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Science Response 2021/009

RECOVERY POTENTIAL ASSESSMENT FOR SIX DESIGNATABLE UNITS OF WHITEFISH (*COREGONUS* SPP.) IN YUKON LAKES

Context

After the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses an aquatic species as Threatened, Endangered or Extirpated, Fisheries and Oceans Canada (DFO) undertakes a number of actions required to support implementation of the *Species at Risk Act* (SARA). Many of these actions require scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for consideration of peer-reviewed scientific analyses into SARA processes including listing and recovery planning.

In 2018, eight Designatable Units (DUs) of whitefish were assessed as Threatened in Canada, and two more were determined to be Extinct, by COSEWIC. This Recovery Potential Assessment (RPA) pertains to six of those DUs; those found in the Yukon Territory in Squanga, Little Teslin and Dezadeash Lakes. This RPA provides descriptions of the known status of these DUs, an overview of the biology and habitat requirements, and an assessment of the threats and factors which contribute to the Threatened status and may limit recovery.

In support of listing recommendations for the six whitefish DUs assessed as at risk in the Yukon Territory, Fisheries and Oceans Canada (DFO) Science has been asked to undertake a RPA, based on the national RPA Guidance. The science advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, development of a recovery strategy and action plan, and to support decision making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of SARA. The advice in the RPA may also be used to prepare for the reporting requirements of SARA s.55. The advice generated via this process will update and/or consolidate any existing advice regarding the six whitefish DUs assessed as at risk in the Yukon Territory.

The RPA provides up-to-date information and discusses associated uncertainties of the 22 elements of the Terms of Reference under the following categories:

- Biology, life history, abundance and distribution
- Habitat and residence requirements
- Threats and limiting factors to survival and recovery
- Recovery targets
- Scenarios for mitigation of threats and alternatives to activities
- Allowable harm

This Science Response results from the Science Response Process of April 14, 2020 on the Recovery Potential Assessment – Whitefish - Yukon Lakes Designatable Units.

Canada

Introduction

After the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses an aquatic species as Threatened, Endangered or Extirpated, Fisheries and Oceans Canada (DFO) undertakes a number of actions required to support implementation of the *Species at Risk Act* (SARA). Many of these actions require scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) that is conducted shortly after the COSEWIC assessment. This timing allows for consideration of peer-reviewed scientific analyses into SARA processes including listing and recovery planning.

Species Information

Scientific name: *Coregonus clupeaformis*

Common name: English: Lake Whitefish (Mitchill 1818)

French: grand corégone

Other names: whitefish, common whitefish, Sault whitefish, eastern whitefish, Great Lakes whitefish, inland whitefish, gizzard fish, lake herring, Labrador whitefish, sead, humpback, buffalo back, whitebait, corégone, poisson blanc, pi-kok-tok, jikuktok, anahik, kapihilik, pikuktuuq, kakiviatktok, kavisilik, anâdlerk, kakiviartût, keki-yuak-tuk, anadleq, qelaluqaq (Coad 2013).

Scientific name: *Coregonus lavaretus* (Linnaeus 1758)

Common name: English: European Whitefish

French: corégone européen

Other names: common whitefish, pollan, powan

The taxa included in this report belong to two recognized species. For many years, European Whitefish (*C. lavaretus*) was not considered native to North America (Page et al. 2013). However, genetic evidence suggests that this species migrated to North America during the Pleistocene and has existed in sympatry with Lake Whitefish in Alaska and northwestern Canada (Bodaly et al. 1991; Bernatchez et al. 1996; Mee et al. 2015). In 2016, *C. lavaretus* was added to the official North American names list as native to Canada and the United States by the American Fisheries Society and American Society of Ichthyologists and Herpetologists.

