 2000). They are also abundant in the reservoir proper itself. Approximately 125 km of stream habitat were lost with the construction of Duncan Dam

There is no information as to the presence or status of pygmy whitefish in the Duncan River system prior to dam construction in 1967. Observations within the upper Duncan River suggest that pygmy whitefish are present in some tributaries both above the dam (D.S. O'Brien, DFO, pers. comm.) and in areas below the dam.

Duncan River including Lardeau River - K8
Recent fish surveys in the Lower Duncan River and Lardeau River found that mountain whitefish were present and abundant in a variety of habitats (Hagen and Decker 2006). There has also been some recent radio telemetry work that identified seasonal movements between the lower Duncan River and the Lardeau River (Baxter 2007).

Cora Lynn Dam to Brilliant Dam - K9
There is no information on the status of mountain whitefish populations in this reach of the Kootenay River prior to the construction of Brilliant Dam in 1944. Natural upstream migration barriers (Bonnington Falls) effectively isolated fish in this reach from Kootenay Lake. Studies in the early 1980s suggest that mountain whitefish inhabit this dam footprint area in low abundances (Hirst 1991).

Compensation Options Related to Footprint Impacts for Whitefish

In the recently developed BC Ministry of Environment Conservation Framework that provides a set of science-based tools and actions for conserving species and ecosystems in B.C., both native species of whitefish are not identified as being species of concern. There is however limited data on both species within the dam footprint area, so it is unknown as to the status of these populations. As such, basic distribution, life history and biological data is limited, and it is likely that a long term understanding of the two species within the different areas of the footprint area is warranted.

<u>i) Determine adult whitefish distributions and biology within the BC Hydro dam footprint area</u>

Action items:

1. Presence/absence studies.
2. Information on habitat use and biology for fluvial populations should be gathered (particularly for the pygmy whitefish).

Summary and Conclusions

The extent of the impact of dam building and reservoir filling upon whitefish populations in the BC Hydro dam footprint area is largely unknown. Both of these species may make local migrations to preferred spawning areas (Morrow 1980) and impoundments could have fragmented populations.

Mountain whitefish are an abundant sportfish in most of the reaches in which they occur. Current provincial regulations allow a daily catch quota of 15 individuals for all whitefish species combined. For most populations this should be a sustainable harvest although smaller isolated populations could be disproportionately impacted, but the harvest levels suggest that it is believed whitefish are generally not at a level of conservation concern.

Whitefish may be vulnerable to predation from exotic fish species and may become extirpated from some lakes as has happened in Washington State (Hallock and Mongillo 1998). *Prosopium* and pygmy whitefish in particular, are a sensitive coldwater stenotherm (narrow range of temperature requirements). In lakes they prefer deeper (> 10 m) and colder (< 10 °C) waters that serve as refuges from predation.

Our knowledge gaps remain the most acute for the biology of fluvial pygmy whitefish. This species' biology is poorly known. They are usually viewed as glacial relicts and their habitat is characterized as deep oligotrophic lakes. However, most of the populations in the upper Columbia are fluvial, which is a unique biological situation. Their habitat use and biology are completely unknown. Any increase in our understanding of this species will help in its future management, and in understanding the potential impacts of hydroelectric facilities on this species.

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WESTSLOPE CUTTHROAT TROUT POPULATIONS IN THE BC HYDRO DAM FOOTPRINT IMPACTS AREA

Introduction

Westslope cutthroat trout (*Oncorhynchus clarki lewisi*), a subspecies of cutthroat trout, has a native distribution centered in southeastern British Columbia in the Columbia Basin. This trout also occurs in Alberta, and south into Oregon and the eastern slope of the Cascade Mountains in Washington.

Westslope cutthroat trout populations in the FWCP dam footprint area occur primarily in the upper Kootenay River drainage and its major tributaries, but there are isolated populations mostly above barriers in some upper Columbia River and lower Kootenay River systems (COSEWIC 2006). Little or no pre-impoundment data on the distribution and status of this endemic trout exists for the Columbia and Kootenay regions. Recent molecular analyses have shown that hydroelectric dams have further isolated many headwater populations from the effects of hybridization with introduced rainbow trout (*Oncorhynchus clarkii*) (Rubidge and Taylor 2005). Populations that are sympatric with rainbow trout, however, show extensive genetic evidence of hybridization (Rubidge et al. 2001).

This subspecies of cutthroat trout has come under considerable conservation pressure throughout its range because of habitat loss, genetic introgression and competition with non-native salmonids (Shepard et al. 2005). In British Columbia the westslope cutthroat trout is blue listed (species of special concern) by the BC Conservation Data Centre while in Alberta the species has been designated Threatened (i.e., likely to become endangered if limiting factors are not reversed). The species has been put under review in Canada under the Species at Risk Act (SARA) and in the United States populations of nonhybridized westslope cutthroat trout have been proposed for protection (Allendorf et al. 2004) although how strict the definition of "nonhybridized" will be remains under discussion (Campton and Kaeding 2005).

In the BC Hydro dam footprint area, westslope cutthroat trout are likely impacted by the following footprint impacts (as defined in Appendix A): i) construction impacts related to sediment and water quality; ii) habitat loss; iii) nutrient and/or contaminant effects related to flows released from the reservoir; iv) reduction in natural turbidity levels due to interception of sediment in reservoirs; v) fragmentation and loss of habitat connectivity at the landscape level (barriers to fish movement and migration); and, vi) fish entrainment and loss of fish. These impacts are discussed further below.

Life History

Spawning

May and June are the typical months for spawning for this species. Rising water temperature and water levels cue spawning migrations. Spawning in westslope cutthroat trout populations occurs primarily in smaller tributary streams or lake outlets. Females select redd sites primarily in glide tail-outs where water velocity is low and depth is shallow. Historical spawning sites are unknown for westslope cutthroat trout populations in the FWCP dam footprint area. Impoundment may have inundated preferred spawning grounds however the BC Hydro facilities that are on rivers with westslope cutthroat trout populations are all "run of the river" facilities. A far larger impact undoubtedly resulted from the construction of the Libby Dam in the United States with the 145 km long Koocanusa reservoir flooding extensive areas of the Kootenay drainage.

Rearing
Fry and juveniles typically occupy stream margin areas of low velocity and complex cover (McPhail 2007).

Overwintering
Similar to other salmonids, cutthroat trout adults require ice free areas with groundwater influence. Adults prefer pool habitats and juveniles will shelter within instream structures or off-channel habitat (COSEWIC 2006). Flooding from dam construction may have eliminated some of this preferred habitat forcing fish into sub-optimal habitat or into contact with other species.

Feeding
Westslope cutthroat trout are primarily an insectivore feeding species. Adults will target winged insects while in the lacustrine environment they may also eat zooplankton. It is unlikely that the impoundment effects on adult feeding patterns were substantial.

Dam Footprint Impacts and Cutthroat Trout Populations

It is clear that dam construction in the Columbia Basin has isolated westslope cutthroat trout populations that were once potentially able to interbreed given the species ability to migrate long distances (Schmetterling 2001).

Habitat Loss
Westslope cutthroat trout have to ability to occupy a wide range of habitats including lakes, large rivers and small streams. The species, however, has relatively strict habitat requirements within its various life stages. Overall, they have need of clean cold waters and relatively complex habitat (COSEWIC 2006).

The specific impoundment effects of dam construction are unknown for westslope cutthroat trout. Flooding certainly had a strong impact on all life stages, particularily in the Kootenay River above Libby Dam. There is also the potential that dams on the mainstem Columbia River impacted westslope cutthroat trout populations on the upper Columbia (Oliver 2009).

Construction Impacts and/or Contaminant Effects
It is unknown if there were any construction impacts and/or contaminant effects on westslope cutthroat trout populations that were associated with the construction of BC Hydro facilities. These were likely limited however as these facilities were all built on natural barriers (i.e., Elk River, Spillamacheen River and Bull River).

Turbidity
Unknown, but likely limited.

Habitat Fragmentation
Westslope cutthroat trout show a wide variety of movement patterns related to spawning, feeding, overwintering and life history changes (COSEWIC 2006). Many of the rivers and streams in the Columbia Basin historically contained naturally occurring barriers to migration that were augmented by dam construction. While the populations above these barriers remained relatively unaffected, dam construction likely affected the movements and/or migrations to spawning, rearing, overwintering, and feeding habitats for downstream populations. Two of the facilities affecting cutthroat trout populations (Elko and Aberfeldie) are run of the river facilities which likely minimize downstream habitat effects. Population subdivision can have several deleterious effects. Small population may be subject to founder effects or genetic drift when their access to the larger meta-population is restricted. Furthermore, the effects of introgressive hybridization with other species may be heightened when the population is small.

Fish Entrainment and Loss of Fish
Although the impacts of entrainment are unknown for westslope cutthroat trout populations, there is likely some mortality associated with the potential diversion of fish down penstocks and through turbines.

Water Quality (e.g. Temperature, TGP, DO)
Stream temperatures are an essential habitat parameter for cold water salmonids like westslope cutthroat trout (COSEWIC 2006). In the Columbia Basin the ability to access colder, higher elevation areas of habitat is critical for the species.

Impoundments within the Columbia River have created changes to the thermal regimes both downstream of dams and within the reservoirs (Hamblin and McAdam 2003). Downstream reaches below two of the major reservoirs in the dam footprint area showed elevated water temperatures during the warming phase (spring and summer) of the year compared with pre-impoundment data. Additionally, both the inflow regime and thermal profile of the reservoirs were significantly modified by dam construction.

Westslope cutthroat trout have some of the lowest upper tolerance limits and optimal temperature range of any fish within the Columbia River Basin.

Status of Isolated Groups or Sub-Populations within the BC Hydro Dam Footprint Area

Spillimacheen - C2
The status of westslope cutthroat trout in this system is unknown. In total 0.15 km (Thorley 2008) of this river was lost due to backflooding with the construction of the dam.

Bull River - K2
Several iterations of impoundment have been built on the Bull River since 1922. A large set of falls and velocity barriers below the dam site have likely kept fish populations in this dam footprint area relatively isolated apart from human introductions. Cutthroat trout populations have been found above the Aberfeldie Dam in several post-impoundment surveys (Hirst 1991; Taylor et al. 2003). Genetic data analyses have shown this population to be pure westslope cutthroat trout having no evidence of hybridization with rainbow trout (*Oncorhynchus mykiss*) (Rubidge and Taylor 2005). In total there was 3 km of the Bull River inundated with the construction of Aberfeldie Dam.

Elk River - K4
The Elko Dam constructed in 1924, isolated fish populations which were already likely separated by natural upstream migration barriers. In the Elko Dam footprint area westslope cutthroat trout assessments were not made prior to impoundment. Recent studies have shown that there are some pure westslope cutthroat trout populations in the upper Elk River however samples from some tributaries to the Elk River did show evidence of hybridization (Rubidge and Taylor 2005). This would suggest that rainbow trout have in the past been stocked into the Elk River drainage after the dam was built. There were habitat losses of 4 km of river habitat in the Elk River.

Creel surveys in the Elk River upstream of the Elko Dam have been conducted for over two decades. Results from these data sets show that westslope cutthroat trout are the second most abundantly caught species after mountain whitefish (Martin 1983; Westover 1994; Heidt and Stalker 2007).

U.S.A. Border to Kootenay Lake - K5
There have been no assessments of the population status of westslope cutthroat trout within this dam footprint area prior to the construction of the Libby Dam. Cope (2001) found evidence of cutthroat trout in the lower Goat River, and they are known to be present in the upper Goat River above a barrier.

Kootenay Lake and tributaries - K6
Westslope cutthroat trout are present in some tributaries to Kootenay Lake (Timberland Consultants Ltd. 2000), primarily in upper reaches above waterfalls where they may have been stocked.

