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MEMORANDUM

TO: **Nechako Water Engagement Initiative Technical Working Group**
FROM: **Susan Johnson, Ph.D. and Jayson Kurtz, M.Sc., R.P.Bio, P.Bio., Ecofish Research, Ltd.**
DATE: **December 7, 2022**
FILE: **1316-09**

RE: **Review of Flow Effects on Nechako River Freshwater Mussels (Issue #27)**

1. INTRODUCTION

During Main Table and Technical Working Group (TWG) meetings of the Nechako Water Engagement Initiative (WEI), concerns were raised about the presence and apparent decline of freshwater mussels in the Nechako River. The TWG asked Ecofish Research Ltd (Ecofish) to review available information to determine the extent of freshwater mussel distribution and the effects of the flow regime from Kemano Hydroelectric Project (Project) operations on freshwater mussels in the Nechako River.

The changes in flow in the Nechako River due to Project operations has the potential to impact freshwater mussel populations through a variety of pathways including; water temperature, water chemistry, physical habitat, and effects on fish species that host larval mussel life stages. This memo provides a review of the available information on the presence of freshwater mussels in the Nechako River including their known historical and present distribution, potential limiting factors, current data gaps, and potential performance measures (PMs) related to freshwater mussel populations in the Nechako River.

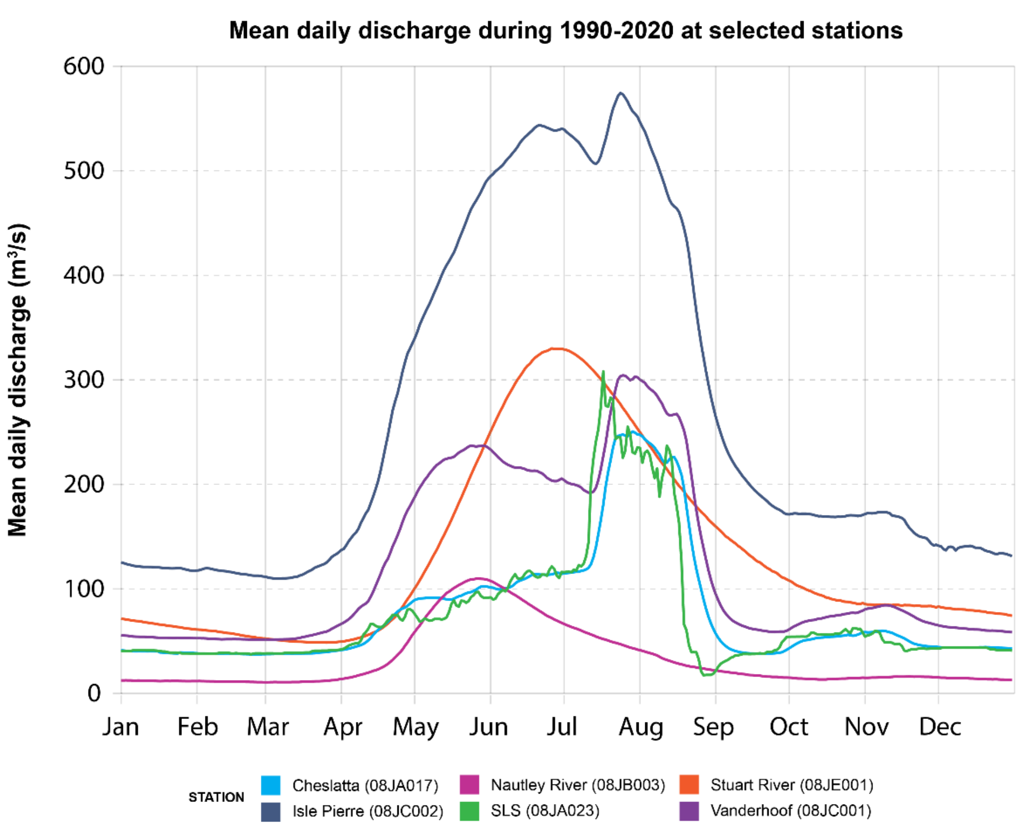
2. BACKGROUND

2.1. Hydrology of the Nechako River

The Nechako Reservoir is located approximately 200 km west of Prince George, BC (Map 1) and was created to provide water for Rio Tinto Alcan's (RTA) Kemano Hydroelectric Project, which was constructed in the 1950s to provide energy to operate an aluminium smelter in Kitimat, BC. The reservoir was formed by the construction of the Kenney Dam on the Nechako River (at the east end of the reservoir), which inundated a chain of six major lake and river systems (Ootsa, Whitesail, Knewstubb, Tetachuck, Natalkuz, and Tahtsa, ~420 km total length). The Nechako Reservoir is ~910 km^2 with a normal annual drawdown of ~3m (10'); low water is in late spring and high water occurs in late summer.

