Fisheries and Oceans Canada / Pêches et Océans Canada
Ecosystems and Oceans Science / Sciences des écosystèmes et des océans

Central and Arctic Region

Canadian Science Advisory Secretariat
Science Response 2018/029

REVIEW OF THE DOMINION DIAMOND EKATI ULC JAY PROJECT OFFSETTING PLAN, JANUARY 2018

Context

Dominion Diamond Ekati ULC (Dominion or the Proponent) is expected to submit an application for a *Fisheries Act* authorization for the construction of a dyke within, and dewatering a portion of Lac du Sauvage, and diverting a portion of two streams around the pipe area to develop the Jay pipe mining operation (Jay Project). The Proponent has estimated the fish biomass (productivity) that will be lost during the life of the mine operation. To offset this loss, in consultation with Fisheries and Oceans Canada (DFO) Fisheries Protection Program (FPP) and local communities, the Proponent has proposed to conduct an egg stocking program for Inconnu (S*tenodus leucichthys*) in the Yellowknife River, NT. Dominion has described their proposed offsetting plan in the document "Jay Project Final Offsetting Plan, January 2018". Within this report they present the rationale and describe the proposed offsetting project.

On August 18, 2017, DFO Fisheries Management, in consultation with FPP and DFO Science, declined a License to Fish for Scientific Purposes (LFSP) application for an Inconnu stocking pilot program. It was during this process that FPP became aware of the ongoing DFO research projects in Great Slave Lake (GSL), more specifically on mixed-stock genetic fishery analysis of the Great Slave Lake Inconnu populations. The application was rejected for two reasons: (1) further information was required to determine if the pilot study and offsetting plan would interfere with current studies in the lake; and (2) the Slave River (Rapids of the Drowned in Fort Smith) is the proposed source location for eggs, however the Fort Smith Métis Council was not on the list of community engagement sessions in the LFSP.

FPP requested that DFO Science conduct a review of the proposed offsetting plan. The objectives of this review were to evaluate the Proponent's predicted biomass gains (i.e., fish production model), habitat suitability models and other models proposed by the Proponent, to determine whether the proposed offsetting plan will generate self-sustaining benefits over the long-term, and lastly identify if the proposed offsetting plan will impact the sustainable management of the fisheries of GSL (including DFO GSL research). The information from this review will be used by FPP to advise the Proponent on their eventual *Fisheries Act* authorization application. Science advice will also be used to advise FPP on whether or not the proposed offsetting plan will benefit fisheries productivity.

This Science Response Report resulted from the Science Response Process of March 28, 2018 on the Review of the Dominion Diamond Ekati ULC Jay Project Final Offsetting Plan.

Background

The Ekati mine and Jay pipe

The Ekati mine is located 300 km northeast of Yellowknife, NT (Figure 1). The Jay kimberlite pipe is located beneath Lac du Sauvage, mean depth 6.8 m, max depth 40.4 m, surface area 8651 ha. A horseshoe shaped dike will be constructed to isolate the portion of Lac du Sauvage

Canada

overlying the Jay pipe. The isolated portion of Lac du Sauvage will be fished out and dewatered to allow for open-pit mining of the kimberlite pipe. Total habitat loss from the dyke and de-watering will be 338.3 ha. Moreover, a diversion channel will be constructed to divert water from two small drainage areas away from the Jay Pit to Lac du Sauvage.

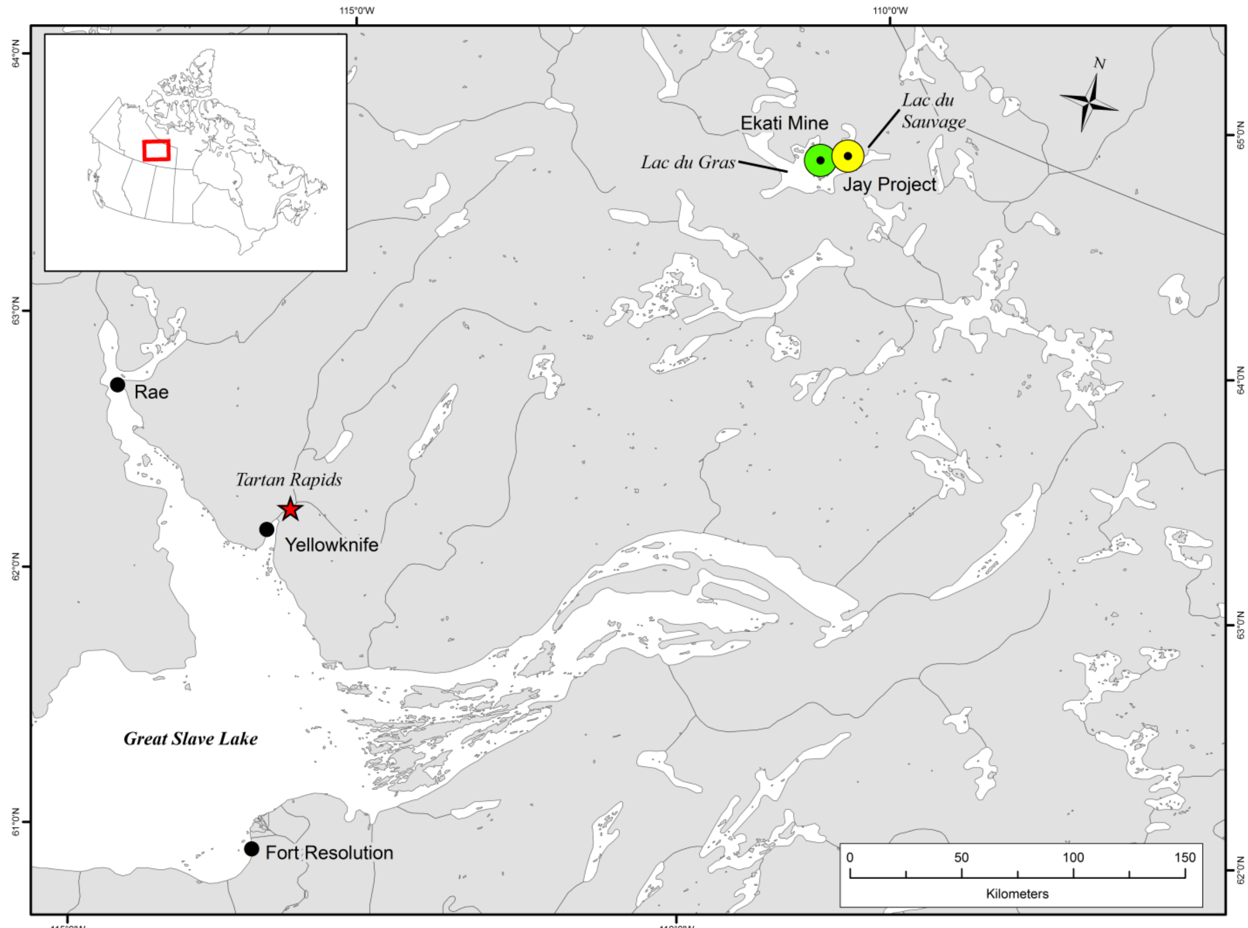

Figure 1. Map showing the location of Ekati mine on Lac du Gras (green circle), the Proponent's Jay Project on Lac du Sauvage (yellow circle), and Tartan Rapids (red star), the proposed location of the offsetting program (Inconnu Stocking Project) on the Yellowknife River.