Compensation Options Related to Footprint Impacts for Cutthroat Trout

In the recently developed BC Ministry of Environment Conservation Framework that provides a set of science-based tools and actions for conserving species and ecosystems in B.C., westslope cutthroat trout were identified as being a species of special concern, and a high priority across the three goals of framework. Identified actions in the framework that would fall within the mandate of Fish and Wildlife Compensation Program include detailed assessment, habitat management where appropriate (e.g., habitat construction), other non-habitat management (e.g., predator control, captive breeding) where required, and integrated planning. There is however limited data on many populations within the dam footprint area, so it is unknown as to the status of these populations. As such, basic distribution, life history and biological data is limited, and it is likely that a long term understanding of populations within different areas of the footprint area is warranted.

i) Assess and protect cutthroat trout spawning and rearing habitat

Action items:

1. Identify critical streams or lake outlets used by lacustrine populations, especially within the dam impact area.

ii) Monitor and protect isolated headwater cutthroat trout populations

Action items:

1. Identify and protect critical spawning and overwintering habitats from degradation.
2. Monitor and prevent rainbow trout introductions to isolated westslope trout cutthroat populations.

Summary and Conclusions

Irrespective of impoundment effects, populations of pure westslope cutthroat trout are already under pressure from many of the problems impacting coldwater native salmonids – hybridization and habitat loss. Dam construction likely exacerbated these impacts to some degree but the full extent to which they contributed is unknown.

Population fragmentation from dam construction in many cases may have been beneficial for populations that were originally isolated or partially isolated from other salmonids. The few remaining populations of pure westslope cutthroat trout that remain above impoundments may act as a genetic repository while downstream populations become more introgressed through hybridization with rainbow trout.

Given the distribution of westslope cutthroat trout in the Columbia Basin, the construction of BC Hydro dams may have altered or flooded spawning, rearing, and overwintering areas in the basin. The exact distribution of habitat loss and alteration likely varied by the historical distribution of cutthroat as well as the specific local channel morphology. It is likely however that the direct loss of westslope cutthroat trout habitat is limited.

Some fairly comprehensive studies of the genetics of westslope cutthroat trout in the Columbia Basin have already been undertaken (Rubidge et al. 2001; Rubidge and Taylor 2005). Introgression between westslope cutthroat trout and rainbow trout appears to be increasing at least in the upper Kootenay River. Introductions of rainbow trout to the Koocanusa reservoir and its tributaries are likely the primary factor in this problem. Where possible, introductions should be discouraged or stopped. Those populations of pure westslope cutthroat trout that have been identified should be placed at a higher priority for conservation, one such example is the upper Bull River that has been identified as being a genetically pure population.

Habitat loss remains an extremely important issue facing populations of westslope cutthroat trout. Timber harvesting and other forms of resource extraction can introduce fine sediments into critical spawning areas that can have deleterious effects on sensitive eggs and alevins. Roads and culverts can change channel morphology and block access to critical habitat areas.

An effective conservation plan for westslope cutthroat trout in the BC Hydro dam footprint area will require a population by population synthesis of the limiting factors in play. Habitat loss, overharvesting, and nonnative introductions are all critical factors that place differential pressure upon extant populations. Conservation priority should be placed on genetically pure westslope cutthroat populations. Integration of traditional conservation methods with modern genetic techniques may be the most effective way to address the declines in this species.

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SCULPIN POPULATIONS IN THE BC HYDRO DAM FOOTPRINT IMPACTS AREA

Introduction

Five species of sculpins (Family Cottidae) occur in the BC Hydro Dam Footprint area — the prickly sculpin (*Cottus asper*), the slimy sculpin (*Cottus cognatus*), the shorthead sculpin (*Cottus confusus*), the Columbia sculpin (*Cottus hubbsi*), and the torrent sculpin (*Cottus rhotheus*). Traditionally, sculpin taxonomy has been difficult and the nomenclature of species is often confusing. Recently, molecular and morphological research has begun to untangle the species boundaries and nomenclature problems (Kinziger et al. 2005). Nonetheless, more changes probably will occur before a stable taxonomy is achieved.

All of the sculpins in our area are nocturnal and usually shelter in the substrate during the day; however, both the prickly and torrent sculpin sometimes forage during the day. Adults of both of these species have big mouths, are highly predaceous, and include small fishes in their diet. The other three species have smaller mouths and forage primarily on the larvae and nymphs of aquatic insects. The five species also differ in their habitat use. Prickly sculpins occur in lakes, large rivers, and streams. Generally, they are a quiet water species, and in streams they are usually found in pools. In large rivers like the Columbia and Kootenay, they occur in moderate currents over cobble bottoms during the day and move into quieter water at night. In lakes and reservoirs, prickly sculpins can occur at depths ranging from the littoral zone down to 100 or more metres. In contrast, the torrent sculpin usually is associated with fast water in rivers and streams; however, in our area it also occurs in lakes. The other three sculpins (slimy, Columbia, and shorthead) appear to be primarily fluvial species.

The pre-impoundment distributions and abundances of sculpins are poorly known, however, there are pre-impoundment records (UBC Fish Museum) of prickly, slimy, and torrent sculpins from the area covered by the BC Hydro Dam footprint. There are no pre-impoundment records of shorthead or Columbia sculpins from our area; however, both species have a tangled taxonomic history and it is possible that there are records of these species listed under different scientific names. Both of these species have geographically restricted distributions in our area — the Columbia River below Hugh Keenleyside Dam (HKD) and the lower Kootenay River and its tributaries below Bonnington Falls.

Despite the lack of pre-impoundment information, all of these sculpins probably have been affected by the following footprint impacts (as defined in Appendix A): i) construction impacts related to sediment and water quality; ii) habitat loss; iii) nutrient and/or contaminant effects related to flows released from the reservoir; iv) reduction in natural turbidity levels due to interception of sediment in reservoirs; v) fragmentation and loss of habitat connectivity at the landscape level (barriers to fish movement and migration); and, vi) fish entrainment and loss of fish. These impacts are discussed further below.

Life History of Native Species

Prickly sculpin (Cottus asper)
The prickly sculpin has a moderately wide range in our area: its native distribution in the upper Columbia drainage was from the US border upstream to at least the present site of Mica Creek Dam, and in the Kootenay River and tributaries upstream to Bonnington Falls. Like many other species, there are two forms of the prickly sculpin in BC: a coastal and an interior form. The two forms differ in their prickle pattern (Kresja 1967) and their physiology (Bohn and Hoar 1965). There also is some evidence of molecular differentiation between the forms (McPhail 2007). Consequently, there also may be ecological and behavioural differences between the coastal and interior forms and the ecology and life history of the interior form has not been studied. Since most of the following life history information is based on the coastal form, some caution should be used in extrapolating information derived from coastal prickly sculpins to the prickly sculpins in our area. Prickly sculpin is not a listed species. Nevertheless, the coastal and interior forms probably would qualify as separate DUs (Designated Units) if reviewed by COSEWIC. It is not clear whether this would affect the conservation status of the interior form.

Spawning
Prickly sculpins spawn in the spring (April to late June on the coast but probably later in the Columbia area). Like most sculpins, the males are territorial and defend a spawning site. Normally, spawning sites are cavities beneath rocks. Usually the male excavates the cavity but they will use almost any site with overhead cover (e.g., old tires, tin cans, bottles, and cavities in logs). The spawning behaviour of the interior form has never been documented but, presumably, it is similar to that of the coastal form. The male courts females (this courtship is quite elaborate and involves colour changes, sound production, and behaviour). Eventually, the female enters the nest and deposits her eggs on the ceiling of the nest cavity. The male then fertilizes the eggs and tends them until they hatch. The eggs are small (about 1.6-1.8 mm in diameter) and fecundity is high: a large female can produce up to 10,000 eggs. The males normally spawn with more than one female and some nests contain up to 30,000 eggs (Kresja 1967). The eggs take about two weeks to hatch at 12ºC.

Rearing
If the behaviour of newly hatched fry in the interior form is similar to that found in the coastal form, then the fry are unusual for interior sculpins — they are small (5.0-6.0 mm in total length) and are active immediately upon hatching. On the coast, fry are swept downstream into estuaries or lakes where they rear for a year before moving back upstream. This aspect of their life history may be maladaptive in higher gradient interior rivers and streams, and it is possible that in the interior form there has been selection for fry that burrow into the substrate. In some coastal lakes the fry remain pelagic for several weeks before settling to the bottom. It is possible that a similar prolonged limnetic phase may also occur in lake or reservoir-dwelling larvae. In the Columbia River below HKD newly metamorphosed young (about 12 mm in length) are common in shallow, seasonally flooded vegetated areas.

Overwintering
On the coast, young-of-the-year overwinter in quiet water (estuaries or lakes). As yearlings they move upstream and overwinter in pools. The adults also overwinter in pools and there may be

some separation among year classes that is driven by the adults preying on smaller individuals. In coastal streams, there is a tendency for body size to increase upstream. In winter in lakes, adults move from littoral areas into deeper water, and juveniles shelter in the substrate.

Feeding

Adult prickly sculpins are efficient crepuscular and nocturnal predators, and the coastal form often aggregates below salmon spawning sites and preys heavily on newly emerged salmonine fry and downstream migrants. It is known that the interior form also preys on small fish (Northcote 1954) but it is not known if this predation is a serious source of mortality on salmonine fry in lakes and reservoirs.

Larval prickly sculpins feed on microplankton. Young-of-the-year fish become benthic after they transform into miniature versions of the adults and the proportion of benthic prey in their diet increases as they grow. In streams, rivers, and lakes, juveniles forage primarily on the nymphs and larvae of aquatic insects.

Slimy sculpin (Cottus cognatus)

Although slimy sculpins are distributed throughout the BC Hydro dam footprint area, their distribution in the southern part of the area is fragmented. Apparently, slimy sculpins are absent from the Columbia River between HKD and the US border, and the Kootenay River below Bonnington Falls but are present in these systems above natural barriers. This may be a result of either the slightly warmer temperatures in these areas relative to the rest of the footprint area or a result of interactions with other sculpins. Regardless of the reasons, slimy sculpins in the Slocan drainage system (and in other areas where *C. confusus* and *C. hubbsi* occur) are absent below natural barriers but abundant above them. In contrast, in the Columbia and its tributaries above HKD, and in the Kootenay River and its tributaries above Bonnington Falls, slimy sculpins are the dominant stream-dwelling sculpin. They also occur throughout the Pend d’Oreille system.

Like the prickly sculpin, the slimy sculpin is not listed by either COSEWIC or the BCCD; however, their status could change. COSEWIC has not assessed this wide-ranging species — its native distribution extends from eastern Siberia across the breadth of North America, and from the Arctic Coast south to Idaho. In BC, there are at least two morphological forms (a northern and a southern form) as well as a morphologically intermediate form sandwiched between the northern and southern forms (McAllister and Lindsey 1960). Molecular studies of other species with similar wide geographic ranges (McPhail 2007) hint that such widely distributed species may represent complexes of several species. Consequently, the conservation status of the slimy sculpins in our area could change in the future.

Spawning

Normally, slimy sculpins spawn in the early spring (at water temperatures above 4ºC); however, in glacier-fed streams in the upper reaches of the Columbia system some individuals spawn as late as mid-August (McPhail 2007). Like most sculpins the males are territorial and excavate a nest under a rock. Again, the courtship is complex and involves colour changes and intricate behaviours. Once a female enters the nest she deposits her eggs on the nest roof where the male fertilizes them. The male guards and tends the eggs until they hatch. The eggs are about 2.5 mm in diameter and usually there are clutches from several different females in a nest. The eggs take about a month to hatch at low temperatures (Van Vleit 1964).