All flow from Nechako Reservoir to the Nechako River is currently via Skins Lake Spillway, which directs flow into the Cheslatta watershed, from where water flows into the Nechako River, downstream of Cheslatta Falls (Map 1). The Nechako Reservoir provides the majority of flow in the upper Nechako River (there is minimal local inflow); here, flow is reduced to ~30% of pre-dam conditions and mean flow ranges from ~40 m^3/s - 240 m^3/s (Figure 1). The Nautley River (~95 km downstream of the dam) combined with local inflows make moderate inflow contributions and mean discharge in the Nechako River at Vanderhoof (~150 km downstream of the dam) ranges from ~65 m^3/s to 270 m^3/s. The Stuart River also contributes significant inflow, and by Isle Pierre (~215 km downstream of the dam) mean flows range from ~120 m^3/s to 560 m^3/s. The Nechako River flows into the Fraser River at Prince George ~275 km downstream of the dam.

Figure 1. Nechako River mean daily discharge 1990 to 2020 at select stations (see locations on Map 1). "SLS" denotes Skins Lake Spillway.



2.2. General Description of Freshwater Mussels

Freshwater mussels are the most endangered animal group in North America and nearly 75% of all North American species are considered imperilled (MOE 2000; Nedeau *et al.* 2009; Galbraith and Vaughn 2011). While there are a variety of species distributed throughout North America, Six species of freshwater mussels are known to be present in British Columbia (MOE 2000). All native freshwater mussels in North America are associated with benthic habitats and are suspension feeders as adults (Lee 2000). Freshwater mussels are known to be extremely vulnerable to changes in habitat and are generally very slow to recover from population declines because they are long lived species with delayed reproduction and low juvenile survival (MOE 2000; McMahon and Bogan 2001).