Eleven species of fish occur in the lake (Table 1), with Lake Trout (*Salvelinus namaycush*) and Lake Whitefish (*Coregonus artedi*) being the dominant species (60 % and 22.9 % of total fish population respectively). Stream habitat used by Arctic Grayling (*Thymallus arcticus*) will also be affected by a diversion of the lower reaches of two streams. Total fish biomass loss (all species) over the life of Jay Project is estimated to be 1,434 kg from initial fish-out, and annual losses to fish biomass production of 301.1 kg/y for 20 years. Fish-out data (methods described by Tyson et al. 2011) will be used to confirm or modify estimates of loss of fish production.

Table 1. Fish species that occur in the Lac Du Sauvage, NT.

Species	Scientific name
Lake Trout	*Salvelinus namaycush*
Arctic Grayling	*Thymallus arcticus*
Cisco	*Coregonus artedi*
Lake Whitefish	*Coregonus clupeaformis*
Round Whitefish	*Prosopium cylindraceum*
Northern Pike	*Esox lucius*
Burbot	*Lota lota*
Longnose Sucker	*Catostomus catostomus*
Ninespine Stickleback	*Pungitius pungitius*
Lake Chub	*Couesius plumbeus*
Slimy Sculpin	*Cottus cognatus*

Great Slave Lake

Great Slave Lake (GSL), NT is one of three great lakes in the Mackenzie River Basin (Janjua and Tallman 2015). It is the second-largest lake in the NT and the ninth largest lake in the world. It is a deep, oligotrophic lake and falls within two physiographic regions, the Precambrian Shield and the Interior Plains or lowlands, with a combined drainage basin of 983,000 km^2.

Yellowknife, Snare and several smaller rivers drain from the north and east (Precambrian Shield; Figure 2). They contribute relatively little discharge, compared with the Slave, Taltson, Buffalo and Hay rivers, which flow into GSL from the south (Figure 2). The Yellowknife River at Tartan Rapids (the proposed egg transplant location) drains an area of approximately 16,300 km^2 above Tartan Rapids at the outlet of Prosperous Lake (Environment Canada Station 07SB0002). The Yellowknife River flows south from the Precambrian Shield through a lake/river complex. The river flow is regulated by the operation of the Bluefish Hydro Electric Power Station; however the Proponent notes that up to 30 % of flows come from the unregulated Cameron River, which joins the Yellowknife River downstream of the power station. It is not known, to what extent, Prosperous Lake attenuates flow at downstream reaches of the river. The Bluefish Hydro Electric Power Station has the potential to block fish passage, thus excluding access to upstream spawning locations.

The area to the south and west of the Precambrian dividing line is known as the Mackenzie lowlands. The north flowing Slave River contributes almost 87 % of the water, along with large quantities of nutrients and sediments. Slave River begins at the confluence of the Peace and Athabasca rivers, both which originate far back in the Rocky Mountains; in total the Slave River watershed has a drainage area of 616,400 km^2. Other important rivers flowing from the south include Hay, Buffalo and Taltson rivers.

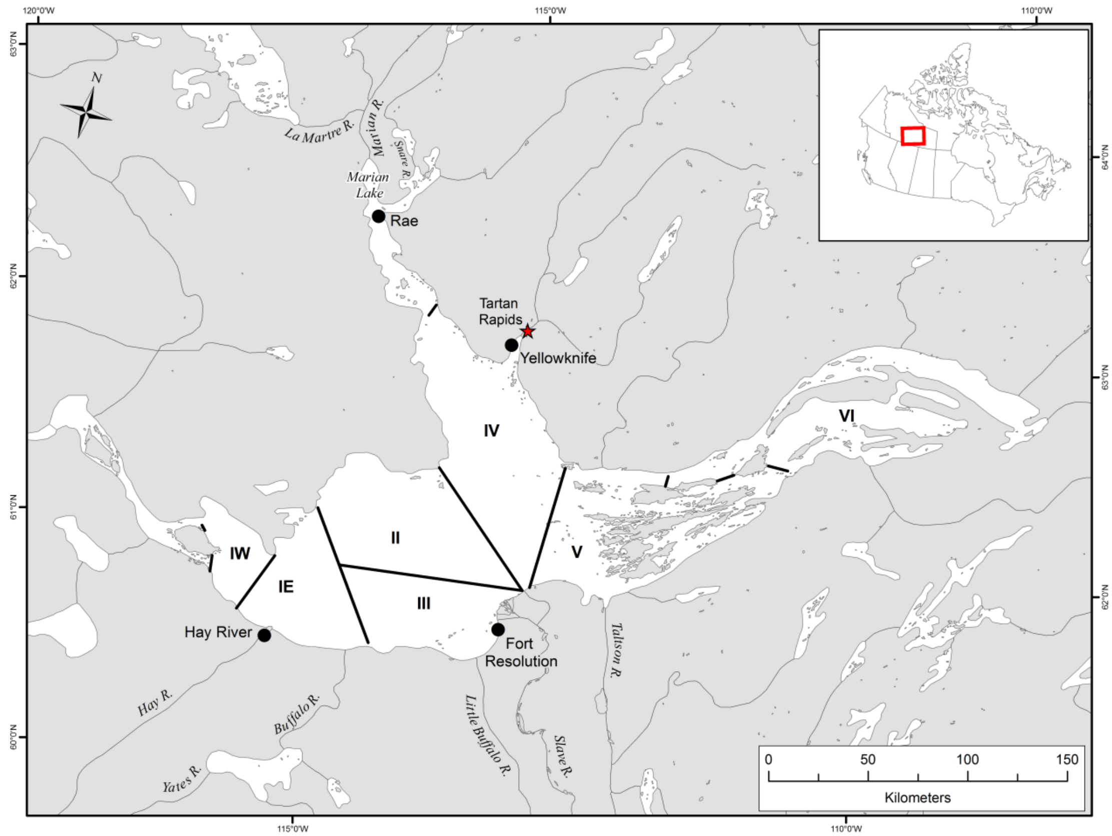

Figure 2. Map of Great Slave Lake, showing the current fishery management areas (IW, IE, II–VI), and place names mentioned in this report.

Great Slave Lake Fishery

There are at least 25 fish species in the lake, five of which are of commercial importance. The major commercial species is Lake Whitefish, (*Coregonus clupeaformis*), along with Lake Trout (*Salvelinus namaycush*), and by-catch species of Inconnu, Northern Pike (*Esox lucius*), and Walleye (*Sander vitreus*). Lake Cisco (*Coregonus artedii*), Burbot (*Lota lota*), and Longnose Sucker (*Catostomus catostomus*) are other valuable species. In addition to the highest sustained harvest for Lake Whitefish, Inconnu has been utilized both as important commercial harvest by international markets and subsistence use by local communities around the lake. The eastern arm of GSL supports a trophy fishery for Lake Trout.