Rearing

Upon hatching the larvae burrow into the substrate where they remain for about two weeks, and then emerge as miniature copies of the adults. In the Great Lakes, however, the newly hatched young emerge as larvae and remain in the limnetic zone until fall when they transform and become benthic (Wells 1976). It is not known if this happens in the large lakes and reservoirs within the BC Hydro Dam footprint area; however, some flexibility in the early life history is common (see the rearing section under the torrent sculpin). In streams, young-of-the-year fish remain in edge environments and do not move into deeper and faster water until fall (Johnson et al. 1992).

Overwintering

Nothing is known about the overwintering behaviour of slimy sculpins in our area; however, in streams and rivers they probably shelter in the substrate during the winter but emerge at night to feed. In natural lakes, juveniles probably shelter at depths below the influence of ice action and emerge to forage at night. In contrast, adults probably occupy deeper water and remain active during the day (Brandt 1986).

Feeding

In flowing water, adult slimy sculpins forage mainly on the nymphs and larvae of aquatic insects. The major diet items found in newly transformed fry are chironomid larvae. The diet of lacustrine larvae is unknown but probably starts with microplankton and gradually shifts to chironomid larvae. In the Great Lakes, juvenile slimy sculpin (<35 mm) forage at night while adults in deeper water show no diel feeding periodicity (Brandt 1986).

Shorthead sculpin (Cottus confusus)

The shorthead sculpin has a restricted distribution in the BC Hydro Dam footprint area — it occurs in the mainstem Columbia River between HKD and the US border, and in the mainstem Kootenay River below Bonnington Falls. In both these rivers, however, it is rare in the mainstems and common in small to medium sized tributaries. In these tributaries, it is associated with the first one or two kilometres upstream from their confluence with the main river. Although, shorthead sculpins are found in high velocity areas in such tributaries, they are rarely found above the first natural barrier on these streams. The shorthead sculpin is listed as threatened by COSEWIC and S3 (rare or uncommon by the BCCD). Given its limited distribution in Canada, these listings are unlikely to change.

Spawning

In BC, the breeding season appears to be protracted: mid-May to mid-July. Like most sculpins the males are territorial and excavate a nest under a rock. The courtship is complex and involves colour changes and intricate behaviours. Once a female enters the nest she deposits her eggs on the nest roof where the male fertilizes them. The male guards and tends the eggs until they hatch. The eggs are large (about 3-3.5 mm in diameter) and most nests contain from one to four separate egg clumps. Presumably, these separate egg clumps represent the clutches of different females. Fecundity is low (50-200 eggs). At 10ºC, the eggs take about four weeks to hatch. After hatching, the larvae burrow into the substrate and remain hidden for about two weeks. They emerge as miniature copies of the adults.

Rearing
Upon emergence, the miniature sculpins move into edge habitats along stream margins. Like most of the other sculpins in our area, the newly emerged young are found in shallow, seasonally flooded areas where vegetation provides some cover. They remain in such areas until water levels begin to drop. At this time they shift into deeper areas but remain along the stream margins. In the fall they move into deeper water with higher surface velocities and gravel substrates. They probably remain spatially segregated from adults until they are large enough to avoid adult predation (Freeman and Stouder 1989).

Overwintering
Not much is known about the overwintering behaviour of this species; however, like other sculpins most individuals probably shelter in coarse gravel or among cobble during the day and emerge to forage at night (Dishoeck and Gebhart 2003).

Feeding
Adult shorthead sculpins are primarily insectivores and forage mainly on the nymphs and larvae of aquatic insects (Johnson et al. 1983); however, the stomachs of large adults sometimes contain fish (usually small sculpins). The major diet item found in newly transformed fry are chironomid larvae.

Columbia sculpin (Cottus hubbsi)
The Columbia sculpin is another sculpin with a confusing taxonomic history (Peden et al. 1989). In BC it has been identified as the mottled sculpin, *Cottus bairdii* and mistaken for both shorthead and Rocky Mountain sculpins. Its range in our area is restricted to the Columbia River from the US border upstream to HKD, and in the Kootenay River and tributaries upstream to Bonnington Falls. There is a dubious record (R.L.& L. 2001) from the Kinbasket Reservoir. This record is suspect as there are no confirmed records of this species above HKD. It is possible, however, that the Columbia sculpin did originally occur above the present site of the HKD. Certainly, the fact that this species occurs in the mainstem Columbia immediately below the present dam site suggests that it also could have been present upstream of the site. In our area, the Columbia sculpin is most common in the mainstem Columbia and Kootenay rivers. COSEWIC lists *C. hubbsi* as a species of concern and the BCCD lists it as S3 (rare or uncommon); however, these listing were established when this species was thought to be a western outlier of a common eastern species (*C. bairdii*). Now it is recognized as a distinct species that is endemic to the Columbia Basin. Consequently, it is possible the listing will be changed when the species is reviewed.

There is an additional problem involving another species (*Cottus bendirei*). Originally, this species was thought to be restricted to the Malheur Basin (an internal drainage in Oregon). It now appears that the species is more widespread than previously thought (Markle and Hill 2000) and may occur in B.C. (McPhail 2007). With one exception, all the BC records of sculpins that match the description of *C. bendirei* are from outside the BC Hydro dam footprint (the Similkameen system). The exception is a specimen from the Little Slocan River. Morphologically and molecularly this specimen matches *C. bendieri*. Consequently, a review of museum specimens from the mainstem Columbia and Kootenay rivers may turn up specimens of *C. bendieri* within the BC Hydro Dam footprint. When *C. bendieri* is assessed by COSEWIC and the BCCD, it will almost certainly be listed as either threatened or endangered.

<u>*Spawning*</u>
In BC, this species spawns from mid-May to mid-June. Like most sculpins the males are territorial and excavate a nest under a rock. The courtship is complex and involves colour changes and intricate behaviours. Once a female enters the nest she deposits her eggs on the nest roof where the male fertilizes them. The male guards and tends the eggs until they hatch. The eggs are large (average diameter is 2.8 mm) and most nests contain two or three separate egg clumps. Presumably, these separate egg clumps represent the clutches of different females. Fecundity is low (50-100 eggs). The incubation period is unknown but probably similar to other sculpins with large eggs. The larvae burrow into the substrate and remain hidden for about two weeks. They emerge as miniature copies of the adults.

<u>*Rearing*</u>
The newly emerged sculpins move into edge habitats along stream margins. Like most of the other sculpins in our area, the newly fry are found in shallow, seasonally flooded areas: however, unlike the other species Columbia sculpin fry appear to be most common in shallow embayments where there is little or no vegetative cover. They remain in such areas until water levels begin to drop and then shift into deeper areas but remain along the margins of large rivers like the Columbia and Kootenay rivers. In the fall they move into somewhat deeper water with higher surface velocities and sand-gravel substrates. They probably remain spatially segregated from adults until they are large enough to avoid adult predation (Freeman and Stouder 1989).

<u>*Overwintering*</u>
The overwintering behaviour of this species has never been studied; however, the Columbia sculpin was probably one of the species grouped as “sculpins” by (van Dishoeck and Gebhart 2003). In this study (conducted on the lower Columbia and Kootenay rivers during the winter) sculpins were relatively more common at night than during the day, and appeared to move into shallower water at night.

<u>*Feeding*</u>
Although adult Columbia sculpins are primarily insectivores and forage mainly on the nymphs and larvae of aquatic insects, they have relatively large mouths and often prey on small fishes (McPhail 2007). The major diet items for newly transformed fry are chironomid larvae; however, as they grow they add larger items to their diet.

Torrent sculpin (Cottus rhotheus)
Like the slimy sculpin, the torrent sculpin occurs throughout the BC Hydro Dam footprint area. In the Columbia River, it occurs to the very headwaters (Columbia Lake) and in the Kootenay system it is widely distributed above Bonnington Falls. The common name (torrent sculpin) is a

bit misleading. Over most of its geographic range (it is also a Columbia endemic), this species is associated with fast water, but in our area it also occurs in lakes and reservoirs and there is some evidence from its life history that it can adapt to lacustrine environments (see section on reproduction). The torrent sculpin has not been assessed by either by COSEWIC or the BCCD.

Spawning
In our area, this species spawns from mid-April to early June. Like most sculpins the males are territorial and excavate a nest under a rock. The courtship is complex and involves colour changes and intricate behaviours. Once a female enters the nest she deposits her eggs on the nest roof where the male fertilizes them. The male guards and tends the eggs until they hatch. The eggs are large (average diameter is about 2.8 mm) and most nests contain different coloured eggs at different stages of development. Presumably, these different coloured eggs represent the clutches of different females. Fecundity is moderate (50-500 eggs). The incubation period is unknown but probably similar to other sculpins that spawn large eggs.

Rearing
In streams, the larvae burrow into the substrate and remain hidden for about two weeks. They then emerge as miniature copies of the adults. They commonly occur in shallow, quiet edge environments over sand and silt substrates. The fry are usually found in, or near, vegetation. In contrast, in Columbia Lake this species nested under rocks along the gravely part of the lakeshore; however, when they hatched the larvae moved into the water column. They appear to remain in the water column until they are at least 15 mm long (in rivers the metamorphosed fry average about 12 mm). In Columbia Lake they disappear from the water column at about 15 mm but do not appear inshore for another two months. In late August they suddenly appear on the gravel beaches where they reside for at least a year (McPhail 2007).

Overwintering
During the winter in large rivers like the Columbia and Kootenay, torrent sculpins probably remain in deep water during the day (mostly sheltering in the substrate). Apparently, they become more active at night and move into shallower water (van Dishoeck and Gebhart 2003).

Feeding
Adult torrent sculpins have large mouths and are highly predaceous. Although they forage mainly at night, in areas where there are concentrations of cyprinid and sucker fry they often burrow into the soft substrate until only their eyes are visible. In this way they ambush small fishes and their stomachs are often swollen with fry. Along with the prickly sculpin, they are probably the most piscivorous of the sculpins in our area. Like most of our other sculpins, they usually start feeding on chironomid larvae; however, lake-dwelling populations with larvae in the water column may feed on microplankton. In streams, they add the nymphs and larvae of aquatic insects to their diet as they grow.

Dam Footprint Impacts and Sculpin Populations

Habitat Loss

Three of the sculpin species found in the BC Hydro Dam Footprint Area are capable of adapting to large lakes and, thus, may survive in reservoirs; however, two of our species (*C. confusus* and *C. hubbsi*) are primarily fluvial and probably were adversely affected by reservoir development. Since most sculpins spawn on riffles, the BC Hydro Dam footprint probably eliminated some spawning areas, and it is unlikely that the reservoirs created by the dams increased the amount of nursery area suitable for sculpins; however, downstream of the dams the changed hydrograph may have made more nursery areas. Although there is no way to quantify exactly what the impacts of reservoir formation and stream habitat loss were on sculpin populations in the dam impacts footprint area, there is no doubt that there were significant losses of habitat that would have had some impact on many fish that there is currently very little data or information on.

Construction Impacts and/or Contaminant Effects

Typically, dams are constructed at sites where rivers narrow and water velocities increase relative to those in less constricted parts of the rivers. Consequently, most dam sites probably are situated on good sculpin habitat. The temporary increases in sedimentation and degradation in water quality downstream of construction sites may have affected local sculpin populations; however, these effects were probably short term and unlikely to have had little lasting impacts on local populations.

Turbidity

Unknown impacts.

Habitat Fragmentation

Almost nothing is known about the migrations and movements of sculpins within the footprint area of BC Hydro dams; however, most sculpins are relatively sedentary (e.g., Bailey 1952; McCleave 1964) and generally their movements are small (< 1 km). Thus, it is unlikely that any major sculpin migrations were disrupted by BC Hydro dams. During both the summer and winter, fluvial sculpins appear to make short diel on-shore and off-shore movements (R.L.& L. 1995) and it is possible that HKD operations may cause some stranding, but this is largely an operational impact.