2.2.1. Life History

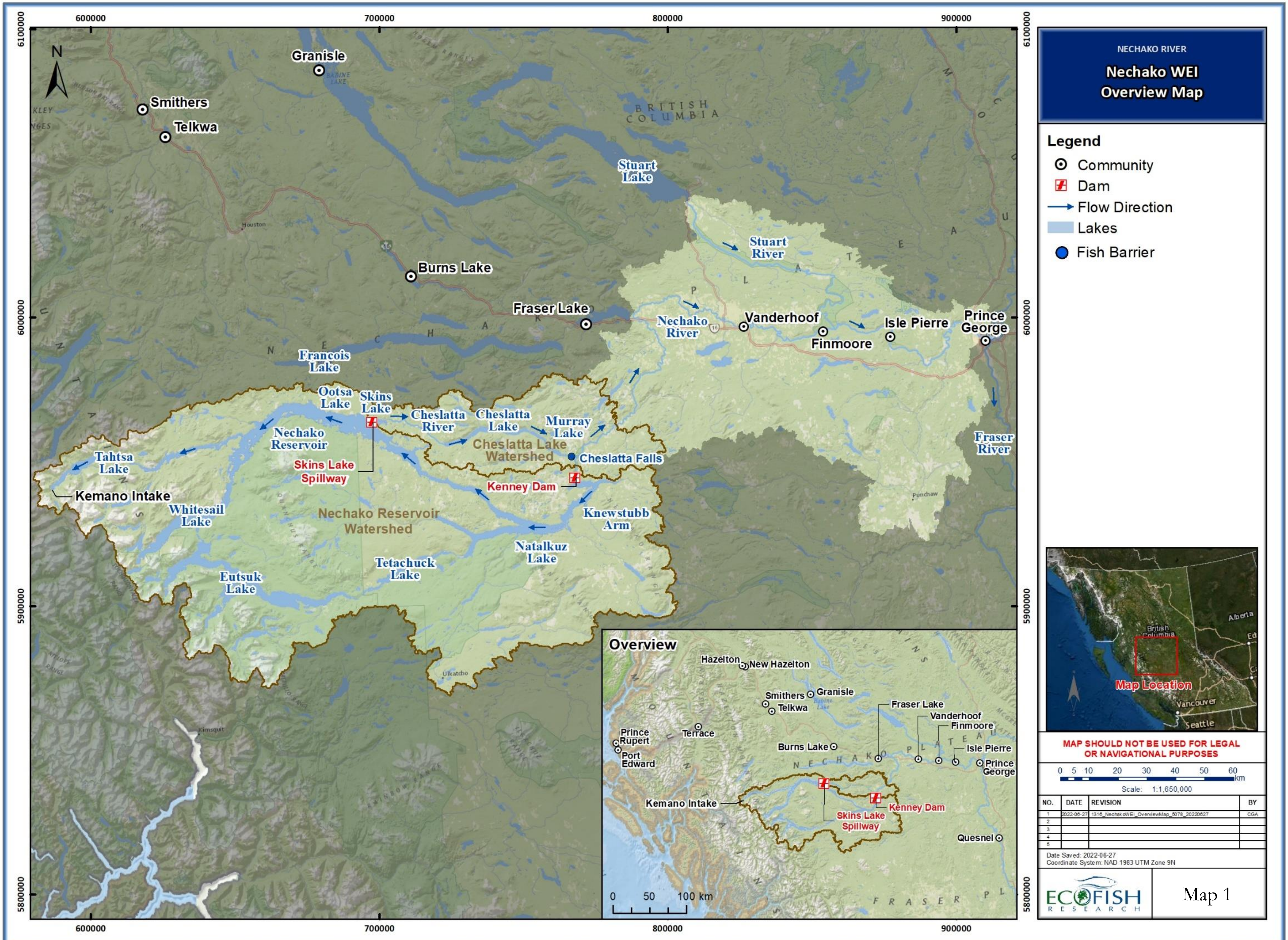
Freshwater mussel life history is unique and requires a host fish to complete the larval stage of development (MOE 2000; Nedeau *et al.* 2009). Adult male freshwater mussels release sperm into the water and eggs retained by females are fertilized when females filter sperm from the water. Although there are separate sexes, hermaphrodites with both male and female traits capable of self fertilization do exist (Nedeau *et al.* 2009). Embryos develop into larvae called glochidia that are released into the water where they must attach to a host fish (usually the fins or gills) for development. Once attached, glochidia form a cyst on fish tissue where they remain for several weeks while developing into a miniature adult (Nedeau *et al.* 2009). The release of glochidia varies by species, environmental conditions (e.g., flow, water temperature) and host fish presence. Some mussel species broadcast thousands of glochidia, expecting some will successfully encounter a host. Other species, such as Western Pearlshell, release glochidia in aggregates called conglutinates bound together with mucus (that often resemble prey of fish: worms or insect larvae). The conglutinates are consumed by fish that become host to the glochidia (Nedeau *et al.* 2009). Some mussel glochidia are generalists that can utilize several different fish species as hosts, where others are specialists and require a specific fish species as a host (Nedeau *et al.* 2009). After 10 to 30 days of glochidial development, juvenile mussels release from the fish host and burrow into the sediment where they remain until mature. Adult freshwater mussels remain in the general location where they are released from their fish host (Nedeau *et al.* 2009) and move only between 1 and 100 m (Gates *et al.* 2015). Freshwater mussels are long lived compared to many aquatic organisms and do not become sexually mature until they are at least six years old (Imlay 1982; McMahon and Bogan 2001). Some species of freshwater mussels can live longer than 100 years are among the longest-lived animal species on earth, while other species may live only 10 to 15 years (Nedeau *et al.* 2009). Adult fecundity in freshwater mussels is high, but survival from the glochidial stage to adulthood is typically low (Yeager *et al.* 1994; McMahon and Bogan 2001). The juvenile life stage is the most sensitive to changes in water quality, habitat, and fish community composition and is less understood than the adult life stage.

2.2.2. Habitat Requirements

Freshwater mussels can be found in a variety of aquatic habitats such as creeks, rivers, ponds, and lakes. Freshwater species such as *Margaritiferidae* are always found in running streams, while *Unionidae* are found in both lotic and lentic habitats (Clarke 1981). Adult freshwater mussels remain partially burrowed into the substrate and filter water for respiration and feeding (MOE 2000), thus stable flows or water levels (to prevent dewatering), good water quality (e.g., well-oxygenated), stable substrate, and a diverse fish community (adequate host fish) are usually required for successful mussel populations (Nedeau *et al.* 2009). Freshwater mussels that live in flowing water are typically found in low gradient creeks or rivers and are often absent in high-gradient, rocky rivers where erosive forces may be too strong for juveniles to become established (Nedeau *et al.* 2009). Although many mussel species are sensitive to water quality and habitat disturbance, others appear to tolerate some moderate levels of disturbance and persist in areas where human populations are dense. Some mussel species that inhabit lakes and ponds may utilize muddy substrates and can be found in habitats with lower levels of dissolved oxygen and higher water temperatures than those inhabiting flowing water habitats. Mussels may also be found in freshwater tidal habitats (e.g., the lower Columbia River) and short exposure to dewatering during low tides does not seem to affect their populations (Nedeau *et al.* 2009).