A commercial fishery has been in operation on GSL since 1945. Prior to 1970, Lake Whitefish and Lake Trout were the two target species for this fishery. The combined quota was established from 1949 through 1971 was 4.1 million kg. The commercial fishery quota has changed several times since 1971, but currently the combined quota (includes both Lake Whitefish and Lake Trout; Day et al. 2013) is 1.68 million kg. The commercial fishery used bottom set gillnets of 140 mm stretched mesh size until 1977 and subsequently changed to 133 mm stretched mesh. Fish are processed at the Hay River fish plant. In the past, other plants have operated on the lake (VanGerwen-Toyne et al. 2013, Zhu et al. 2015).

Throughout the history of the fishery development, the lake has been divided into a variety of management areas for which boundaries, nomenclature and quotas have changed. Since 1972, the lake has been divided into seven management areas: 1 West (IW), 1 East (IE), 2 (II), 3 (III), 4 (IV), 5 (V), and 6 (VI) (Figure 2). A majority of the commercial fishery occurs in Areas 1E and 1W. The harvest levels from sources other than the commercial fishery (i.e., recreational and subsistence) are not well known. This remains a key gap in knowledge and information for the assessment of stock status and the establishment of sustainable harvests in GSL (DFO 2015, Zhu et al. 2015).

Inconnu

Inconnu occur in northwestern Canada, primarily in large silty rivers (e.g., Mackenzie River) and associated lakes. Inconnu exhibit both anadromous and adfluvial life history types; the GSL Inconnu are adfluvial. They spawn in the rivers in late September through early October, for which there appears to be a high degree of site fidelity (e.g., Slave River; Howland 1997). Inconnu are known to make long spawning migrations (e.g., up to 300 km in Slave River; Howland 1997). Inconnu in ripe and running condition have been captured in the Slave River at the base of the Rapids of the Drowned, suggesting that they spawn in the vicinity (Howland 1997). Moreover, Yellowknives Dene First Nation have observed and depended on spawning runs of Inconnu in the Yellowknife River for centuries. Melville (1914) noted that Inconnu probably ascended most of the rivers flowing from the north, but Inconnu were more pronounced in south shore drainages of Buffalo, Slave and Talston rivers. In Alaska, Inconnu are known to spawn over coarse gravel substrates and in water depths of 1.2–2.3 m (Alt 1969). There may be some differential selectivity of spawning locations for Inconnu. For example in the Arctic Red River, Howland et al. (2000) found Lake Whitefish and adfluvial Cisco spawning in the mouth of the river, but anadromous Inconnu migrated much further upstream to reaches with clear water and gravel substrates to spawn. This differential selectivity has yet to be confirmed for adfluvial Inconnu of GSL because detailed spawning substrate/flow relationships have not been determined for spawning Inconnu in spawning tributaries.

Inconnu are considered a top predator in the GSL ecosystem, with a strong trophic linkage to Cisco (i.e., predator-prey relationship) (Zhu et al. 2017). They are usually found in inshore areas of the main body of the lake, except in fall when rivers are ascended for spawning. Pre-spawning concentrations at the mouth of spawning rivers makes them especially susceptible to over-exploitation.

Standardized fishery-independent surveys indicated that the abundance and production of Inconnu were higher in Area IV, than those in the western basin (Areas IW and IE) and Area II of the main basin of GSL (Zhu et al. 2017; Figure 3). Tagging data suggest that Inconnu from the Slave River reside primarily in Area III and V (VanGerwen-Toyne et al. 2013). Inconnu is historically an important cultural part of the subsistence fishery. The current harvest for the subsistence and domestic fisheries are unknown.

Stock identification has not yet been fully resolved; however, recent work suggests that there are distinct stocks based on homing rivers and geographic separation (e.g., Marian River; Wiens et al. 2016, 2017).

Of the known stocks, the status of the Yellowknife and Taltson river stocks have not been assessed, although clearly they are not at historic levels of abundance. Slave River and Marian Lake stocks are considered healthy, while the Buffalo River stock of Inconnu are considered in the Critical Zone of the Precautionary Approach model framework (DFO 2013a). DFO Fisheries Management initiated a series of fishery closure zones along the south shore to support the recovery of depleted Inconnu stocks (Figure 4).

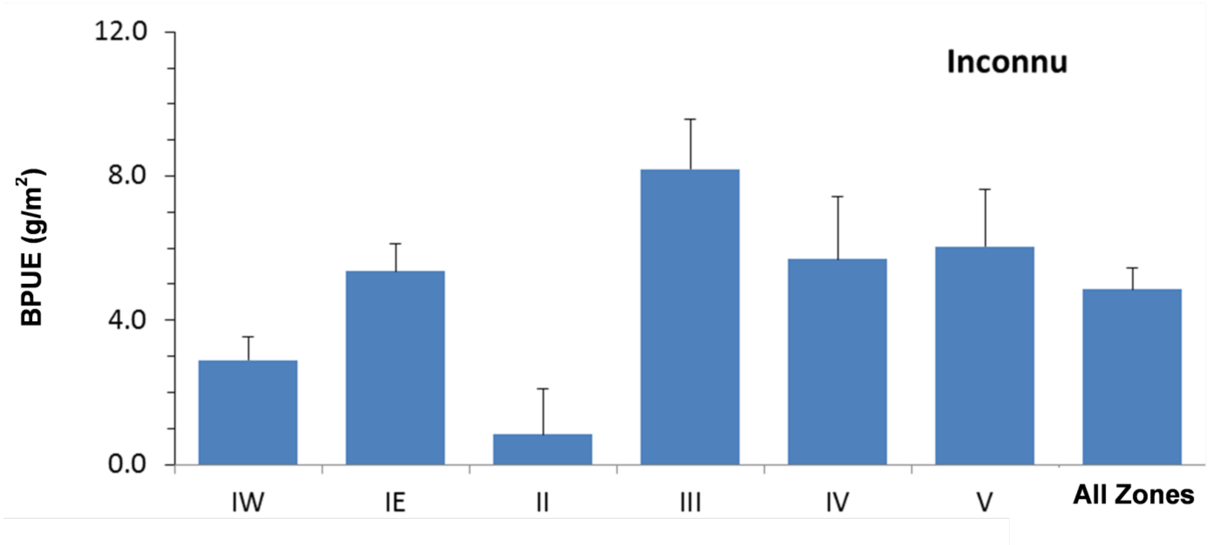

Figure 3. Spatial comparison of biomass density (g/m²) of Inconnu for each Great Slave Lake administrative area from fishery-independent survey data during 2011-2016 (Zhu et al. 2017). Yellowknife Bay area is located within area IV.