There is one consequence of dams that has some potential for conservation concern — the fragmentation of populations. Dams are barriers to gene flow (at least in the upstream direction). They subdivide populations and inevitably the subdivided populations are smaller than the original population. They are also a genetic subset of the original undivided population. This creates the possibility of founder effects.

For the widely distributed sculpins in our area (e.g., prickly, slimy, and torrent sculpins) stochastic processes like founder effects and genetic drift probably are not a concern (the original populations were probably large, even after subdivision). For the more narrowly distributed sculpins (especially the shorthead sculpin) in the lower Columbia, however, many tributary stream populations are small and gene flow among tributaries may be restricted.

Fish Entrainment and Loss of Fish
It is unknown what the impacts of entrainment are on sculpin populations but there is most likely some displacement and potential mortality of sculpins that must occur at some facilities. This impact would largely be considered an operational impact.

Water Quality (e.g. Temperature, TGP, DO)
Water temperature changes related to the construction of a dam can be significant both within the reservoir and downstream of the dam (Hamblin and McAdam 2003; Prowse et al. 2006). For sculpins, dam-related changes in the hydrograph and thermograph appear to have had little adverse effect.

Status of Isolated Groups or Sub-Populations within the BC Hydro Dam Footprint Area

Donald-Mica - C3
Torrent and slimy sculpins occur in this reach and it is possible that the prickly sculpin is also present. Potentially, these species could adapt to reservoir habitats; however, it is not clear that they actually have adapted to reservoir life. It is possible that once continuous populations are now fragmented. Abundance information for these species is needed. A total of 744 km of riverine habitat was flooded in this dam unit.

Revelstoke Reservoir (Mica Dam to Revelstoke Dam) - C4
The same three species of sculpins are present (or potentially present) in this reach and, again, it is not clear that they have adapted to reservoir life. A total of 142 km of the mainstem Columbia River was flooded, with an additional 128 km tributary habitat lost due to flooding.

Arrow Lakes - C11
Originally, at least three (and possibly four) sculpins occurred in this reach: prickly, slimy, torrent and perhaps Columbia sculpins. The populations of prickly and slimy sculpins do not appear to be in trouble. There is no data on whether torrent sculpins are still abundant in the reservoir. Although there are no records of Columbia sculpins in the reservoir area, it is unlikely that anyone has looked for them. A total of 291 km of river habitat was lost in this dam unit.

Whatshan River - C8
There appears to be no assessment of sculpin species or abundance in Whatshan Lake and its tributaries prior to impoundment in 1951. Apparently, there was a species assessment made in the river in the mid 1980s (Hirst 1991) with no mention of sculpins among the non-sportfish species that were sampled.

Upper Columbia River (HLK Dam to Canada-U.S.A border) - C9
The upper Columbia River portion extends 56 km from the Hugh Keenlyside Dam to the US border where the riverine habitat extends another 180 km to Roosevelt Lake and the Grand Coulee Dam. Fairly intensive studies have been undertaken in this portion of the river to monitor (index) population parameters of resident fish stocks (Golder 2002). Sampling methodologies which captured sculpins were only undertaken in the area of the confluence of the Columbia and Kootenay Rivers. These programs found three species of sculpins to occur within

this reach: prickly sculpin, torrent sculpin, and mottled sculpin. An attempt to develop abundance estimates for the sculpin species was abandoned due to low capture numbers.

U.S.A. Border to Kootenay Lake - K5
The impacts in this dam unit were likely minimal as there was no habitat lost and there are only slimy sculpins distributed in this section of river. Most impacts would be operational due to the change of flows through Libby Dam.

Kootenay Lake and tributaries - K6
As in dam unit K5, slimy sculpin are the only species distributed within this area, and as the species is fairly abundant and common, impacts are likely minimal.

Duncan Reservoir - K7
Within this dam unit, approximately 125 km of stream habitat was inundated with the construction of Duncan Dam. As only slimy sculpins are distributed within this dam unit and the species is fairly abundant, the impacts are likely minimal but unknown.

Duncan River including Lardeau River - K8
Recent night surveys have found the presence of slimy sculpins at a number of sites in lower Duncan River side channels (Hagen and Decker 2006). No habitat was lost in this dam unit due to inundation.

Cora Lynn Dam to Brilliant Dam - K9
Although it is unknown what the impacts of dam construction in this dam unit are on the native sculpin species distributed here, all the species of sculpin are likely found here, and at the very least have been isolated from the Columbia River populations.

Compensation Options Related to Footprint Impacts on Sculpins

In the recently developed BC Ministry of Environment Conservation Framework that provides a set of science-based tools and actions for conserving species and ecosystems in B.C., all species of sculpin in the study area were identified as having data limitations in order to make assessments on their status. As such, basic distribution, life history and biological data is limited, and it is likely that a long term understanding of species and populations within different areas of the footprint area is warranted.

<u>i) Determine current distribution of sculpins within footprint areas</u>:

Action items:

1. Presence/absence surveys. Special attention should be paid to lower Arrow and Kinbasket reservoirs.
2. Establishment of index areas to identify trends in abundance.
3. Survey both the lower Kootenay and Columbia rivers for *C. bendieri*.

Summary and Conclusions

Unfortunately, very little is known about the short or long term impacts of dam construction on sculpins in the BC Hydro footprint area. There has been virtually no historical study of the distributions or abundances of these species in the Columbia or Kootenay rivers. Much of our information comes from presence accounts or incidental catch records from studies targeting other species.

Clearly, impoundments have created fragmented populations of sculpin. The result of this fragmentation almost certainly resulted in declines in abundances however to what extent is unknown. The more widely distributed sculpin species were likely more robust to these disturbances than those species with more restricted distributions.

Dam construction undoubtedly strongly impacted local populations at dam sites. In addition, flooding affected vast areas of spawning, rearing and overwintering areas both upstream and downstream of impoundments. The consequences of these habitat alterations upon sculpin populations in the BC Hydro dam footprint area remains unknown.

To date there have been no programs undertaken to examine the distribution of sculpin species across the Columbia Basin. Further, much of the life history information comes from populations outside this area. Baseline studies to determine habitat preferences and habitat availability for sculpin species, especially those with limited distribution in the BCH footprint area, are a necessary first step in evaluating the populations of these neglected species.

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DACE POPULATIONS IN THE BC HYDRO DAM FOOTPRINT IMPACTS AREA

Introduction

A total of four species of dace are endemic to the British Columbia portion of the Columbia Basin. Longnose dace (*Rhinichthys cataractae*), leopard dace (*Rhinichthys falcatus*) and Umatilla dace (*Rhinichthys umatilla*) all occur in some portion of the Columbia River Dam Footprint area. The fourth of these cyprinids, speckled dace (*Rhinicththys osculus*), is only distributed within the Kettle River valley (outside the FWCP area) and is unimpacted by BC Hydro impoundments.

Very little information is available on the status of dace populations in the Columbia Basin prior to impoundment. The taxonomy of dace has historically been confused, for example, with Umatilla dace once thought to be a hybrid between Leopard dace and speckled dace, but is now recognized as distinct species (Haas 2001). Furthermore, longnose dace within British Columbia have been categorized into subspecies however this designation may not be valid (McPhail 2007).

Dace are a bottom dwelling fish often found among the rocks and boulders in flowing waters. These cyprinids may also occur among the inshore areas of lakes over rocky substrates or where there is some current. Adults generally occupy swifter riffle type habitats though leopard dace tend toward slower, deeper flows than the other dace species (Wydoski and Whitney 1979). The diet of dace species consists of aquatic insect larvae with adults taking terrestrial insects when available. *Rhinichthys* appear to spawn in riffles over a gravel bottom or shallow, pebble-bottomed, wave-swept shorelines of lakes. Fry occupy quiet shallow sheltered margins of streams and move into swift water within 6 weeks.

Despite the lack of pre-impoundment information, all of these dace species have likely been affected by the following footprint impacts (as defined in Appendix A): i) construction impacts related to sediment and water quality; ii) habitat loss; iii) nutrient and/or contaminant effects related to flows released from the reservoir; iv) reduction in natural turbidity levels due to interception of sediment in reservoirs; v) fragmentation and loss of habitat connectivity at the landscape level (barriers to fish movement and migration); and, vi) fish entrainment and loss of fish. These impacts are outlined further below.

Life History of Native Species

Longnose dace (Rhinichthys cataractae)
The longnose dace is widely distributed in British Columbia and the Columbia Basin. There are currently some unresolved taxonomic issues with this species however within the BC hydro dam footprint area the species is consistently present and abundant (McPhail 2007). There appear to be no conservation issues with longnose dace populations within British Columbia (listed as Not

at Risk by the BC Conservation Data Centre). The following life history information comes primarily from fluvial populations, but the species does occur in lacustrine environments as well.

Spawning

Longnose dace are spring spawners (May or June) and exhibit a preference for riffle habitat and coarse gravel substrate in their spawning sites. The species has complex spawning behaviour that involves acquiring and defending territories in addition to intricate courtship habits. Breeding females fecundity is positively correlated with fish size and egg number may range from 150 to 3000. Eggs from longnose dace adhere in clumps to the substrate and average approximately 2.4 mm in diameter. Hatching typically occurs quite quickly (within a week).

Rearing

Fry are about 6.0 mm in total length after hatching. In the first year of growth they will reach 25 – 30 mm fork length. Sexual maturity is reached by the end of the second summer and most adults will spawn the following spring.

Overwintering

The winter biology of longnose dace, and of dace in general, is unclear. It is likely that in smaller streams they behave similarly to an eastern dace, *Rhinichthys atratulus*, and occupy crevices within larger cobble substrate as water temperatures decline (Cunjak and Power 1985). In larger rivers and lakes dace possibly move to deeper water habitats during the winter months.

Feeding

Adults are nocturnal feeders and are primarily associated with feeding on the benthos. Aquatic larvae, terrestrial insects and occasionally fish larvae comprise the main diet of adults while juveniles may also include periphyton in their diet.

Leopard dace (Rhinichthys falcatus)

The position of the leopard dace within the *Rhinichthys* species complex remains unclear, however the species appears most closely related to the speckled dace. Leopard dace populations in the Columbia River are generally associated with the larger mainstem reaches. In particular, they can be found from the lower Arrow Lake to the US border and in the Kootenay River below Bonnington Dam. In smaller watersheds, adults occupy flowing pools and gravel runs of creeks and small to medium rivers although they can also be found in the rocky margins of lakes (Page and Burr 1991).

Leopard dace populations are considered not at risk in Canada (COSEWIC) and British Columbia populations are listed as secure (B.C. Conservation Data Centre 2008). Nevertheless, leopard dace populations are relatively rare in the BC Hydro Dam footprint area which may be a result of hydroelectric development (Peden 1991).

Spawning

Specific reproduction information for leopard dace from the Columbia Basin is unknown. In the lower Fraser these dace spawn in the summer (July and August) and likely have similar characteristics to dace in the BC Hydro dam footprint area. Breeding habitat is likely comparable to that of other dace that spawn in riffles. The eggs are small (2.0 – 2.5 mm) and are released into the substrate where they adhere within the interstices. Larvae hatch in about a week and remain in the substrate for another week before emerging.

Rearing
Newly emerged fry will begin feeding in August at about 9.5 mm total length. By the end of the first year leopard dace juveniles will reach approximately 20 mm.

Feeding
Young-of-the-year feed mostly on diptera larvae. Late in their first year juveniles begin feeding on aquatic insect larvae (e.g., Ephemeroptera and Diptera) in addition to terrestrial insects. Adult diet consists of aquatic insect larvae and terrestrial insects.