Due to their broad distribution, whitefish (*Coregonus spp.*) have undergone significant speciation and local adaptions in many lakes resulting in many discrete populations. Whitefish are often found in species pairs, i.e., two distinct and genetically isolated morphological forms occurring within the same lake. Because lakes containing whitefish populations are geographically isolated from all others, species pairs are unique and endemic to each lake. Each species pair in each lake therefore represents a unique component of whitefish diversity and each DU in each species pair should be considered discrete and significant (COSEWIC 2018). The six whitefish designatable units (DUs) assessed by COSEWIC exist in species pairs within three lakes in the Yukon Territory: Squanga Lake, Little Teslin Lake and Dezadeash Lake (Table 1). European Whitefish is present in all three lakes, and Lake Whitefish is present in two (Little Teslin and Squanga) of the three lakes included in this report (Table 1).

Table 1. Yukon Territory designatable units of whitefish assessed by COSEWIC.

Designatable Unit (DU)	COSEWIC Status	Reason for Designation
European Whitefish (*Coregonus lavaretus*) – Squanga Lake small-bodied population	Threatened	This species is known from a single lake in southern Yukon, where it coexists with a species derived from the Lake Whitefish. Its persistence is threatened by the risk of establishment of invasive species that could alter the ecological niches of the species pair. If exotic species invade, this fish could become extinct in a short period of time.
Lake Whitefish (*C. clupeaformis*) – Squanga Lake large-bodied population	Threatened	This species is known from a single lake in southern Yukon, where it coexists with a smaller species derived from the European Whitefish. Its persistence is threatened by the risk of establishment of invasive species that could alter the ecological niches of the species pair. If exotic species invade, this fish could become extinct in a short period of time.
European Whitefish (*C. lavaretus*) – Little Teslin Lake small-bodied population	Threatened	This species is known from a single lake in southern Yukon, where it coexists with a species derived from the Lake Whitefish. Its persistence is threatened by the risk of establishment of invasive species that could alter the ecological niches of the species pair. If exotic species invade, this fish could become extinct in a short period of time.
Lake Whitefish (*C. clupeaformis*) – Little Teslin Lake large-bodied population	Threatened	This species is known from a single lake in southern Yukon, where it coexists with a smaller species derived from the European Whitefish. Its persistence is threatened by the risk of establishment of invasive species that could alter the ecological niches of the species pair. If exotic species invade, this fish could become extinct in a short period of time.
European Whitefish (*C. lavaretus*) – Dezadeash Lake small-bodied population	Threatened	This species is known from a single lake in southern Yukon, where it coexists with a distinct large-bodied form of the species. Its persistence is threatened by the risk of establishment of invasive species that could alter the ecological niches of the species pair. If exotic species invade, this fish could become extinct in a short period of time.

Designatable Unit (DU)	COSEWIC Status	Reason for Designation
European Whitefish (*C. lavaretus*) – Dezadeash Lake large-bodied population	Threatened	This species is known from a single lake in southern Yukon, where it coexists with a distinct small-bodied form of the species. Its persistence is threatened by the risk of establishment of invasive species that could alter the ecological niches of the species pair. If exotic species invade, this fish could become extinct in a short period of time.

Listing and Recovery Background

COSEWIC undertook an assessment of ten whitefish (*Coregonus* spp.) DUs in 2018 (COSEWIC 2018). This served as an update and expansion on an earlier assessment of the Squanga Lake Whitefish populations (Bodaly et al. 1987; Sparling and Bodaly 2007). Previously, Squanga Lake Whitefish were considered a single unit and were designated as Special Concern in April 1987. However, in the more recent assessment, Squanga Lake Whitefish were separated into the two recognized species: European Whitefish (small bodied population) and Lake Whitefish (large bodied population). In addition to Squanga Lake, distinct whitefish DUs within Little Teslin Lake were also assessed and separated into the two recognized species: European Whitefish (small bodied population) and Lake Whitefish (large bodied population). In Dezadeash Lake, distinct DUs of European Whitefish (small and large bodied forms) were also assessed. These six discrete and evolutionary significant DUs within the Yukon Territory have all been designated as Threatened by COSEWIC (Table 1). Although there are other populations of whitefish throughout the Yukon Territory and their Canadian range, this report focuses specifically on just the species pairs within Squanga Lake, Little Teslin Lake and Dezadeash Lake.