2.2.3. Importance in Ecosystems

Freshwater mussels provide a variety of ecosystem services to the aquatic communities in which they are found. They are important to food webs, water quality, nutrient cycling, and habitat quality in freshwater ecosystems (Spooner and Vaughn 2006; Nedeau *et al.* 2009). Mussels filter suspended material (e.g., algae, bacteria, zooplankton, and sediment) from the water column in a substantial volume and may help reduce turbidity and control nutrient levels (Nedeau *et al.* 2009). In addition to effects on the water column, mussels improve habitat quality and promote a higher diversity of benthic macroinvertebrates by moving sediment and increasing the exchange of oxygen and nutrients between the sediment and water (Nedeau *et al.* 2009). Freshwater mussels provide biogenic structure for invertebrates and increase the availability of algae and organic matter for invertebrates through excretion and deposition (Spooner and Vaughn 2006). Freshwater mussels are an important food resource for animals dependent on aquatic ecosystems such as river otters (*Lontra canadensis*) and muskrats (*Ondatra zibethicus*) and populations that are low density, fragmented, or are subject to excessive predation or harvest may be at risk of extinction (Nedeau *et al.* 2009). Freshwater mussels also have significant cultural importance to Native Americans in the Pacific Northwest (references within Blevins *et al.* 2017). Because freshwater mussels are long lived, they are ideal biomonitors of aquatic ecosystem long term health that can provide insight into extreme environmental events that occur over time as well as the cumulative effects of environmental conditions.



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3. METHODS

A literature review was conducted on freshwater mussel presence and distribution in northern BC to gain insight into limiting factors for those species present in the area, data gaps that need to be filled in order to better understand limiting factors, and operational considerations for freshwater mussels in the Nechako River.

Most of the key studies on freshwater mussels in the literature focus on species found in the southern United States. Freshwater mussels in the Pacific Northwest of North America are poorly studied. There were very few literature sources or studies of freshwater mussels for BC and specifically in the Nechako River. However, one comprehensive study of freshwater mussel distribution and ecology in Northern BC does include the Nechako River (Lee 2000).

4. RESULTS

4.1. Freshwater Mussel Distribution in British Columbia

There are three freshwater mussel groups in the Pacific drainage of North America consisting of genera *Anodonta*, *Gonidea*, and *Margaritfera* (Pennak 1989; Lee 2000). The range of two species *A kennerlyi* (commonly Western Floater) and *M. falcata* (commonly Western Pearlshell) includes parts of northern BC, while *G. angulata* (commonly Western Ridged Mussel), *A. oregonenis* (commonly Oregon Floater) and *A. nuttalliana* (commonly Winged Floater) are known to occur only in southern BC (Lee 2000). A third *Anodonta* species (*A. beringiana,* commonly Yukon Floater) was thought to occur in the Fraser and Columbia River systems in BC, but recent records confirm the presence of this species only in the Yukon Territory in Canada (Clarke 1981; Lee 2000; Nedeau *et al.* 2009).

The literature review identified only one study on the distribution and habitat preferences of freshwater mussels in northern British Columbia, including the Nechako River (Lee 2000). This study reported a relatively low abundance of freshwater mussels in waterbodies in northern BC (Lee 2000). Although sites in the Nechako River watershed were included in the Lee (2000) study, no specific information on site locations were provided in the report. The Western Floater species was found at 22 of the 176 sites surveyed in northern BC and were found in eight lake sites in the Nechako watershed (Lee 2000). Western Pearlshell mussels were generally uncommon in northern BC and was previously only known to be present in the Lakelse River in northern BC (Clarke 1973). Lee (2000) found Western Pearlshell mussels at 8 of 176 sites in streams wider than four meters in northern BC, including one site in the Nechako River watershed. Below we provide an overview of the two freshwater mussel species known to be present in northern BC and that were found to be present in the Nechako River specifically (Lee 2000).