Umatilla dace (Rhinichthys umatilla)
Umatilla dace have a restricted distribution within British Columbia. In the BC Hydro dam footprint area they occur below the Hugh Keenleyside Dam in the mainstem Columbia River, in the Kootenay River below Bonnington Falls, the Slocan River, and in the lower Pend d'Orielle River (McPhail 2007).

In contrast to the other two Columbia Basin dace species, the Umatilla dace is listed by COSEWIC as a species of special concern and red listed as a candidate for - Extirpated, Endangered, or Threatened status in British Columbia (B.C. Conservation Data Centre 2008).

Spawning
Very little information exists on the reproductive habits of the Umatilla dace. They are probably similar to other dace species in the area in that they spawn in the summer months.

Rearing
Fry and juvenile Umatilla dace will occupy shallow near shore habitats with little or no velocity in large rivers (McPhail 2007).

Overwintering
It is unknown what specific habits the Umatilla dace have in the winter.

Feeding
Aquatic insects are the primary food item for Umatilla dace although they also exploit periphyton and other detritus from the benthos.

Dam Footprint Impacts and Dace Populations

Of the three species of dace extant in the BC Hydro dam footprint area, longnose dace are by far the most widespread and likely have been the most resilient to impacts from hydroelectric development. The other species, Umatilla dace and leopard dace, are more restricted in their distribution and may have been extirpated from some reaches where they were originally distributed.

Dace are primarily a riverine species although they can and do occur in the lake environment. Dam construction and reservoir creation undoubtedly had deleterious impacts on dace population both at local scales and more regionally. Downstream effects of dam construction may have resulted in increased siltation in riffle habitats which are preferred by dace for spawning.

Habitat Loss
There were extensive losses of riverine habitats with the dam footprint area that have likely directly limited the amount of habitat available to dace species, primarily in riverine habitat that was inundated. For a detailed summary of the estimated habitat lost overall and by dam unit see Thorley (2008). Basic summaries of habitat lost by dam unit are presented below.

Construction Impacts and/or Contaminant Effects
It is unknown what the construction impacts of dams in the study area may have been, but there is the possibility of contaminant effects.

Turbidity
Unknown impacts.

Habitat Fragmentation
Populations of dace have most definitely been fragemented by the construction of dams. It is unknown however, as to the population level impacts of this fragmentation, but they are likely minimal.

Fish Entrainment and Loss of Fish
The impacts of entrainment on dace populations are unknown, but there is likely some displacement of fish through hydroelectric facilities. These impacts are operational in nature.

Water Quality (e.g. Temperature, TGP, DO)
There is no doubt that the construction of dams has altered the water quality characteristics of the rivers on which they were built. Water temperatures have generally become more stable, with cooler water temperatures in the summer, and warmer temperatures in the winter.

Status of Isolated Groups or Sub-Populations within the BC Hydro Dam Footprint Area

Columbia Lake to Donald Station - C1
Longnose dace is the only species in this cyprinid genus which occurs in this section of the upper Columbia River (Ahrens and Korman 2004). The construction of the Mica dam has isolated these populations from those in the downstream reaches however there has been no assessment as to whether dam construction impacted dace, although it is unlikely that populations of longnose dace have been impacted to a point of conservation concern.

Donald-Mica - C3
Longnose dace are distributed in this section of the Columbia River and its tributaries. In total 744 km of river habitat was inundated (Thorley 2008).

Revelstoke Reservoir (Mica Dam to Revelstoke Dam) - C4
Longnose dace are the only species distributed here. Construction of Revelstoke Dam flooded 270 km of river habitat.

Arrow Lakes - C11
Longnose dace and leopard dace are distributed within this section of the Columbia River (Arrow Lakes Reservoir), although impacts on these dace species are unknown.

Upper Columbia River (HLK Dam to Canada-U.S.A border) - C9
Large river surveys in 2001 found both Umatilla dace and longnose dace present in the Columbia River throughout this reach (Golder 2002). Umatilla dace catches were relatively rare but longnose dace comprised 1.7% of the total catch and 13.3% of the non-sportfish catch. Impacts to these species are largely operational as there was no habitat inundated by dam construction.

Pend d'Oreille (U.S.A. Border to Waneta Dam) - C10
Longnose dace and Umatilla dace occur in this system. Impacts are unknown, but a total of 16 km of stream habitat was inundated.

Headwaters to Wardner - K1
Longnose dace are distributed in this section of the Kootenay River.

Bull River - K2
Longnose dace occur in this river and are found above and below the dam.

Koocanusa Reservoir - K3
In total, 128 km of habitat in the Kootenay River were lost due to construction of the Libby Dam. Although longnose dace are distributed here, populations were likely not impacted to conservation concern levels.

Elk River - K4
Longnose dace are distributed above the Elko dam, where 4 km of stream were lost with the construction of Elko Dam.

U.S.A. Border to Kootenay Lake - K5
Longnose dace occurs here. No stream habitat was lost in this section of the Kootenay River, and impacts are likely operational in nature due to flow changes.

Kootenay Lake and tributaries - K6
Longnose dace occur in this dam unit, and have likely been unimpacted by dam construction to any great degree.

Duncan Reservoir - K7
In this dam unit a total of 125 km of stream habitat were lost due to dam construction. Longnose dace occur within this dam unit and were likely not impacted to a large degree by this flooding.

Duncan River including Lardeau River - K8
Surveys undertaken recently in side channel reaches of the lower Duncan River have found low abundances of longnose dace (Hagen and Decker 2006).

Cora Lynn Dam to Brilliant Dam - K9
Longnose dace and Umatilla dace are distributed in this dam unit, impacts are unknown.

Brilliant Dam to confluence with Columbia River - K10
River surveys in 2001 found longnose dace and Umatilla dace occurred in this dam footprint area (Golder 2002). Umatilla dace numbers were substantially higher than those recorded in the Columbia River below HLK dam.

Compensation Options Related to Footprint Impacts for Dace

In the recently developed BC Ministry of Environment Conservation Framework that provides a set of science-based tools and actions for conserving species and ecosystems in B.C., the three species of dace in the study area were identified as having data limitations in order to make assessments on their status. As such, basic distribution, life history and biological data is limited, and it is likely that a long term understanding of species and populations within different areas of the footprint area is warranted. The main species of concern is the Umatilla dace.

<u>i) Locate and monitor Umatilla dace populations</u>

Action items:

1. Survey lower Columbia and Kootenay rivers for Umatilla dace.
2. Maintain index sites to monitor population trends.

Summary and Conclusions

The historical impacts of dam construction and reservoir filling on native dace populations in the BC Hydro dam footprint area are unknown. Longnose dace appear to continue to be widely distributed throughout the Columbia and Kootenay Rivers. Umatilla dace and leopard dace, two closely related species, have a much more restricted distribution. For all populations trend information on abundance is limited.

Population fragmentation due to dam construction has almost certainly occurred for many dace populations in the Columbia Basin. However, adult movements and migration are of relative short distance and most population effects were likely local in scale.

Dace species require reasonably specific habitat characteristics for their life history. An abundance of shallow riffle habitat and low velocity backwaters are critical requirements for spawning and rearing. Reservoir creation decreases the availability of these habitat characters by eliminating run of the river reaches. It is unknown to what degree essential spawning, feeding and overwintering habitat was lost to these species.

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MINNOW POPULATIONS IN THE BC HYDRO DAM FOOTPRINT IMPACTS AREA

Introduction

Seven species of endemic minnows (Family Cyprinidae) occur in the British Columbian portion of the Columbia Basin that has been impacted by hydroelectric development. This report reviews impacts on four of our native species. The remaining three native species are dace (*Rhinichthys* spp.), that are discussed in a separate section of this report.

The four species covered in this section are lake chub (*Couesius plumbeus*), peamouth chub (*Mylocheilus caurinus*), northern pikeminnow (*Ptychocheilus oregonensis*), and redside shiner (*Richardsonius balteatus*). All of these species occur as both lacustrine and fluvial populations. Generally, they are most abundant in relatively quiet waters where summer water temperatures reach 15ºC.

Although the pre-impoundment abundances of these minnows were never rigorously studied, they were common in the warmer parts of the BC Hydro Dam footprint area. Despite the lack of pre-impoundment abundance data, all four species probably have been affected by the following footprint impacts (as defined in Appendix A): i) construction impacts related to sediment and water quality; ii) habitat loss; iii) nutrient and/or contaminant effects related to flows released from the reservoir; iv) reduction in natural turbidity levels due to interception of sediment in reservoirs; v) fragmentation and loss of habitat connectivity at the landscape level (barriers to fish movement and migration); and, vi) fish entrainment and loss of fish. These impacts are outlined below.

Life History of Native Species

Lake chub (Couesius plumbeus)
Lake chub are widely distributed throughout British Columbia. They are a northern species and most abundant in the central and northern parts of the province. At present, their taxonomy is in a state of flux, and there may be more than one species in North America. The populations west of the Continental Divide were named as a separate subspecies (*C. p. greeni*) and, presumably, the lake chub in our area are this subspecies. Apparently, they were never abundant in the southern part of the province, and the southern portion of their range appears to coincide closely with the BC Hydro Dam footprint area. The populations in this area are scattered and isolated from one another. Many of these scattered populations existed in small lakes and were eradicated with rotenone in 1950s and 1960s. It is not clear how many populations remain in our area.

Historically, lake chub, like the majority of other minnow species, have been viewed as a 'coarse' species and of little intrinsic value other than as prey for more desirable sport species. Consequently, the impacts of hydroelectric development upon these species populations have been poorly documented.

The conservation status of lake chub does not appear to be of concern taken across their North American distribution. In Canada, the species is widespread, abundant and secure and they have no federal listing in the United States. British Columbia (BC Conservation Data Centre 2008) lists lake chub as secure and not at risk within the province. In Washington State, however, there is only one confirmed population and the species is a state candidate for a species of concern status. Conservation concerns regarding lake chub will probably change as their taxonomy is sorted out, and it is possible that in the future the populations in southern BC will be given a higher listing.

Spawning

Lake chub spawn in the spring or early summer. In southern BC most spawning occurs in lakes but elsewhere in their Canadian range stream-spawning populations are common. The eggs are small (about 2 mm in diameter) and non-adhesive. The spawning behaviour of the western populations has not been documented. The eggs develop rapidly and in southcentral BC they hatch in about a week.

Rearing

Newly hatched lake chub are usually found inshore and near vegetation (often in backwaters and shallow embayments). As they grow they move out to the margins of vegetated areas but remain close to cover.

Overwintering

Nothing is known about the over-wintering habitats of lake chub in our area, but in northern BC they remain active at temperatures close to 0ºC.

Feeding

Lake chub appear to be trophic generalists. Adults forage primarily on benthic organisms (amphipods and chironomids) but they will take insects from the surface. In lakes, at night they are often found near the surface and well offshore. In such cases, they may be feeding on plankton.

Peamouth chub (Mylocheilus caurinus)

Peamouth chub are endemic to the Columbia River system and rivers that received their fauna from the Columbia system (McPhail and Lindsey 1970). The genus is relatively old: it is known from Miocene (about 8 million years ago) deposits in southwestern Idaho and Oregon; however, the peamouth is the only extant species. The BC populations appear to fall into two groups: a coastal group restricted to the lower Fraser system, Vancouver Island, and the Sechelt Peninsula, and a widespread interior group. There are probably physiological and behavioural differences between the two groups but the species has not been widely studied. The interior group is widespread in the BC Hydro Dam Footprint area, and occur from Columbia Lake to the US border, as well as the Kootenay and Pend d'Oreille drainages.

The conservation status of this species appears to be secure. In British Columbia, the species is listed as not being at risk (BC Conservation Data Centre 2008).