In support of listing recommendations by the Minister for the six whitefish DUs assessed as at risk by COSEWIC in the Yukon Territory, DFO Science has been asked to undertake an RPA, based on the national RPA Guidance. The advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing decision, development of a recovery strategy and action plan, and to support decision making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions, as per sections 73, 74, 75, 77, 78 and 83(4) of SARA. The advice in the RPA may also be used to prepare for the reporting requirements of SARA s.55. The advice generated via this process will update and/or consolidate any existing advice regarding the six DUs of European Whitefish and Lake Whitefish.

Analysis and Response

Biology, Abundance, Distribution and Life History Parameters

Element 1: Summary of whitefish biology

Specific biological information for each of the six whitefish DUs discussed herein is largely unknown; thus, unless specifically stated, the general biology of the Lake Whitefish is provided. This includes European Whitefish as the species have not been differentiated in existing North American literature and, to date, there has been no specific description of the biology of European Whitefish in North America.

Morphology

The Lake Whitefish is elongate with the greatest body depth at the front of the dorsal fin (Scott and Crossman 1973). It averages about 30 cm total length (TL), but varies depending on location and form (see below). The head is short with a rounded snout projecting beyond the inferior mouth. Scales are large and cycloid, with 70–97 in the lateral line. Gill-raker counts typically range from 19–33. It is silvery in colour with fins ranging from clear or lightly pigmented to black, depending on geographical location. Breeding males have nuptial tubercles on a minimum of three rows of scales above the lateral line and on six rows below it.

In 18 Canadian lakes, including the three Yukon Territory lakes covered by this report, morphologically, ecologically, and evolutionarily discrete forms of Lake Whitefish have been found to occur in sympatry (Bernatchez et al. 1996; Rogers 2009; Mee et al. 2015). These often include a small-bodied form with a smaller mean body size and shorter generation time than the large-bodied form (Mee et al. 2015). Note that in the published scientific literature on the small- and large-bodied forms referred to in this report are referred to alternately as dwarf and normal, or limnetic and benthic, or densely rakered and sparsely rakered forms (Bernatchez et al. 2010; Bhat et al. 2014; Mee et al. 2015; Reid and Parna 2017; Sevellec et al. 2018). Here, the small- and large-bodied descriptors are used as they better define the general evolutionary patterns observed across multiple lakes.

In Squanga Lake, Little Teslin Lake and Dezadeash Lake (collectively referred to as Yukon Territory lakes in this report), small-bodied forms tend to have higher mean gill-raker counts than the large-bodied form (Bodaly 1979). For example, in Dezadeash Lake, Bodaly (1979) found that the small-bodied form had a high number of gill-rakers (mode 33, range 29–36) as compared with the large bodied form (gill rakers ranged from 20–26, mode 23). Samples collected in 1992 by Bernatchez *et al.* (1996) confirm the earlier findings with the small-bodied form gill raker count ranging from 30-36 and the count for the large-bodied form ranging from 21–25. Similarly, in Little Teslin Lake and Squanga Lake, the small-bodied forms had a greater number of gill rakers (range 28–33 and 26–32, respectively) than the large-bodied form (range 24–27, and 22–27, respectively) (Bernatchez et al. 1996).

Habitat

Adult Lake Whitefish are bottom feeders and occupy cool waters, typically in the deeper waters of lakes in southern areas of Canada and shallower waters in northern areas. Whitefish typically spend the entire life cycle in lakes, although some populations are known to migrate into streams for spawning (Dryer 1964). The species may move between shallow and deep waters within a lake, depending on the season (Scott and Crossman 1973). It appears to have a preference for deeper, cooler waters in the summer and shallower habitat in the fall or early winter that is more suitable for spawning (Begout Anras et al. 1999). Whitefish in Squanga Lake likely move to other lakes, but these movements have not yet been well studied (Sparling and Bodaly 2007). Little Teslin Lake and Dezadeash Lake are isolated; therefore, dispersal by natural means between and beyond them is not possible (Sparling and Bodaly 2007).