4.1.1. Western Pearlshell (*M. falcata*)

Western Pearlshell are the longest-lived freshwater mussel species. They typically live between 60 and 70 years but can live longer than 100 years. Western Pearlshell are considered Near Threatened the International Union for Conservation of Nature (IUCN) Red List Categories (Blevins *et al.* 2017) and yellow listed in the BC provincial database with secure populations not at risk of extinction (BC 2022). The Western Pearlshell coastal and large river populations are nearly extirpated (Nedeau *et al.* 2009; Blevins *et al.* 2017). This mussel species prefers cold, clean creeks and rivers and are distributed from small headwater streams to large river habitat. Stable sand, gravel, and cobble substrate, and banks and pools are often favorable habitats because currents are weaker and shear stress is lower (Nedeau *et al.* 2009). In ideal habitat, Western Pearlshell can attain high densities (>300 per square yard) (Nedeau *et al.* 2009). The species may be hermaphroditic, but it is rare. Fertilization is thought to occur in the spring and the timing of glochidia release and the amount of time spent attached to the host fish are strongly influenced by water temperature (Nedeau *et al.* 2009). Cutthroat Trout (*Oncorhynchus clarkii*) are an important host for this freshwater mussel species, but host fish may include other native and non-native trout and salmon including Rainbow Trout (*O. mykiss*), Chinook Salmon (*O. tshawytscha*), Coho Salmon (*O. kisutch*), Sockeye Salmon (*O. nerka*), steelhead (*O. mykiss*), Brook Trout (*Salvelinus fontinalis*), and Brown Trout (*Salmo trutta*).

4.1.2. Western Floater (*A. kennerlyi*)

Western Floater mussels typically live between 10 and 15 years (Nedeau *et al.* 2009) and is considered Least Concern on the IUCN Red List Categories (Blevins *et al.* 2017) and yellow listed in the BC provincial database with secure populations not at risk of extinction (BC 2022). The distribution of the Western Floater is from across southern BC into west central Alberta extending southward in the Pacific drainage to Oregon (Clarke 1981). Western Floater mussels inhabit more lentic environments in lakes, reservoirs, and downstream low gradient reaches of rivers in pool habitats and are more tolerant of low oxygen than other freshwater mussel species in BC (Nedeau *et al.* 2009). This species has thin shells that are prone to damage in higher flow environments, but they can be found in sandbars near the mouths of tributaries or below riffles (Nedeau *et al.* 2009). Western Floater mussels breed in the summer and spawn in in the fall or spring and little is known about host fish species for larval development and dispersal (Nedeau *et al.* 2009).

4.2. Nechako River Freshwater Mussels

Our understanding of mussels in the Nechako River comes from both scientific studies (described in Section 4.1) and local knowledge/observation. Local knowledge suggests that historically there were large mussel beds in rocky areas of the Nechako River that are now silt covered and contain no mussels (Salewski, pers. comm. 2021). Incidental observation of mussels while conducting sturgeon telemetry (Gantner, pers. comm. 2021) confirms large accumulations of mussel shells on the Nechako River shoreline (Figure 2) and live mussel beds located in riffle habitat in the 16 km stretch of the upper

Nechako River between Diamond Island and Fort Fraser Bridge. Fewer freshwater mussels were observed in the lower Nechako from Vanderhoof to the Hulatt Rapids (Gantner, pers. comm. 2021).

Figure 2. Mussel shells accumulating on the shoreline of the upper Nechako River in July 2019 (photo by Nikolaus Gantner).

4.3. Habitat Variables for Freshwater Mussels

Along with surveying the distribution of Western Floater and Western Pearlshell mussels in northern BC including the Nechako River watershed, Lee (2000) also studied whether water quality parameters contributed to mussel distribution. Lee (2000) examined a suite of environmental variables known to affect freshwater mollusc distribution at the sites where freshwater mussels were found (Table 1). This analysis combined data from all northern BC sites and were not specific to the Nechako River watershed. Both high and low water temperatures and dissolved oxygen are known to restrict mollusc distribution by affecting physiological functions. Calcium is essential to shell construction and reproductive function and the concentration of dissolved calcium can be derived from conductivity (McMahon 1983; Lee 2000). pH can also affect the distribution of freshwater molluscs because low pH is generally associated with low calcium concentrations and with levels of carbon dioxide that may impede gas exchange (Fuller 1974).

Although in general, Lee (2000) found that water temperature was the least important of the environmental variables measured for determining overall mollusc distribution, the Western Pearlshell mussel species was found at significantly colder water temperatures than the Western Floater. (Table 1). This is likely due to the habitat differences between species as the Western Pearlshell is found in lotic environments where water temperatures are often cooler than in the lentic habitats that the Western Floater typically occupies (Lee 2000). Higher water temperatures at which

Western Floater were collected suggested that warm temperatures may not limit the range of this species in northern BC (Lee 2000). The broad ranges for other environmental variables measured by Lee (2000) including dissolved oxygen, conductivity/calcium concentration, and pH suggest that these factors may not be controlling for the distribution of Western Floater and Western Pearlshell mussels (Table 1).