Spawning
Peamouth spawn in the spring: April in the lower Fraser Valley and June in the Interior. Spawning appears to be induced by day length and water temperature (>9ºC). Most populations spawn in streams but some populations are lake spawners. On the coast, spawning usually occurs at night, and the population moves into a stream and appears to spawn en masse. In contrast, most interior populations spawn during the day. There is no site preparation and usually several males accompany a single female. The eggs are released on a riffle and sink into cracks in the bottom. The eggs are adhesive and about 2 mm in diameter. They hatch in about 6 days at 18ºC.

Rearing
In lakes, newly hatched peamouths aggregate in vegetation near the shore. The fry often occur in mixed schools of other minnows (usually pikeminnows and redside shiners). As they grow, they move out to the margins of vegetated areas but remain close to this cover. In the fall, they join the adult population.

Overwintering
In large lakes, adult peamouth seek deeper water during the winter and are closely associated with the bottom (MacLeod 1960). The location of over winter habitat in rivers is unknown.

Feeding
In large lakes, during the summer, adult peamouth perform a diel migration — to the surface and inshore at night, and a reverse migration at dawn. Presumably this is a feeding migration. In lakes, adults forage on plankton but also on benthic organisms. In rivers, during the summer, adults forage on drifting insects but also feed at the surface on insects.

Northern pikeminnow (Ptychocheilus oregonensis)
The northern pikeminnow is another endemic Columbia minnow. Again, the genus is relatively old and is known from Miocene (about 8 million years ago) fossils in Idaho and Oregon. Three other extant species of *Ptychocheilus* occur in western North America: one each in the Umpqua, Sacramento-San Joachim, and Colorado River systems. Like the other minnows in our area (except for *Couesius*), the northern pikeminnow is a warm water species. Nonetheless, although it does best in warm water, it occurs throughout the BC Hydro Dam footprint area, and is common in the lower Columbia, upper Columbia, lower and upper Kootenay, and Pend d'Oreille rivers.

The northern pikeminnow is listed as Yellow (Not at Risk) in British Columbia by the BC Conservation Data Centre (2008). Although not at risk, in the past the species has been subject to organized control programs and bounties.

Spawning
The northern pikeminnow spawns in the spring. Apparently, rising water temperatures trigger spawning migrations. The threshold spawning temperature is around 12ºC. It spawns in both lakes and rivers. In rivers and streams it spawns over gravel riffles. There is no site preparation and usually more than one male accompanies a spawning female. The eggs are demersal and

adhesive. They sink to the bottom and stick to the gravel. The eggs are about 2.5 mm in diameter and, at 18ºC; they hatch in about 6 days.

Rearing
In lakes, newly hatched pikeminnows aggregate in vegetation near the shore (often in backwaters and shallow embayments). The fry often occur in mixed schools of other minnows (usually peamouth and redside shiners). As they grow, they move out to the margins of vegetated areas but remain close to this cover. In the fall, they join the adult population.

Overwintering
The over-wintering behaviours of riverine adults and juveniles are unknown; however, in lakes, adults move into deep water and are quiescent during the winter.

Feeding
Pikeminnow fry forage primarily on chironomid larvae but also take prey from the water column (e.g., cladocerans and copepods). As they grow they add larger prey to their diet, and by about 250 mm they forage mainly on other fishes. They often contain smaller pikeminnows and the presence of adults probably influences the local distribution of the fry and juveniles. Adults are primarily crepuscular feeders.

Redside shiner (Richardsonius balteatus)
This fish species is another Columbia endemic. The genus is known from Pliocene deposits (3-4 million years ago) in southwestern Idaho. Besides the redside shiner there is one other extant species of *Richardsonius* that occurs in the Great Basin region of Utah, Nevada and eastern California. In addition, the redside shiners in the Umpqua River system in Oregon were named as a separate species. Molecular and morphological data suggest that the Umpqua *Richardsonius* probably are a species distinct from the redside shiner.

The redside shiner is one of the most abundant and widely distributed cyprinids in the Columbia Basin. In the BC Hydro Dam footprint area, redside shiner populations remain abundant; however their distribution in this area has been increasingly fragmented by dam construction. The creation of reservoir habitats in the region has certainly increased the nearshore habitat available to lacustrine populations. There is also the potential that dam construction can make habitats below the dam more suitable for non-native species (i.e., reductions in turbidity and increases in water temperature may make habitats more suitable for non-native species that may predate native species).

Few pre-impoundment estimates of redside shiner distribution and abundances are available. This is not unexpected given the historical perception of these minnows as a ‘coarse’ forage fish. At present, they are found in the upper and lower Columbia, the upper and lower Kootenay, and Pend d’Oreille river systems. There is no US or Canadian federal listing for populations of this species, and provincially redside shiners are listed as apparently secure and not at risk of extinction (BC Conservation Data Centre 2008).

Spawning

Redside shiners spawn in the spring. Increasing day lengths and rising water temperatures trigger spawning. The threshold breeding temperature is about 10ºC. Typically, spawning occurs in flowing water, however, some populations probably spawn in lakes. Usually spawning occurs on a riffle with a coarse gravel substrate. Typically, a gravid female is accompanied by three or four males, and the eggs and sperm are released close to the bottom. The eggs are demersal and adhesive. They lodge in spaces between the gravel and stick to rocks. The eggs are about 2 mm in diameter and at 18ºC they hatch in about 5 days.

Rearing
In lakes, newly hatched redside shiners aggregate in vegetation near the shore (often in backwaters and shallow embayments). The fry usually occur in mixed schools with other minnows (usually peamouth and northern pike minnow). As they grow, they move out to the margins of vegetated areas but remain close to this cover. In the fall, they join the adult population.

Overwintering
The over-wintering behaviours of riverine adults and juveniles are unknown; however, in lakes, adults move into deep water during the winter.

Feeding
Adult redside shiners forage on a wide range of prey and forage on both benthic and water column prey. In the summer, in large oligotrophic lakes, adults move offshore at night and forage on plankton and move inshore during the day and forage on benthic prey. They also take insects off the water surface.

Dam Footprint Impacts and Minnow Populations

It is likely that none of the four species of native minnow (peamouth chub, lake chub, redside shiner, or northern pikeminnow) have been impacted to a level of conservation concern.

Habitat Loss
There were extensive loss of riverine habitats within the dam footprint area that have likely directly limited the amount of habitat available to all fish species, primarily in riverine habitat that was inundated. For a detailed summary of the estimated habitat lost overall and by dam unit see Thorley (2008). Although these impacts are unknown, at the very least the loss of these habitats is a footprint impact that requires some level of compensation.

Construction Impacts and/or Contaminant Effects
It is unknown what the construction impacts of dams in the study area may have been, but there is the possibility of contaminant effects.

Turbidity
Unknown impacts.

Habitat Fragmentation
Populations of minnows have most definitely been fragemented by the construction of dams. It is unknown however, as to the population level impacts of this fragmentation, but they are likely minimal.

Fish Entrainment and Loss of Fish
The impacts of entrainment on minnow populations are unknown, but there is likely some displacement of fish through hydroelectric facilities. These impacts are operational in nature.

Water Quality (e.g. Temperature, TGP, DO)
There is no doubt that the construction of dams has altered the water quality characteristics of the rivers on which they were built. Water temperatures have generally become more stable, with cooler water temperatures in the summer, and warmer temperatures in the winter. In some cases this may be beneficial to minnows such as peamouth chub, northern pikeminnow, and lake chub

Status of Isolated Groups or Sub-Populations within the BC Hydro Dam Footprint Area

Arrow Lakes - C11
Golder (2002) encountered a single redside shiner during their Large River Indexing Program. This species was also captured in Gee traps in nearshore sampling in Arrow Lakes Reservoir in 2004 (S. Arndt, Fish and Wildlife Compensation Program, pers. comm.).

Whatshan River - C8
Gillnet assessments of species abundance conducted from 1985-1987 indicate that peamouth was one of the most abundant fish species in the lake 30 years after impoundment (Hirst 1991). Northern pikeminnow abundances were also high.

Upper Columbia River (HLK Dam to Canada-U.S.A border) - C9
Recent sampling in this footprint area found peamouth in low abundances distributed in the upper sections near the dams (Golder 2002).

Surveys conducted in the Columbia River downstream of Keenleyside dam 13 years after impoundment indicate that redside shiner was the most abundant of the fish species sampled (Hirst 1991).

Pend d'Oreille (U.S.A. Border to Waneta Dam) - C10
Sampling within the Seven Mile Reservoir in 1987 confirmed the presence of peamouth chub (Hirst 1991) however no information is available for this reach of the Pend d'Oreille prior to the construction of either the Seven Mile Dam or the Waneta Dam.

The Waneta Reservoir was sampled in 1974 between the time of the construction of the Waneta Dam and the Seven Mile Dam. Redside shiner was the second most abundant species encountered (Hirst 1991). Further sampling in the Seven Mile Reservoir in 1987 showed that redside shiner was still present however the species made up the smallest proportion of endemic cyprinids within the reservoir (Hirst 1991).

Prior to the construction of the Seven Mile Reservoir in 1979, assessments in the Waneta Reservoir found that northern pikeminnow made up nearly half of the sample abundance (Hirst 1991). Gillnet sampling in the Seven Mile Reservoir in 1987 confirmed the continued presence of northern pikeminnow which comprised the largest proportion of the sample catches (Hirst 1991).

Duncan Reservoir - K7
Data from a lake survey conducted in 1949 indicate that "chub" (presumably lake chub) were present in Duncan Lake.

Duncan River including Lardeau River - K8
Recent assessments within side channels of the lower Duncan River have found peamouth chub present in low abundances (Hagen and Decker 2006).

Surveys in the lower Duncan River recently have found redside shiner to be the most abundant non-sport species observed (Hagen and Decker 2006).

Both adult and juvenile northern pikeminnow have been observed in side channel studies within the lower Duncan River (Hagen and Decker 2006).

Cora Lynn Dam to Brilliant Dam - K9
There were no assessments made as to the presence or status of peamouth chub populations within this dam footprint area prior to construction of the Brilliant Dam in 1944. Fisheries surveys in 1984 indicated that peamouth chub were one of the most abundant of the 'coarse' species found in the Brilliant Reservoir (Hirst 1991).

Compensation Options Related to Footprint Impacts for Minnows

In the recently developed BC Ministry of Environment Conservation Framework that provides a set of science-based tools and actions for conserving species and ecosystems in B.C., redside shiner, Northern pikeminnow, peamouth chub, and lake chub were all identified as not being at a level of conservation concern. Basic distribution, life history and biological data is limited, and it is likely that a long term understanding of species and populations within different areas of the footprint area is warranted.

<u>i) Assess the distribution and abundance of minnow species in the region</u>

Action items:

1. Presence/absence surveys in dam footprint area in which no species information is currently available

<u>ii) Survey reservoir nearshore areas for minnow spawning</u>

Action items:

1. Determine whether minnow spawning habitat is vulnerable to reservoir drawdowns

Summary and Conclusions

The four species of minnows discussed in this section are not considered to be of any particular conservation concern in the Columbia Basin. Long-term effects of dam construction and reservoir creation remain largely unknown. Clearly, some once interbreeding populations were separated; however, the increase in lacustrine environments has probably been of benefit to many of these minnow species.

Special concern should be given to the preservation of wetted areas along the lakeshore in the spring. All of these minnows broadcast spawn their eggs along shallow rocky areas of the lake. Reservoir drawdowns may strand eggs or fry occurring in shoal areas with resulting mortality.

All of these minnow species are relatively sedentary and population structure was likely little affected by dam construction. Lake chub may make migrations of up to 1.6 km between spawning and feeding areas (Scott and Crossman 1973) creating the possibility of some historical population fragmentation.