In lakes with whitefish species pairs, the small-bodied and large-bodied forms have evolved to fill two separate niches within the lakes. The small-bodied form is often limnetic as adults, while the large-bodied-form adults are often found in the benthic zone (Mee et al. 2015). The species pairs in different lakes have differentiated to varying degrees, and this differentiation has taken multiple trajectories resulting from different modes of divergence but, in all cases, the divergence is likely the result of local adaptation (Bernatchez et al. 2010). This adaptation likely occurred because of an increased predation pressure in the limnetic zone, which drove the small-bodied form to grow slower and mature at a quicker rate (Sparling and Bodaly 2007; Rogers 2009).

Life cycle and reproduction

In the spring and early summer, Lake Whitefish occupy shallow areas of lakes. As the temperature of the lake increases, fish move to deeper, cooler waters. In the fall, mature Lake Whitefish move back towards shore to spawn. Lake Whitefish are an oviparous species. Spawning is an annual occurrence for most individuals in the southern parts of its range, but in the northern part of its range individual whitefish may only spawn every other or third year (Kennedy 1953). Spawning can occur between September and January, with more northern populations generally spawning earlier (Kennedy 1953). In the Yukon populations, spawning occurs annually in the fall and the different forms may use the same sandy or rocky shoals as spawning grounds at different time periods (Bodaly 1979). The small-bodied forms can sometimes also spawn in inlets and outlet streams in November and December (Bodaly et al. 1988). Gonad development in June suggests that the large-bodied forms spawn later (Lindsey 1963). One female and one or more males will rise to the surface of the water where the pair will release eggs and milt and then descend back to deeper waters. The number of eggs released is usually in the thousands, but this number depends on the size of the female fish (Scott and Crossman 1973). Spawning can last 7–10 days, and eggs are deposited in small batches over several days to increase egg success.

The gestation period for whitefish eggs is, on average, 133 days and can range from 30 days in warmer water (6.1^{o}C) to 140 days in cooler water (0.5^{o}C)(Price 1940). Only about 13% of eggs survive to become larvae (Hart 1931). Eggs hatch in early spring. There is no parental care and larvae group together along the shoreline, with separation of forms often occurring through different timing windows for spawning. This stage lasts through the spring and they leave the shallows as juveniles in the early summer (Hart 1931).

In the Yukon Territory lakes, the small-bodied form was found to be shorter lived and earlier maturing than large-bodied form, although growth rates for each form were similar (Bodaly 1979). In Dezadeash Lake, the forms mature at age 4–5 and the small-bodied form has a maximum age of 7 and the large-bodied form a maximum age of 10 (Bodaly 1979; Bodaly et al. 1988). In Little Teslin Lake, the forms mature at age 2–3; the small-bodied form has a maximum age of 6 and the large-bodied form a maximum age of 10 (Bodaly 1979; Bodaly et al. 1988). The age of maturity and maximum age has not been reported for the Squanga Lake whitefish species pair. The spawning behaviour of whitefish in Squanga Lake is likely similar to other Lake Whitefish populations (Bodaly 1979).

Diet

Lake Whitefish of larval and post-larval stages feed on plankton. Once the larvae reach 76–102 mm, they switch to feeding on benthic organisms, which they will consume for the remainder of their lives (Hart 1931). Adult Lake Whitefish consume a wide variety of benthic invertebrates and small fishes. In Squanga Lake, the small-bodied form was found to feed primarily on plankton, while the large-bodied form feed on benthic organisms (Lindsey 1963).