Table 1. Environmental ranges for freshwater mussels sampled in northern BC including the Nechako River watershed (Lee 2000).

	Western Pearlshell	Western Floater
Number of samples	4	12
Water temperature range (°C)	9.6 - 17.9	16.2 - 26.5
Dissolved oxygen range (%)	55 - 80	44 - 93
Conductivity (μS)	67.8 - 213.0	20.1 - 203.0
Calcium (mg/L)	8.8 - 30.4	1.7 - 29.0
pH	6.4 - 8.0	5.3 - 8.6

5. DISCUSSION

5.1. Mussel Distribution in the Nechako River

Information on freshwater mussel distribution suggests that Western Pearlshell and Western Floater freshwater mussels can be found in the Nechako River watershed. It is likely that the mussels in the Nechako River (e.g., Figure 2) are Western Pearlshell mussels given this species is found commonly in rivers and Western Floaters are most common in lakes. Lee (2000) did not provide site-specific information on the location of mussel distribution within the Nechako River watershed, but local knowledge suggests that in some areas freshwater mussels are abundant in the river (Section 4.2). Specific habitat information on where freshwater mussels are found in the Nechako River is limited and remains a data gap (see Section 5.3). Lee (2000) provided limited information on water quality parameters that may limit distribution of mussels in the Nechako River (Section 4.3) but critical factors such as sedimentation and flow were not studied and remain a data gap (see Section 5.3).

5.2. Potential Limiting Factors for Freshwater Mussels in the Nechako River

There are a variety of factors that may limit freshwater mussels in the Nechako River depending on life stage. For juveniles the abundance and distribution of host fish species, and habitat quality and quantity are most important, while for adults important limiting factors include flow, water quality and water temperature, habitat quality and quantity, and predation. Likely it is a combination of these factors that limit distribution no matter the life stage. For example, the distribution of freshwater mussels is thought to be most strongly influenced by complex hydraulic parameters (e.g., shear stress and shear velocity) (Hardison and Layzer 2001; Gangloff and Feminella 2007; Allen and Vaughn 2010), followed by geomorphology (Gangloff and Feminella 2007; Atkinson *et al.* 2012), and substrate (Gangloff *et al.* 2004; Steuer *et al.* 2008; Allen and Vaughn 2010; Bodis *et al.* 2011). Lee (2000) examined a few of the water quality issues that may be limiting and found no clear link between mussel distribution and dissolved oxygen, conductivity/calcium concentration, and pH.

5.2.1. Flow

Freshwater mussels in North America are known to be sensitive to flow alterations (Gates *et al.* 2015) and particularly vulnerable to flow alterations created by impoundment releases (Vaughn and Taylor 1999; Galbraith and Vaughn 2011; Allen *et al.* 2013). Flow may have an effect in reducing sedimentation of riverbed (low flow) or disturbing habitat (high flows washing away juveniles developing in sediments or adults). Additionally, freshwater mussels need habitat that will not become dewatered thus minimum flow will determine the maximum habitat area available.

Natural temporal flow variability has been found to be important for successful freshwater mussel recruitment (Vaughn and Taylor 1999; Hardison and Layzer 2001). Environmental flows have been used to improve flow regimes for freshwater mussel habitats, similar to those that have been used for optimizing habitat for fish species and must be adapted to the unique habitat requirements and life histories of the mussel species (Gates *et al.* 2015).

The success of mussel reproduction and larval life stages is promoted by the natural flow regime favourable to both mussels and their host fish species (Barnhart *et al.* 2008) and is affected by the following aspects of regulated flow regimes.

- Increases in high flow magnitude may prevent juveniles from settling in new habitat or dislodge recently settled juveniles (Neves and Widlak 1987; Holland-Bartels 1990; Layzer and Madison 1995; Hardison and Layzer 2001; Daraio *et al.* 2010) and create sediment scour that interferes with mussel feeding, reproduction, and survival (Young and Williams 1983; Dennis 1984; Aldridge *et al.* 1987).
- Variation in the timing of high and low flows may a) alter temperature regimes causing reproductive issues through several pathways (e.g., altered gamete viability, inappropriate reproductive cues, changes in sex ratios) or alterations in food availability (Galbraith and Vaughn 2011) or b) indirectly affect mussels by preventing host fish species to be present at proper timing for larvae attachment (Freeman and Marcinek 2006; Gido *et al.* 2010).
- Extreme hydraulic events such (i.e., floods or droughts) have a stronger influence on the distribution of adult mussels than average hydraulic conditions (Gangloff and Feminella 2007;