The inundation of important spawning, rearing and feeding areas with the filling of reservoirs may have occurred to varying degrees throughout the BC Hydro Dam Footprint Area. Without any pre-impoundment information on the life histories of these minnow species in the region it is difficult to assess what the short and long term impacts have been on these fishes.

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SUCKER POPULATIONS IN THE BC HYDRO DAM FOOTPRINT IMPACTS AREA

Introduction

Four species of suckers (Family Catostomidae) occur in the Canadian portion of the Columbia Basin — the longnose sucker (*Catostomus catostomus*), the bridgelip sucker (*Catostomus columbianus),* the largescale sucker *(Catastomus macrocheilus),* and the mountain sucker (*Catostomus platyrhynchus*). Ecologically, two of the species (*C. catostomus* and *C. macrocheilus*) are generalized benthivores (bottom feeders) and the other two (*C. columbianus* and *C. platyrhynchus*) are more trophically specialized periphyton grazers. Of the two trophically specialized species, the mountain sucker is morphologically and ecologically more specialized than the bridgelip sucker. This latter species is in some ways intermediate between the largescale and mountain sucker (McPhail 2007).

The four species also differ in their habitat use. Longnose suckers are a cool-water species found in lakes, large rivers, and small streams, whereas bridgelip suckers also occur in lakes and rivers but in warmer, more productive waters, and larger streams. The largescale sucker tolerates a wide range of temperatures but is most abundant in large lakes and large to moderate sized, low gradient rivers. In rivers with a broad range of summer temperatures, largescale suckers are associated with the warmest areas (Rosenfeld 1996). The mountain sucker is primarily a species of smaller, cold-water rivers and streams and, as its common name suggests, within most of its geographic range it is associated with mountain streams.

Not surprisingly, the pre-impoundment distributions and abundances of these species are poorly known; however, there are pre-impoundment records (UBC Fish Museum) of both longnose and largescale suckers from lakes and large rivers throughout the Canadian portion of the Columbia Basin. Pre-impoundment records of the bridgelip sucker are rare and geographically restricted (e.g., the Columbia River below Hugh Keenleyside Dam, Lower Arrow Lake, and the Pend d'Oreille and lower Kootenay rivers). There are no pre-impoundment records of the mountain sucker.

Despite this lack of pre-impoundment information, all four of these suckers probably have been affected by the following footprint impacts (as defined in Appendix A): i) construction impacts related to sediment and water quality; ii) habitat loss; iii) nutrient and/or contaminant effects related to flows released from the reservoir; iv) reduction in natural turbidity levels due to interception of sediment in reservoirs; v) fragmentation and loss of habitat connectivity at the landscape level (barriers to fish movement and migration); and, vi) fish entrainment and loss of fish. These impacts are discussed further below.

Life History of Native Species

Longnose sucker (Catostomus catostomus)
Although longnose suckers are widely distributed in the Canadian portion of the Columbia Basin, not a lot is known about their biology in our area. They are, however, often abundant in a wide range of habitats (e.g., large lakes and reservoirs, small lakes, swamps, beaver ponds, and streams of all sizes). Generally, this species is not a conservation concern. Nonetheless, there may be populations within our area that would qualify under COSEWIC as Designated Units. For example, dwarf populations (made up of adults of <250 mm fork length) are common in headwater streams in the upper reaches of the Columbia and Kootenay rivers. It is not known if these dwarf populations represent a genetically distinctive life-history form or are simply food limited populations, but there is one record of both “normal” and “dwarf” populations in the same lake in the East Kootenay region (Geen 1958). The co-occurrence of two forms of the same “species” in a small lake often signals a scientifically important situation.

<u>Spawning</u>
Longnose suckers spawn in the early spring (April or May), and their spawning migrations often begin shortly after ice-out. Usually spawning occurs in streams but occasionally in lakes. In both environments spawning occurs during the day over gravel substrates. In streams, spawning takes place on shallow riffles with moderate (<0.5 m/s) water velocities; while in lakes, spawning occurs in shallow water subject to some wave action. Although most longnose suckers spawn at relatively low temperatures (<10ºC) some populations spawn in mid-June at temperatures of about 15ºC. Egg number varies with female size and ranges from 3,000 eggs in dwarf populations to over 44,000 eggs in large-bodied populations. Development time varies with temperature (11 days at 10ºC and 7 days at 16ºC).

<u>Rearing</u>
In rivers and streams longnose sucker fry that have begun exogenous feeding usually aggregate in shallow edge habitats where the current is slow, the substrate silty, and flooded vegetation provides cover. In lakes they are found in similar shallow habitats near cover. As they grow, they move farther offshore into deeper water.

<u>Overwintering</u>
Adult longnose suckers overwinter in deep pools and in streams they are often associated with beaver dams. In lakes and reservoirs, they move into deep water during the winter.

<u>Feeding</u>
Adult longnose suckers primarily are benthivores and feed heavily on chironomid larvae; however, in lakes they will switch to plankton (especially *Daphnia*) when these planktivores are abundant. Young-of-the-year forage in shallow water on plankton but as they grow they shift to benthic prey.

Bridgelip sucker (Catostomus columbianus)
Bridgelip suckers are not widely distributed within the BC Hydro Dam Footprint area. They occur in the Columbia River between HKD and the US border, and they are recorded from Lower Arrow Lake and may occur in Upper Arrow Lake; however, they are absent from the

Columbia River and its tributaries above Revelstoke Dam. They also occur in the lower Kootenay River but apparently never colonized the Kootenay system above Bonnington Falls.

In areas where they occur, bridgelip suckers are most often found in large to moderate sized rivers and in small lakes. They appear to be rare in large lakes. Although it is a small (usually <300 mm fork length) species, bridgelip suckers are exceptionally long-lived: a 272 mm female was aged by otoliths at over 32 years. There are records of individuals >500 mm in fork length in the Columbia River below Castlegar (R.L. & L. 1993); however, these records probably are based on hybrids between largescale and bridgelip suckers. The bridgelip sucker is not listed either by COSEWIC or the BCCD.

Spawning
Bridgelip suckers spawn in the spring but there is little information on either their spawning sites or their spawning behaviour. In the Fraser River they have been observed to spawn from mid-May to mid-June at temperatures ranging from 11-16ºC. The spawning sites typically are located on shallow riffles ranging in small to moderate sized rivers. The substrate usually is gravel, and water velocities are moderate (<25 cm/m). Fecundity ranges from about 10,200-20,000 eggs (Dauble 1980), and eggs began hatching about three weeks after fertilization (Wydoski and Whitney 2003).

Rearing
Bridgelip sucker fry that have begun exogenous feeding appear to favour seasonally flooded backwaters and embayments as nursery areas. Here, they are often associated with flooded terrestrial vegetation. Juveniles are found in deeper water and farther from shore than the fry.

Overwintering
Little is known about the overwintering behaviour of bridgelip suckers. Presumably, however, they refuge in deep water during the winter.

Feeding
Bridgelip sucker fry forage primarily on plankton; however, as their mouths shift from terminal to subterminal they begin including chironomids and some periphyton in their diet (Dauble 1980). The proportion of periphyton in their diet increases as they grow and is mainly periphyton in adults (at least in the summer). Like other periphyton scrapers they probably shift their diet in the winter when periphyton becomes scarce.

Largescale sucker (Catostomus macrocheilus)
Not much is known about the pre-impoundment status of largescale suckers in the Canadian portion of the Columbia River system other than that they were present throughout the system (i.e., from Columbia Lake and the Kootenay River near Canal Flats, to the US border). Post-impoundment data on this species is also sparse except for the section of the river between HLK Dam and the US border. In this river section, there is data on their movements, age, and growth (R.L.& L. 1993). This is the largest sucker in our area and some individual reach lengths of slightly over 700 mm (R.L.& L. 1993).

Typically, adults occur in lakes and large to medium sized rivers. In lakes they are most abundant in inshore littoral habitats (at least in the summer), and in large rivers they often use mid channel areas (Dauble 1986). However, habitat use changes seasonally (and sometimes diurnally), and is different for different life-history stages. These seasonal and ontogenetic habitat shifts make it difficult to assess the impacts of the BC Hydro dam footprint in the region. This species is not listed by either COSEWIC or the BCCD.

Spawning
Largescale suckers will spawn in both lakes and rivers, and often make short (>10 km) spawning migrations within rivers or between lakes and rivers. Spawning usually occurs in the spring (May-June), although in cool waters it can extend into summer (July-August). Typical spawning sites are in shallow water over coarse gravel, although substrate size can be variable (McPhail 2007). Females release several thousand adhesive eggs that sink to the bottom and adhere to the substrate or sink into interstices between stones. Hatching occurs in about 20 days at 10ºC. Potentially, reservoir drawdowns during the spawning period could dewater largescale sucker spawning areas and cause some egg mortality.

Rearing
Larval largescale suckers aggregate in low velocity nursery areas. Typical nurseries are shallow, warm (relative to the main river) embayments with silt bottoms and some vegetation. On the mainstem Columbia River, seasonally flooded grassy areas appear to be major nursery sites. In contrast to fry, juveniles usually are found in somewhat deeper water than the fry (0.25-0.5 m) are found near margin waters in association with vegetation and silty substrate (Golder 2002).

Overwintering
Largescale suckers use deep pools in rivers and probably deep water in lakes and reservoirs as overwintering sites.

Feeding
Trophically, largescale suckers are the most versatile of our sucker species. Although they are morphologically adapted for bottom feeding they will exploit seasonally abundant prey such as fish eggs, emerging aquatic insects or algae.

Mountain sucker (Catostomus platyrhynchus)
The mountain sucker appears to have the most scattered and naturally fragmented distribution of any sucker in the Canadian portion of the Columbia Basin. The only river system where it is even moderately abundant (the Similkameen River) lies outside the area of the Columbia BC Hydro Dam Footprint. There is, however, one unconfirmed record of this species within the footprint area — a site near the confluence of the Pend d'Oreille and Salmo rivers (Baxter et al. 2003). It is a small species (usually <20 cm in fork length) and easily overlooked. This species is not listed by either COSEWIC or the BCCD; however, this could change. Molecular data indicate that mountain suckers on the east and west sides of the Continental Divide differ substantially (about 5%) in their mitochondrial DNA. This argues that they are different species. If this proves to be true, the Columbia/Fraser species is unnamed and its restricted geographic distribution could result in a COSEWIC and BCCD listing.

Spawning
Mountain suckers spawn in the spring, usually about mid-June, and at water temperatures of about 9-11ºC. The spawning sites typically are located on shallow riffles in small rivers, the substrate usually is gravel, and water velocities are moderate (<25 cm/m). Fecundity ranges from about 1,200-3,000 eggs, and eggs began hatching 7 days after fertilization at 15ºC (Snyder 1983).

Rearing
No description of the rearing habitat is available. Presumably, however, newly hatched young behave like other suckers and favour shallow, warm, edge habitats with silty substrates and some cover. Juveniles also favour shallower water than adults and often aggregate near the mouths of tributary streams.

Overwintering
There is no data on overwintering sites but, again, like other suckers they probably use deep pools as winter refuges and may seek out pools with some ground water intrusion.

Feeding
Adult mountain suckers are periphyton scrapers. They have a specialized lower jaw and in aquaria they have been observed to scrape algae off of rocks. In the summer, adult stomachs usually contain filamentous algae and diatoms. Some temporate zone algae scrapers become omnivorous in the winter (Lassuy 1990) and this may happen in mountain suckers.

Dam Footprint Impacts and Sucker Populations

It is likely that none of the four species of native suckers (longnose sucker, bridgelip sucker, largescale sucker, or mountain sucker) have been impacted to a level of conservation concern.