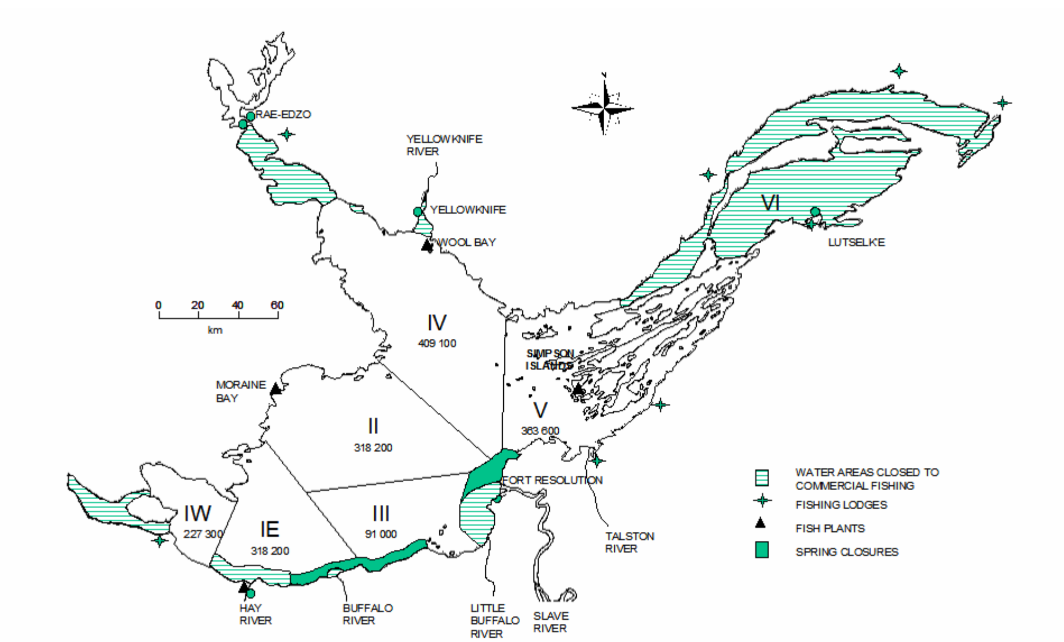

Figure 4. Map of Great Slave Lake showing the administrative boundaries and quotas (kg), areas closed to commercial fishing and the location of the fish plants and fishing lodges (taken from DFO 2013).

In addition to harvesting, there are several other anthropogenic activities that combined, may have contributed to the decline of Yellowknife River Inconnu, such as the construction of the Bluefish Hydro Electric Power Station on the Yellowknife River, activities related to the Giant Mine, increased local access to the Yellowknife River and a growing population in the City of Yellowknife (e.g., Tallman and Howland 2017).

Analysis and Response

Stocking as a measure for offsetting

Stocking is the practice of releasing fish into an ecosystem to augment the natural supply of individuals, increase productivity of a wild population, overcome a recruitment limitation, increase fishery yields, or boost declining fish stocks (DFO 2014). The method by which a stocking program is undertaken (e.g., translocation, hatchery) depends on the current state of the stocked fish population productivity, carrying capacity of the ecosystem and the desired objectives of the stocking program.

The selection of an offsetting measure for a Proponent must be supported by clear fisheries management objectives or regional restoration priorities (DFO 2013b). Offsetting measures should meet the principles laid out in DFO (2013b), including that the proposed measures generate self-sustaining benefits over the long term (DFO 2013b). The offsets should be designed to increase the productivity of the fisheries affected by the serious harm. In specific cases this may be modified by fisheries management objectives or other resource management considerations (e.g., species at risk, aquatic invasive species; DFO 2014).

A recent review of stocking studies showed that most stocking programs had negative ecological or genetic impacts on natural populations of the same species, including reduced reproductive fitness of wild populations through interbreeding and reduced genetic diversity, and reduced survival of wild fish through competition or increased predation (DFO 2014, Loughlin and Clark 2014). Also, most stocking programs require ongoing intervention and are generally found to be not self-sustaining (DFO 2014). This suggests that the use of stocking to augment or establish self-sustaining populations should be carefully planned to achieve the management objectives, have a long term monitoring plan and intervention program and only be used as a last resort.

According to the National Code on Introductions and Transfers of Aquatic Organisms (2003), stocking programs should consider possible ecological fitness and genetic impacts on wild fish. The stocking density varies with other density-dependent factors (e.g., impacts on juveniles, food availability), disproportionate predation of stocked individuals (e.g., juveniles), predator population dynamics and activity periods, timing of release, methods and locations of release of stocked fish, quantities of released fish, impacts on other species, current fishing pressure, availability of suitable habitats, and possibility of attracting fishing effort and predators to an area, possibility of increasing by-catch and predation on non-target species (DFO 2014).

When the objective is to augment or establish self-sustaining populations, success of stocking is increased when local, wild-origin brood stocks are used, proper location and timing windows are identified, and harvest is delayed until at least two reproductive cycles have been completed (most useful in a closed area; DFO 2014). Stocking is likely less successful when introductions take place where existing populations are at or near carrying capacity, released fish are immediately consumed by predators or removed through fishing; and released fish compete with wild stocks for limited resources (DFO 2014). Managing the current wild stocks is the preferred approach.

Likelihood of successful egg stocking in the Yellowknife River

Several sets of cumulative or additive impacts were likely responsible for the decline of Inconnu in the Yellowknife River. For example, overharvesting from commercial, recreational and/or subsistence harvests, impacts associated with the construction and/or operation of the Bluefish Hydro Electric Power Station (e.g., loss of suitable spawning habitat) and contamination from anthropogenic activities (e.g., Giant Mine) (VanGerwen-Toyne et al. 2013, Tallman and Howland 2017) could be responsible for the decline of Inconnu abundance. Local knowledge obtained during community consultations conducted by the Proponent support the hypothesis that Inconnu are no longer abundant in the Yellowknife River due to the above mentioned impacts (Dominion Winter 2017 Community Engagement Sessions, Appendix D). The Inconnu population could recover without management intervention if suitable habitat for Inconnu exists in the Yellowknife River and the impacts have diminished over time (e.g., fishery closures [see Figure 4], ecosystem equilibrium). Habitat, or access to preferred habitat, may remain an issue in the Yellowknife River. Consequently, it is questionable as to how newly stocked Inconnu would survive based on this scenario.

For certain species, such as Inconnu, homing is an important part of the life cycle (i.e., returning to natal stream). As the Proponent has indicated, the use of eggs is preferential when considering this important life history function to ensure that the physical and/or chemical cues to migrate back to their natal streams is learned at the very earliest stage. However, studies indicate that egg survival is highly variable (Cowx 1994), driven by temperature (e.g., Laurel and Blood 2011), hypoxia (e.g., Marcus et al. 2004) and substrate depth and water quality (e.g., Sternecker et al. 2013). This presents a number of limiting uncertainties regarding the success of egg hatch and survival, again questioning the potential for the success of stocking as an offsetting plan.