Allen and Vaughn 2010). During high flow, excessive shear stress (hydraulic forces parallel to the substrate surface) can dislodge substrate where freshwater mussel attach and prevent juvenile mussels from settling into the substrates (Allen and Vaughn 2010). Gangloff and Feminella (2007) found that mussel abundance was highly variable in river sites that experienced low -shear stress during flooding events, while mussel abundance at sites subject to high-shear stress during flooding events was always low.

- Optimum flows need to be low enough to maintain bed stability for deep pools but high enough to prevent sedimentation and poor water chemistry conditions (Vannote and Minshall 1982; Hartfield and Ebert 1986).
- Flow alterations that effect host fish can have effects on mussel populations (Gates *et al.* 2015) and the disappearance of mussel species from several rivers has been linked to the disappearance of the appropriate host fish (Kat and Davis 1984). A decline in host fish availability for the attachment of glochida will directly cause a reduction in the distribution and number of adult freshwater mussels that depend on host fish for the important juvenile life stage and for distribution to new habitat. For example, the blockage of upstream migration of Gulf Sturgeon (*Acipenser oxyrinchus desotoi*), a federally protected fish species by a dam on the Apalachicola River was coincident with far low abundances of the federally protected Purple Bankclimber (*Elliptoideus sloatianus*) freshwater mussel upstream of the dam, requiring restoration of habitat connectivity for fish passage of the host fish species to restore the mussel population (Fritts *et al.* 2012).

5.2.2. Water Quality/Temperature

Extended periods of exposure to high temperatures, low dissolved oxygen, and high ammonia levels have been shown to be lethal for mussels (Gagnon *et al.* 2004; Golladay *et al.* 2004; Cherry *et al.* 2005; Haag and Warren 2008; Strayer and Malcon 2012), however there is often a broad range of physiological tolerances among species within a mussel bed (Spooner and Vaughn 2008, 2009). The concentration of dissolved calcium is considered a major factor in determining the distribution of freshwater bivalves, while pH is not (McMahon 1991). Lee (2000) also indicated that pH did not appear to be limiting in the Nechako watershed, however results on dissolved calcium indicated that Western Floater may not be limited by calcium concentration in the Nechako watershed but Western Pearlshell seemed to be found only at concentrations higher than 8.8 mg/L. Lee (2000) hypothesized that pH, water temperature, or calcium concentration were not limiting in northern BC but oxygen concentration may be important to Western Floater species although the oxygen concentrations in the Nechako River were relatively high and are favourable for fish.

Mussels lack the ability to regulate their own temperature increasing mortality rates during extreme temperature exposure (McMahon and Bogan 2001; Pandolfo *et al.* 2012). Freshwater bivalves use water temperature changes as cues for gamete release (Fong *et al.* 1995; Galbraith and Vaughn 2009), therefore water temperature can affect mussel reproduction (Haley *et al.* 2007). Delivering cold water releases for fish migration in the summer can supress freshwater mussel metabolic rates at a time when growth should be high (McMahon and Bogan 2001) and inhibit reproduction (Layzer *et al.* 1993). For instance, Galbraith and Vaughn (2011) found that freshwater mussel populations in rivers managed to release cold water during the summer months (much colder than the natural flow regime) had lower mussel densities, higher hermaphroditism and parasitic rates, and reduced body condition than those found in rivers managed with more natural flow regimes. The release of optimal flows for mussels can optimize seasonal temperature regimes (Gates *et al.* 2015), although thermal regimes for fish should be considered because most freshwater mussels are more thermally tolerant than their host fish species (Pandolfo *et al.* 2012).

5.2.3. Habitat Quality/Quantity

Habitat alteration, including sedimentation and burial from changes to land use or instream works can adversely affect western freshwater mussels (Vannote and Minshall 1982; Krueger *et al.* 2007). Changes in freshwater mussel community structure and abundance have been linked to deforestation and loss of riparian vegetation (e.g., Neves 1992; Williams *et al.* 1993; Morris and Corkum 1996; Bogan 1998; Brim Box and Mossa 1999). Fine sediments in streams can affect mussels through reducing interstitial flow, limiting burrowing by juvenile mussels, interfering with filter feeding and respiration, and indirectly decreasing food availability by reducing photosynthetic light (Brim Box and Mossa 1999; Goldsmith *et al.* 2021). Additionally, sedimentation can interfere with the mussel-host fish relationship by impacting glochidial attachment and cyst formation or by decreasing host fish habitat and abundance (Goldsmith *et al.* 2021).