Habitat Loss
There were extensive loss of riverine habitats within the dam footprint area that have likely directly limited the amount of habitat available to all fish species, primarily in riverine habitat that was inundated. For a detailed summary of the estimated habitat lost overall and by dam unit see Thorley (2008). Although these impacts are unknown, at the very least the loss of these habitats is a footprint impact that requires some level of compensation.

Since most fluvial sucker populations spawn on riffles, the BC Hydro Dam footprint probably eliminated some spawning areas; however, the reservoirs created by the dams may have increased the amount of nursery area available for most of the suckers. There is some evidence that even the mountain sucker (the most specialized of our sucker species) can adapt to reservoir life (Wydoski and Wydoski 2002). The only data on the impact of reservoirs in our area on the abundace of suckers is some data from the early years of Koocanusca Reservoir (Chisholm et al. 1989). In this reservoir the relative abundance of the two sucker species (*C. catostomus* and *C. macrocheilus*) did not change dramatically after the reservoir was filled — *C. macrocheilus* was abundant in the mainstem Kootenay River before reservoir construction and remained abundant in the reservoir, whereas *C. catostomus* was rare in the river before dam construction and remained rare in the reservoir after the reservoir was filled.

Construction Impacts and/or Contaminant Effects
Typically, dams are constructed at sites where rivers narrow and water velocities increase relative to those in less constricted parts of the rivers. Consequently, most dam sites are not in prime sucker habitats (adults are usually associated with relatively slow currents). Nonetheless, temporary increases in sedimentation and degradation in water quality downstream of construction sites may affect local largescale sucker populations; however, these effects are probably short term and have little lasting impacts on local populations.

Turbidity
Unnkown impacts, although suckers are found in both clear and turbid water in abundance.

Habitat Fragmentation
There is little information regarding the migations and movements of suckers within the footprint area of BC Hydro dams; however, most suckers perform relatively short spawning migrations, and fry typically aggregate in shallow inshore areas. Adult largescale and bridgelip suckers in the Hanford Reach (a major free-flowing reach in the US portion of the Columbia) make diel onshore/offshore movements (Dauble 1986). Generally, adults do not move over long distances although some suckers may make migrations of less than 75 km (McPhail 2007). Consequently although dams may be barriers to some migrations this is not likely to be a serious problem. There are, however, two consequences of dams that have potential for conservation concern. The most obvious is the fragmentation of populations. Dams are barriers to gene flow (at least in the upstream direction). They subdivide populations and inevitably the subdivided populations are smaller than the original population. They are also a genetic subset of the original undivided population. This creates the possibility of founder effects. For most of our suckers stochastic processes like founder effects and genetic drift are probably not a concern (the original populations were probably large, even after subdivision). For the mountain sucker, however, any populations in our area were likely small to begin with, and if they have been subdivided it is possible that stochastic processes are a significant threat.

An often over looked consequence of dam construction is hybridization. Reproductive isolation in most north temperate freshwater fishes is maintained by both ecological and behavioural factors (e.g., spawning site selection, subtle differences in run timing, incomplete resource partioning, slight behavioural differences). Changes in hydrograph and flooding of spawning sites can (and do) result in hybridization, since post-mating isolating mechanisms (e.g., complete sterility) are rare in closely related species. In our area, there is a hybrid swarm involving largescale and bridgelip suckers below HLK dam on the Columbia and Brilliant Dam on the Kootenay River. There also is some indication of reproductive breakdown between longnose and bridgelip suckers in Blueberry Creek (a tributary to the lower Columbia River).

Fish Entrainment and Loss of Fish
The impacts of entrainment on sucker populations are unknown, but there is likely some displacement of fish through hydroelectric facilities. These impacts are operational in nature.

Water Quality (e.g. Temperature, TGP, DO)

Water temperature changes related to the construction of a dam can be significant both within the reservoir and downstream of the dam (Hamblin and McAdam 2003; Prowse et al. 2006). For Columbia endemic fish species, suckers have comparatively high upper tolerance limits and wide optimal temperature ranges (Hamblin and McAdam 2003).

Status of Isolated Groups or Sub-Populations within the BC Hydro Dam Footprint Area

Columbia Lake to Donald Station - *C1*

The only suckers in this dam unit are largescale and longnose suckers. Their populations do not appear to be in trouble, and there was no habitat lost within this dam unit.

Donald-Mica - *C3*

The only suckers in this dam unit are largescale and longnose suckers. Their populations do not appear to be in trouble. Several lakes (24 km^2) and 744 km of riverine habitat was flooded within this dam unit. Petersen and Withler (1965) recorded longnose sucker presence in the Sullivan and Wood rivers prior to Mica Dam.

Revelstoke Reservoir (Mica Dam to Revelstoke Dam) - *C4*

The only suckers in this dam unit are largescale and longnose suckers, and their populations are not of conservation concern. There was however a loss of approximately 270 km of stream habitat.

Arrow Lakes - *C11*

Three species of suckers occur in this reach: largescale, longnose, and bridgelip suckers. The populations of largescale and longnose suckers do not appear to be in trouble. There are so few records of bridgelip suckers from the area that it is difficult to know if they are stable, declining, or extripated. A total of 110 km of the mainstem Columbia River, and an additional 181 km of tributary stream habitat was inundated.

Whatshan River - *C8*

There appears to be no assessment of largescale sucker abundance in Whatshan Lake and its tributaries prior to impoundment in 1951. Given that there is an upstream migration barrier near the outlet to the Arrow Reservoir and that species assessment in the mid 1980s indicate the presence of largescale sucker (Hirst 1991), it is likely that these suckers were present before dam construction. It is also likely that longnose suckers are present in this area. A total of 7 km of stream habitat was lost in this dam unit.

Upper Columbia River (HLK Dam to Canada-U.S.A border) - *C9*

The upper Columbia River portion extends 56 km from the Hugh Keenlyside Dam to the US border where the riverine habitat extends another 180 km to Roosevelt Lake and the Grand Coulee Dam. Fairly intensive studies have been undertaken in this portion of the river to monitor (index) population parameters of resident fish stocks. Population estimates for largescale sucker in 1990/1991 and 2001 indicate this sub-population size to be between 12,000 and 50,000 (Golder 2002).

Duncan River including Lardeau River - K8

Largescale suckers have recently been observed in low abundances in side channel habitats of the lower Duncan River (Hagen and Decker 2006).

Compensation Options Related to Footprint Impacts on Suckers

In the recently developed BC Ministry of Environment Conservation Framework that provides a set of science-based tools and actions for conserving species and ecosystems in B.C., longnose sucker, largesclae sucker, and bridgelip sucker were all identified as not being at a level of conservation concern. The mountain sucker was a higher priority, but given its unkwon distribution in the footprint impact area, the level of conservation concern is unknown. Basic distribution, life history and biological data is limited, and it is likely that a long term understanding of species and populations within different areas of the footprint area is warranted.

<u>i) Determine current distribution of suckers within footprint areas</u>

Action items:

1. Presence/absence surveys. Special attention should be paid to determining the distribution of the mountain sucker (if present).
2. Establishment of index areas to identify trends in abundance.

Summary and Conclusions

The impacts of dam construction on the four species of native suckers are largely unknown. Largescale suckers and longnose suckers are currently widespread within the dam footprint area and are of little conservation concern. The other species of suckers, bridgelip and mountain, are more fragmented in their distribution and consequently populations have an increased vulnerability of extirpation or impact. Trends in abundance are largely unknown for suckers within the dam units in which they occur.

Changes in habitat availability for suckers resulting from impoundment are likely quite variable depending upon which reach of the dam footprint area they occurred. Low gradient, riffle type habitats are the preferred spawning areas of many of these species. Increased water levels from dam construction inundated much of this habitat type; however, the extent to which populations were impacted remains unclear.

Populations of largescale and longnose sucker appear to be widespread and abundant within the BC Hydro Dam Footprint area. The bridgelip sucker, while more restricted in its distribution, is also of little conservation concern. The mountain sucker is not currently listed by the federal or provincial governments as a species requiring any special attention. Recent molecular work indicates that the Columbia Basin population may be unique from those conspecifics on the eastern side of the Continental Divide. This may in turn impact the conservation status of this species in the future. Any information on the distribution and status of these populations in the BC Hydro Dam Footprint Area can only be beneficial.

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Appendix A – Definition of Footprint Impacts

These definitions of operational and footprint impacts associated with BC Hydro's hydro-electrical facilities in B.C. have been proposed to provide clarification to the Fisheries Technical Committees as well as committees involved in Water-Use Planning (WUP) and the BC Hydro Fish & Wildlife Bridge Coastal Restoration Program.

Footprint Impacts:

These impacts would occur primarily as a result of inactive storage and construction of dam structures, and are largely irreversible. Some impacts are re-occurring but the causative agent is usually a one-time action or event. Any footprint impacts should be considered when reservoir is at full pool.

1. Construction impacts (e.g. sediment, water quality) temporary events associated with building and construction.
2. Habitat loss from facilities or structures (e.g. habitat inundation by reservoir): includes loss of riparian area for LWD recruitment and permanent lotic - lentic habitat change and impact.
3. Permanent loss of upland and riparian terrestrial habitats within the full pool footprint and their associated impacts on biodiversity.
4. Fragmentation and loss of habitat connectivity at landscape scale.
5. Changes in the amount and spatial extent of aquatic-terrestrial species interactions due to loss of seasonal habitats, shifts in primary productivity or habitat fragmentation.
6. Nutrient or contaminant effects (e.g. trapping, downstream release, methylation) related to flows released from the reservoir.
7. Water quality in reservoir (e.g. temperature, TGP, DO) related to water quality within the water column of the reservoir.
8. Erosion, sediment transport, erosion and morphological change due to reservoir could include effects of interception of bed load and increased earth slides and instabilities caused by reservoir drawdowns.
9. Impacts to fish movement and migration often due to structures like dams or barriers exposed during reservoir drawdown.
10. Fish entrainment and loss of fish includes loss of fish from reservoir populations with the inability to return to natal areas resulting in a loss of fishing potential or damage to the population numbers, dynamics, etc.

11. Ice regime impacts due to reservoir and effects on tributary systems and ice effects within the reservoir or due to the thermal action of the stored water.
12. Local hydrological effects increased snow or precipitation due to thermal effects of reservoir, evaporative water losses, long-term groundwater effects, greenhouse gas release, cumulative effects from other uses (i.e. increased water withdrawal due to proximity to reservoir).

Operational Impacts:

Operation impacts tend to occur over restricted temporal and spatial, and typically represent the seasonal or operational variation in reservoir elevation and downstream flows within a matter of hours, days, within season or recurring over a multi-year period.

1. Habitat impacts due to hydrological/hydraulic changes: impact on habitats due to fluctuations in flows, velocities or water levels in riverine habitats related to biological suitability, food production, etc.
2. Littoral zone/ shoreline or riparian habitat and vegetation impacts: impact on habitats due to water levels or hydroperiod
3. Erosion, sediment transport and morphological habitat effects related to flow: includes erosion-scour-deposition, sediment quality and geomorphological habitat changes caused by diversions or re-regulation of flows from facilities
4. Entrainment and destruction of fish: includes entrainment and destruction of fish in turbines, stranding due to flow fluctuations
5. Water quality in discharge operations (e.g. temperature, TGP, DO): water quality related to the timing, location and nature of release from reservoirs or operations
6. Impacts to fish movement and migration: includes blockage and delays in upstream and downstream migrations of fish due to operations, flows and water quality impacts
7. Seasonal lentic/lotic habitat change and impact: seasonal, within-year changes in habitat due to operational changes and conditions (i.e. drawdown zones, exposed creek fans)
8. Ice regime impacts: ice effects due to operational changes such as flows and temperature
9. Local hydrological effects: includes seasonal groundwater effects, flooding and seasonal inundation