It is uncertain that co-adapted genetic complexes selected for survival and viability in the Slave River will translate to the Yellowknife River. The Yellowknife River, originating in the Precambrian Shield flows from the north and has different physical/chemical characteristics, while the Slave River originates from the south and flows through the Great Plains, resulting in warmer, more turbid water and siltier substrate. Even if Inconnu survive the first post-egg period, and produce returnees, the introductions could cause the dissolution of existing adaptations through interbreeding. River freeze-up and break-up times along with the hydrological regimes (Howland et al. 2000) are tightly tied to the emergence and success of larvae (i.e., match-mismatch), so the different hydrological regimes between the Slave and Yellowknife rivers could lead to a hatching and/or survival failure of future generations.

The Proponent recognizes the importance of source stock site selection (i.e., consideration of eggs adapted to similar habitat conditions) and the use of eggs for translocation to ensure imprinting (i.e., fishes return to their natal stream). However, the Proponent goes on to propose the Slave River as a source stock based on ease of accessibility to spawning locations and egg collection, not the biological suitability of the source stock. DFO (2014) recommended that the source stock should be selected based on proximity and similarities to the reintroduction site. Site selection should also be consistent with the principals of the management of the fishery, which assumes that Inconnu stocks are relatively independent from each other. This effectively decreases the chance of egg survival. Consequently, Inconnu from sources closer to the Yellowknife River may be more suitable due to adaptations to the river environments flowing from the Precambrian Shield geological areas and those that genetically more related (e.g., La Martre and Marian rivers).

Impact of stocking on the existing GSL ecosystem

DFO Science uses an ecosystem approach when providing Science Advice to management. For GSL, this includes the consideration of biodiversity (e.g., species richness), the sustainability of target fisheries (Lake Whitefish and Lake Trout) and by-catch (e.g., Inconnu) and a healthy state of the ecosystem (Zhu et al. 2017).

Biodiversity exists at several levels, including species richness within the system and the genetic biodiversity within a species group. Destruction and/or homogenization of genetic stocks through stocking can be detrimental to the health of wild stocks and the ecosystem (Hess et al. 2012; DFO 2014). It is unclear what life history form originated from the Yellowknife River (adfluvial versus fluvial), since there are several lakes along the river. Inconnu from the Slave River stock may be adapted to quite different environmental conditions, and as a result, the genetic diversity of any remnant Yellowknife Rivers Inconnu could be homogenized potentially impacting their resiliency.

There are also concerns with the impact of introducing a ‘new’ species to a system that has moved to a new dynamic equilibrium. The Proponent assumes that it is unlikely that “…current populations of coregonids are at, or near the carrying capacity of available habitat…given current harvesting pressures and Traditional Knowledge of historical trends in fish abundance.” (Main Document, Section 5.1.4., pg. 67). If the re-establishment of Inconnu were successful, it seems unlikely that it would have negligible impacts on the existing Yellowknife River fish community and ecosystem. It is known that Inconnu were abundant in this river system nearly 50 years ago and have since been almost locally extirpated, the ecosystem would have moved to a new dynamic equilibrium in the absence of competition for preferred habitat by spawning Inconnu. The re-introduction could thus impact adfluvial Lake Whitefish and Cisco populations because of potential competition for spawning habitat and interstitial space for egg and embryo development (Hayes 1987, Hearn 1987, Howland 1997, Sternecker et al. 2013). DFO science advice suggests monitoring of the local fish community or assemblages that may be negatively affected by interactions with stocked fish (DFO 2014).

The proposed offsetting plan should be designed within an ecosystem scale of potential effects (DFO 2014). This means the context of the offsetting plan should include the general status and trends of the local environment and consider current or proposed stressors on the system (e.g., TerraX drilling gold mine exploration, operation of the Bluefish Hydro Electric Power Station). There is uncertainty in species or ecosystem responses to alteration through stocking (DFO 2014) and therefore a complete understanding of the current ecosystem will assist in predicting ecosystem change and to explain any observed changes.

Impact of stocking on research in support of sustainable GSL fisheries

As part of DFO Science stock assessment research in GSL, projects are focused on stock status (i.e., abundance) and sustainability. As part of this research, understanding stock structure and geographic distribution of Inconnu is a key component. Preliminary genetic analysis of Inconnu in GSL (17 microsatellite markers) suggests the presence of two distinct stocks: Marian Lake and Yellowknife Bay, and the stock from Slave River (Wiens et al. 2016). The samples from the mouth of Buffalo River were inconclusive, likely because of the presence of a mixed stock (Wiens et al. 2016). Further genetic analyses on the natal river sites, such as Buffalo River, will provide resolution on mixed stocks in GSL. Genetic analysis appears to be a valuable tool and research is currently ongoing in the GSL to identify and further refine Inconnu stocks structure.

The translocation of one Inconnu stock (Slave River) to another area that is likely different has the potential to compromise the studies that are currently in progress to determine stock structure using genetics. The proposed offsetting plan may confound the current research and potentially compromise future management decisions if genetic patterns are altered.

Risk of disease

Although less likely with eggs than larval or juvenile transplants, there is a possibility of disease (e.g., viruses/bacteria) being introduced to the recipient population or ecosystem. The following comments and science advice refer to the potential issue of disease transfer with the proposed egg transplantation (CFIA 2018, DFO 2017).

The Proponent references two citations in support of the following statement (p. 69, 135): "There has been no suggestion or evidence to-date in available literature that disease or parasite load was a contributing factor in the decline of Inconnu in the Great Slave Lake Region (e.g., MRBB 2004, VanGerwen-Toyne et al. 2013)." A concern about the potential impact of disease on fish populations was mentioned in MRBB (2004). Disease was not mentioned in VanGerwen-Toyne et al. (2013).

The disease status of Inconnu in GSL is not well known. The Inconnu source river (Slave River) and the recipient (Yellowknife River) proposed by the Proponent are both part of the Mackenzie River drainage basin. However, the Yellowknife River (recipient river) flows south whereas the Slave River (source river) flows north into GSL, which is drained by the Mackenzie River into the Arctic Ocean. Infectious pancreatic necrosis virus (IPNV) is considered to be endemic in Dolly Varden (*Salvelinus malma*) stocks found in tributaries of the lower Mackenzie River where IPNV isolates classified as genogroup (V) have persisted in wild populations for at least 30 years (Souter et al. 1984, 1986, S. Clouthier and Anderson, DFO Winnipeg, pers. comm.). Further, IPNV isolates of genogroup (I) have been detected in cultured and wild rainbow trout *(Oncorhynchus mykiss) (*Yamamoto 1974) and lake trout (*Salvelinus namaycush*) (Larson 1985) in Alberta. The infected watersheds include tributaries of the Athabasca River, which connect the Peace-Athabasca Delta with Slave River, the proposed source of the Inconnu. A mix of these two IPNV genotypes could potentially coexist in GSL. An embryonic cell line derived from eyed eggs of Inconnu supports replication of IPNV and infectious hematopoietic necrosis virus, suggesting that the potential for IPNV in wild Inconnu stocks exists (Follett and Schmitt 1990).