5.2.4. Predation

Excessive predation by muskrats or other predators may be a limiting factor for adult freshwater mussels given that mussels are sessile and unable to avoid predation (Nedeau *et al.* 2009). It was hypothesized that freshwater mussel shells observed accumulated on the shoreline of the upper Nechako River were signs of muskrat feeding sites (Gantner, pers. comm. 2021). River otters were identified preying on juvenile White Sturgeon in the Nechako River through recovery of radio tags in otter feeding sites and latrines (Babey *et al.* 2020). Several sturgeon tags were retrieved in areas also containing freshwater mussel shells suggesting river otters also prey on freshwater mussels in the Nechako River as recorded in other river systems (Serfass *et al.* 1990; Crowley *et al.* 2013).

5.2.5. Host Fish Species Abundance and Distribution

Host fish species abundance may limit juvenile freshwater mussel development and distribution. The dispersal of freshwater mussels occurs during the larval life phase when they are obligatory fish parasites, tying mussel distribution to their host fishes (Pennak 1989). Larvae of mussel species can attach to a wide range of fish or can be specialists that utilize only one or a few closely related fish species (Watters 1992). One study indicated that the distribution patterns of freshwater mussel assemblages was more correlated with host fish community distribution than to physical habitat variables (Haag and Warren 1998). Although the effects that freshwater mussel glochidia have on their host fish species are largely unknown, a few studies have suggested that the parasitic period of Margaritifera mussel juveniles negatively affect the growth rate of their fish hosts (Treasurer *et al.* 2006; Ooue *et al.* 2017; Chowdhury *et al.* 2021). Additionally, glochidial parasitism on the gills of Brown Trout has been found to increase the metabolic rate and hematocrit of infected fish (Filipsson *et al.* 2017). Potential negative effects of the larval life history stage of freshwater mussels should be considered in conservation prioritization (fish species versus freshwater mussels) and management trade off decisions (Schneider *et al.* 2018).

5.3. Data Gaps

Although there is some information on distribution of freshwater mussels in the Nechako River watershed, the data in Lee (2000) was collected over twenty years ago (in 1997) and is limited to mussel distribution in the watershed and no specific site information was provided. Additionally, and importantly, the study only considered a few environmental water quality parameters (not flow, sedimentation, etc. that may be most relevant to WEI). The following are important data gaps that currently exist with respect to freshwater mussel distribution in the Nechako River:

- Additional and more specific information on current distribution and abundance of freshwater in the Nechako River and if available, past distribution through Traditional Knowledge and local knowledge.
- Determination of the host fish species for freshwater mussels in the Nechako River including the abundance, distribution, and population trends of host fish in the areas of mussel beds.
- Data on flow issues related to the freshwater mussel species found in the Nechako River. Flow data was lacking from studies specific to the Nechako River, thus the following questions are unanswered with regard to the operational flow regime:
    - Does flow regulation alter suspended organic material density and reduce freshwater mussel filter feeding efficiency?
    - Has flow regulation affected substrate quality and quantity necessary for the success of populations of freshwater mussels in the Nechako River?
- Information on freshwater mussel predation including suite of potential predators and extent of predation.

5.4. Potential PMs

The data gaps noted above are numerous enough to make it difficult to develop effective PMs for freshwater mussels within the Nechako River. Here we provide a potential PM based on the literature:

- A more naturalized flow regime suitable for freshwater mussels based on their unique life history (e.g., Gates *et al.* 2015).

6. CONCLUSION/CLOSURE

Ecofish was asked to support the WEI by reviewing freshwater mussel information within the Nechako River. The following key points summarize our current understanding of this issue:

- Two species of freshwater mussels (Western Pearlshell and Western Floater) are known to be present within the Nechako River watershed but there is limited data with regard to distribution, abundance, and limiting factors for these mussels specific to the Nechako River.
- Several important data gaps should be addressed to develop effective PMs for freshwater mussels in the Nechako River. There is currently a lack of information for understanding of how flow and flow alteration affects mussel distribution and abundance preventing the development of a flow specific PM. However, the literature suggests that a "natural flow regime" provides suitable freshwater mussel habitat. Therefore, a PM related to more natural flows in the Nechako River may be suitable for freshwater mussels.

Yours truly,

Ecofish Research Ltd.

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