IPNV can be spread through vertical or horizontal modes of transmission. Vertical transmission of IPNV can be intra-ovum or extra-ovum and virus transmission can occur during the process of stripping brood stock and fertilizing ova (Anonymous 2003). Disinfection of fertilized eggs with iodophores reduces but does not eliminate vertical transmission of the virus (Ahne et al. 1989, Bullock et al. 1976, Dorson et al. 1997). Horizontal transmission of IPNV can occur by exposing fish to IPNV-infected water or by cohabitation of native fish with virus-infected fish (e.g., McAllister and Owens 1986, Munang'andu et al. 2016). IPNV is among the most chemically and environmentally stable fish viruses and its stability contributes to the high risk associated with horizontal transmission of the virus (Myrmel et al. 2014).

IPNV has a broad host range which includes fish belonging to at least 32 different families, 11 species of molluscs, and four species of crustaceans (e.g., Munro and Duncan 1977, McAllister 1983, Wolf 1972, Reno 1999). Many of these organisms can serve as reservoirs and vectors of IPNV, transmitting the virus within and between freshwater and marine environments. Adult fish that survive infection can serve as lifelong asymptomatic carriers of the virus (Reno et al. 1978, Swanson and Gillespie 1982, Smail and Munro 1985) shedding virus particles in their urine, faeces, and reproductive products (Yamamoto 1975a, Ahne 1983). Piscivorous birds and mammals can function as vectors of IPNV after feeding on live or dead infected fish. IPNV can also be spread through anthropogenic activities. During fish handling activities, water, equipment, clothing, and transport vessels that come in contact with infected fish can subsequently be a source of IPNV transmission.

DFO Science suggests that baseline information on the virus infection status of fish species, particularly Inconnu, should be gathered throughout GSL, but at a minimum, Slave River, and Yellowknife River prior to considering a stocking program. If virus is detected in one or more of these locations, the virus genotype for each location should be determined.

The life stage with the lowest risk of virus transmission is eggs. It is recommended that only eggs that have been surface disinfected (50 ppm iodophore, 10 min) at the source river prior to transport and again upon arrival at the recipient river should be used. Water hardening of each family of eggs should be kept separate during disinfection in the iodophore and the latter should be replenished and adequately mixed. This recommendation reduces the potential for cross-contamination between egg batches by gamete fluids, increases inactivation of virus on the surface of the egg and in the perivitelline space, and ensures adequate disinfection of eggs given that the quantity of eggs processed in each batch is smaller. Fertilization of eggs from each female should be kept separate to reduce the potential for cross-contamination of eggs batches if one or more males have virus-positive seminal fluid. Stringent disinfection of utensils and containers, etc. should be conducted during and after taking the eggs and egg fertilization to reduce the risk of spreading the virus.

This offsetting project would require an approved Animal Use Protocol from the Freshwater Institute Animal Care Committee, based on the handling and potential mortality of Inconnu and other non-target species. Overall, the proposed stocking plan requires further detail regarding the method of capture, size of holding tubs, and densities expected. If euthanasia is necessary, both target and non-target species should be euthanized using a 2-step method (stunning blow to head, followed by pithing or cervical dislocation). Any individual that will be handling fish during this project should take training in ethical use and handling of fish.

Hydraulic modelling and habitat suitability indices (HSI)

The Proponent has undertaken two years (2015, 2016) of habitat sampling to prepare their rational for the site selections for both the source stock and the reintroduction site (Appendix C and G). There are a number of technical issues that were identified with the hydraulic modelling that may impact the suitability of egg transplant and success of the offsetting program. Firstly, the Proponent’s offsetting plan indicates in Appendix C on page 3-1 that “Validation is necessary to evaluate model reliability and to establish credibility. Field data collected in 2015 provided such opportunity to validate the HSI model for Lake Whitefish egg incubation habitat.” We caution that there is high uncertainty that persists in modelling results due to the transfer of an HSI model developed for one species (i.e., Lake Whitefish) to another species (i.e., Inconnu). Additionally, Lake Whitefish HSI curves were modified to represent Inconnu HSI, however, it was difficult to review the modifications because of insufficient rational and references provided in the report that directly link or rationalize the adjustments (Appendix C, page 3-9). DFO Science would like to review the explanation of how the Proponent changed the curve based on the cited literature.

The Proponent acknowledges that availability of suitable water velocities will impact the egg incubation, however, the report (Appendix C, page 4-5) indicates that for Lake Whitefish egg surveys “The maximum mean water column velocity for egg locations was 0.36 m/s” (Figure 5). However, the HSI curve for velocity suggests a suitability index value of 1 for those velocities that range between approximately 0.1 to 0.75 m/s (Figure 6). Without sufficient rational for the range of values this may be an overestimation of suitable habitat for egg incubation.

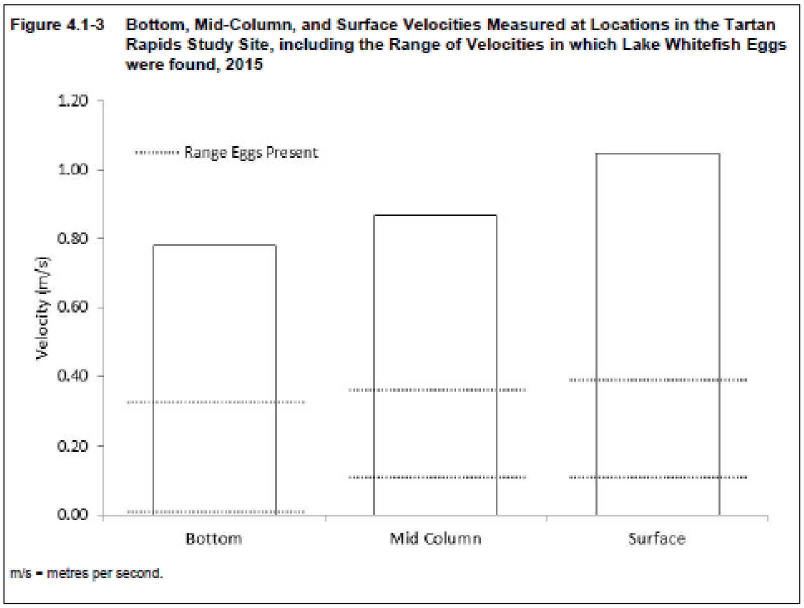

Figure 5. Range of velocities, from the 2015 Baseline study, where Lake Whitefish eggs are found at the Tartan Rapids (Figure taken from Appendix C, Section 4).

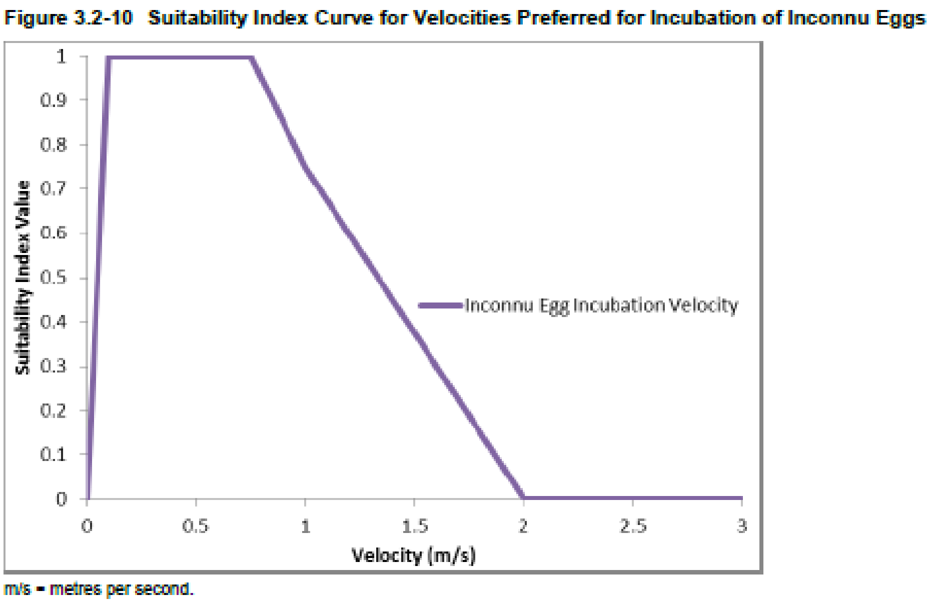

Figure 6. Suitability index curve for velocities preferred for incubation of Inconnu eggs in the Jay Project Final Offsetting Plan (Figure taken from Appendix C, Section 3).

DFO Science suggests data on ice thickness and an annual hydrograph would assist to support the findings of the HSI model validation for the Tartan Rapids. The report states that “The depth SI curve for incubation of Lake Whitefish eggs also accounts for a 0.5 m thick surface ice cover assuming water depths below this threshold have a suitability score of zero. This 0.5 m ice cover was assumed based on ice thickness information for other Canadian river systems (Das 2015, Ryder 1953, Environment Canada 1989)”. DFO Science asks the Proponent to provide an explanation for how the estimate of 0.5 m was obtained for this dynamic stream system (i.e., ice thickness variability within rapids). For example, the New Brunswick River Ice Manual states that “In central New Brunswick, the thickness of thermal ice covers typically ranges between 38 and 80 cm; depending on the severity of the winter season.” One would assume that the severity of the winter season in the study site under review is more severe and consequently ice thickness might be greater than 0.5 m, which would change the depth HSI curves for incubation. Das (2015), who is given as a reference as well, provides an ice thickness of 1.22 m in the Slave River. Using the precautionary approach, DFO Science suggests that the maximum ice thickness should be used to predict incubation habitat.

For Appendix C, section 4, pages 4-23 and 4-26 egg incubation habitat was modelled using October flow scenarios. The Proponent provides a graph for the Tartan Rapids discharge summary in Figure 3.2-2 (Appendix G). The May 1987–November 2016 mean daily discharge (red line Fig. 3.2-2 of Appendix C) shows March–April flows are less (by as much as 22–36 %) than the October flow selected for the model. For the model, the lowest anticipated flows occurring in the hydrograph during the egg incubation period should be selected. Under lower flows, the wetted area will be smaller. DFO Science recommends the model should be rerun using the lowest anticipated flow.

Finally, as an editorial note, Appendix C, Figures 3.2-3 and 3.2-8 and in Appendix A of Appendix C, Figure B1-3 the unit for substrate particle size on the x-axis is incorrect.

In Appendix G, Section 3.5, the Proponent proposes Q50 for their flow scenario. DFO Science recommends that once the appropriate low flow month is selected (i.e., later during the incubation period than October) the total area available for Inconnu egg incubation be estimated using a more conservative approach (i.e., Q25 as opposed to Q50), since we do not want to overestimate the available egg habitat, which in turn results in an overestimation of productivity related to offset targets.

Annual fish production calculations for offsetting

Total fish biomass loss during the fish-out of the diked area is calculated as 1,434 kg. Annual fish production losses are calculated not to be higher than 301.1 kg/year. This results in a total combined loss of 6,022 kg in annual fish production over a 20-year period. Approximately 7,456 kg of fish biomass (all species combined) will be lost. Each stocking event provides an estimated total production of 1,618 kg, and therefore five stocking events may be required to meet the current objective of the offsetting plan (7,456 kg). Depending upon best-estimate and lowest estimate return rate scenarios, “Equivalency is expected to occur between year 6 and 11” (Main Document, Section 5.4, page 88).

A fish model is used to calculate fish production using weight at age estimates from 1955 and 1985, and survival rates based on anadromous Chinook Salmon (*Oncorhynchus tshawytscha*) studies. The weight at age data used by the Proponent (Appendix B, Table 1-1) are dated and based on old ageing techniques using fish scales. Inconnu scales are difficult to read and show variation with increasing fish size (Howland et al. 2004). When comparing current aging data based on otoliths (from the annual survey at the mouth of Buffalo River from 2013 to 2017 and Slave River from 1994) with the aging data used by the Proponent, modelling has overestimated the weight for the age classes 6 to 8 years (Table 2). There is also evidence that weight/size at age has changed (i.e., younger age structure) in more recent years (Howland 2005, Tallman and Howland 2017) (see Table 2).

Further, the use of survival rates from anadromous populations of another species is likely to be inaccurate. Survival rates have been estimated for Inconnu and show that adfluvial populations in GSL have a higher mortality than anadromous counterparts (Howland 2005). The Proponent should consider fishing mortality (i.e., commercial, recreational, Aboriginal subsistence) when calculating survival rates (see Section 5, Table 5.3-2). For Inconnu caught at the mouth of the Buffalo River from 2013–2016 survival rate was calculated as 58-68 %. (M.Y. Janjua, DFO Winnipeg, Pers. Comm.). Survival rate calculations for Inconnu in the Slave River can be found in Howland (2005) and Howland and Tallman (2017). Therefore, the fish production model and data used for calculation of biomass needs revision using adfluvial Inconnu survival rates and updated biomass at age calculations.

In Appendix B, page 11/22 the Proponent states, "Monitoring adult returns is not required to demonstrate that the offsetting targets have been achieved as the contribution to fishery production is achieved through the growth stage while fish are in GSL and is not contingent on the number of returning adults." Instead the Proponent proposes that if egg hatching is successful (based on visual observation and model calculation for mortality) the fish production model then predicts the amount of biomass each hatched Inconnu is expected to reach to determine if their offsetting goals of productivity have been met. DFO Science does not recommend using the current model that is constructed using data inputs from other species of fish, or from historic Inconnu data which contain a high level of uncertainty.

Table 2. A comparison of Inconnu mean weight (g) at age (3-8 years) used by the Proponent (Fuller 1955, RLL 1980) and those collected by DFO in the Buffalo River mouth, Great Slave Lake, NT (2012-2017) and in the Slave River (1994; Howland 2005).

Age	Mean weight (g)		
	DFO Buffalo River index data (2012-2017)	Slave River 1994	Data used by Proponent
3	-	-	628
4	2,052	-	1,296
5	2,646	3,496	2,633
6	3,053	4,057	3,863
7	3,741	4,646	5,140
8	4,533	4,957	6,358

Monitoring

As currently proposed the egg stocking plan is experimental and not necessarily tractable to DFO Science. There are a number of issues with being able to assess the likelihood of success:

- Main Document, page 97, the Proponent states "Results from monitoring egg survival will assist in refining predictions of biomass gains to determine if the objectives of the offsetting plan can be met." How will the Proponent be able to identify Inconnu egg/fry during their monitoring surveys (i.e., hatching success) and will this be used to refine the prediction of the biomass gains?
- Different environmental factors (e.g., temperature, ice-break, water chemistry) between the source river (i.e., Slave River) and the recipient (i.e., Tartan Rapids), how will the Proponent know when to survey for eggs?
- How will the Proponent be certain that the eggs observed is a result of their egg planting, and not from stray GSL Inconnu that found their way into the Tartan rapids?

- Main Document, page 95, the Proponent states that "The results of the juvenile and adult monitoring will contribute to an understanding of the self-sustaining properties of the offset, but will not be linked to a quantitative target for determining effectiveness.". How will the Proponent be able to identify and monitor subsequent stocked juvenile/adults?
- How will the Proponent determine when a stocked fish has successfully been identified versus a transplanted fish from another river (i.e., vagrants)?

In Appendix A, page 4/6 the Proponent states that "... Inconnu population within Great Slave Lake is a management priority for DFO in the region and re-establishing an Inconnu population within the Yellowknife River is a local restoration priority for the Yellowknives Dene First Nation." If restoration of a population in the Yellowknife River is the objective, then the current monitoring plan would not suffice. Long-term monitoring and continued stocking would likely be required to meet the goals of establishing an Inconnu population in the Yellowknife River, thus sustained stocking may be required.

There are conflicting statements throughout the report about the historical abundance of Inconnu in Yellowknife River. On page 61, the Proponent acknowledges that traditional knowledge states that Inconnu were once abundant and "thick" in the Yellowknife River, while on page 62 the report states that the "Historical run was considered relatively small (about 1000 or less fish)". Previous science advice on monitoring for stocking as an offset suggests including an estimation of abundance and biomass of both wild and stocked individuals to establish the baseline on the success of stocking activities and the monitoring of the local fish community or assemblages that may be negatively affected by interactions with stocked fish (DFO 2014).

DFO Science would like resolution of this discrepancy and/or evidence of whether there is still Inconnu spawning that may occur farther upstream similar to Inconnu in other systems. Literature on the migration of Inconnu has reported migrations up to 300 km in GSL (Howland et al. 2000). The Proponent states on page 108 that: "…there are no Inconnu in the Yellowknife River." However, recent tagging data suggest Inconnu are in the Yellowknife Bay (M.Y. Janjua DFO Winnipeg, pers. comm.), also suggesting that strays may also use the river system. This has the potential to confound any monitoring in the river by the Proponent to determine success.

Conclusions

DFO Science recognizes the amount of baseline work that the Proponent has conducted in order to describe the offsets required to meet the loss of fish production with the development of the Jay Project. The objectives of this review were to evaluate the Proponent's predicted biomass gains (i.e., fish production model), habitat suitability models and other models proposed by the Proponent, to determine whether the proposed offsetting plan will generate self-sustaining benefits over the long-term, and lastly identify if the proposed offsetting plan will impact the sustainable management of the fisheries of GSL (including DFO GSL research).

- Habitat suitability indices (HSI) curves for Inconnu should be corrected based on the review comments and validated with field results. DFO Science recommends that the Proponent should rerun the habitat model with revised input parameters (ice thickness and river flows) and HSI curves.
- The fish production model and data used for calculation of biomass revision using adfluvial Inconnu survival rates and recent biomass at age calculations (provided in Table 2) should be used in the fish production model to determine offsetting requirements.

- In general, there is limited knowledge for Inconnu HSIs. DFO Science recommends the Proponent provide rational for the Inconnu HSI parameters. Without these, there is greater uncertainty surrounding the model outputs.
- Based on the Proponent's Offsetting Plan and the uncertainties associated with the stocking plan, it is unlikely that the stocking program will "generate self-sustaining benefits over the long-term".
- Habitat, or access to preferred habitat, may remain an issue for Inconnu in the Yellowknife River if anthropogenic factors were the cause of the initial decline. Consequently, it is questionable as to how newly stocked Inconnu would survive. This presents a number of limiting uncertainties regarding the success of egg hatch and survival, again questioning the potential for the success of stocking as an offsetting plan.
- It is uncertain that co-adapted genetic complexes selected for survival and viability in the Slave River will translate to the Yellowknife River.
- The Proponent recognizes the importance of source stock site selection (i.e., consideration of eggs adapted to similar habitat conditions) and the use of eggs for translocation to ensure imprinting (i.e., fishes return to their natal stream). However, the Proponent goes on to propose the Slave River as a source stock based on ease of accessibility to spawning locations and egg collection, not the biological suitability of the source stock. Consequently, Inconnu from sources closer to the Yellowknife River may be more suitable due to adaptations to the river environments flowing from the Precambrian Shield geological areas and those that genetically more related (e.g., La Martre and Marian rivers).
- DFO Science suggests monitoring of the local fish community or assemblages that may be negatively affected by interactions with stocked fish. Therefore a complete understanding of the current ecosystem will assist in predicting ecosystem change, and to explain any observed changes following any stocking program. This would provide resolution of the discrepancy and/or evidence of whether there are still Inconnu in the Yellowknife River.
- DFO Science recommends that baseline information on the virus infection status of fish species, particularly Inconnu, should be gathered for GSL at a minimum Slave River and Yellowknife River prior to considering a stocking program. If virus is detected in one or more of these locations, the type of virus and its genotype should be determined for each location.
- It is recommended that only eggs that have been surface disinfected (50 ppm iodophore, 10 min) be used, that water hardening of each family of eggs be kept separate during disinfection and that fertilization of eggs from each female be conducted separately.
- Genetic analysis appears to be a valuable tool and research is currently ongoing in the GSL to identify and further refine Inconnu stocks structure. The translocation of one Inconnu stock (Slave River) to another area that is likely different has the potential to compromise the studies that are currently in progress to determine stock structure using genetics. The proposed offsetting plan may confound the current research and potentially compromise future management decisions if genetic patterns are altered.
- For any stocking projects such as this, long-term monitoring is essential to collect first-hand species-specific information for evaluating the effectiveness of the stocking project. The proposed methods seem insufficient to determine if the objectives and productivity will be met and sustained. Additionally, long-term monitoring (> 12 years) and continued stocking would likely be required to meet the goals of establishing an Inconnu population in the Yellowknife River, thus sustained stocking may be required.

- DFO Science recommends that the concept of Inconnu egg stocking be part of a larger integrated fisheries management plan for Inconnu, and that together with other species harvested in the Great Slave Lake fishery, be considered from an ecosystem perspective. This would include an assessment of current Inconnu stock and habitat status in the Yellowknife River. Egg stocking could be considered as part of the fisheries management strategy if stocking is necessary to address a shortage of spawning stock and if sufficient suitable spawning and incubation habitat is available.

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