Interspecific interactions

It is important to understand interspecific interactions, such as competition, for similar food resources and predator-prey relationships, as it may result in a shift in niches or complete loss of the species. In the Yukon Territory, Lake Whitefish are a principal food source for Burbot (*Lota lota*), Lake Trout (*Salvelinus namaycush*), and Northern Pike (*Esox lucius*)(Scott and Crossman 1973). In addition, small-bodied forms of Lake Whitefish typically do not occur when

Ciscoes (*Coregonus* spp.) are present (Trudel et al. 2001). The small-bodied form is likely present in Squanga Lake as a result of the absence of Least Cisco (*Coregonus sardinella)* (Lindsey et al. 1981). This is likely due to Least Cisco being able to outcompete the small-bodied form for food resources (Bodaly 1979). Therefore, the introduction or dispersal of Ciscoes into lakes that support the small-bodied form might lead to a reduction in abundance or loss of small-bodied whitefish from the lake. Lake Whitefish has also been documented to shift niches in the presence of pelagic Cisco and native, benthic Round Whitefish (*Prosopium cylindraceum*) (Carl and McGuiness 2006). When Cisco is present, Lake Whitefish are fewer and larger in size and shift from feeding on both plankton and benthic prey to primarily benthic prey (Carl and McGuiness 2006). When Round Whitefish is present Lake Whitefish are fewer and smaller in size and move deeper in the lake due to competition for similar benthic food resources. These interactions are important to consider in areas where Cisco and Round Whitefish are present within the Yukon Territory because they may significantly limit or alter the density and age structure of Lake Whitefish.

The interspecific interaction between whitefish and invasive species has also been examined. Case studies have revealed that the introduction of Rainbow Smelt (*Osmerus mordax*) into Ontario lakes resulted in the decline of Lake Whitefish recruitment due to Rainbow Smelt preying on Lake Whitefish larvae (Evans and Loftus 1987).

Another example of the impact of the invasion of a vertebrate planktivore in native European Whitefish was described for a northern Finnish lake (Bhat et al. 2014). In this system, the invasion of a superior trophic competitor resulted in the collapse of a whitefish pair within approximately three generations. However, efficient invertebrate planktivores can have equivalent impact. Como Lake in Ontario was invaded by the Spiny Waterflea (*Bythotrephes longimanus*) and its establishment likely caused the extinction of at least one of the Lake Whitefish species pair in that lake (Reid and Parna 2017).

Special significance

Whitefish small and large bodies forms from the three Yukon Lakes represent lineages of both *C. clupeaformis* and *C. lavaretus* which survived the last glacial maximum in Berengia (the region around what was the Bering land bridge) (Bernatchez and Dodson 1991). Genetic data suggests that the six Yukon DUs represent groups which are discrete from all other North American *C. clupeaformis* (Mee et al. 2015). Because of their broad distribution, Lake Whitefish and European Whitefish have undergone substantial speciation and local adaptations (Landry et al. 2007; Mee et al. 2015). While this variation makes the taxonomy of Lake and European Whitefish difficult to elucidate, it also makes them exemplary model organisms for the study of adaptive evolution and ecological speciation (Landry et al. 2007; Rogers and Bernatchez 2007; Bernatchez et al. 2010). The Yukon whitefish populations are geographically isolated from other populations and species pairs are unique to their lake. The six designatable units discussed herein, in Squanga, Little Teslin and Dezadeash lakes, are found in species pairs that are likely irreplaceable if lost. The forms in these lakes have differentiated to varying degrees by different mechanisms but, in all cases, the divergence is likely the result of local adaptation. There is a strong argument that each form in each species pair in each lake represents a unique component of whitefish diversity; therefore, each form within each species pair should be considered discrete and significant.

Element 2: Distribution, number of populations and abundance trajectory

Distribution

Lake Whitefish are found throughout most of northern North America (Page and Burr 2011). In North America, European Whitefish are native only to Alaska and the Yukon Territory (Mee et al. 2015). Distribution of the six DUs in this report is restricted to individual lakes within the Yukon Territory: Dezadeash Lake (60°29'0"N, 136°58'0"W) in the Alsek River basin; and Squanga Lake (60°29'0"N, 133°38'0"W) and Little Teslin Lake (60°29'1"N, 133°27'16"W), in the Squanga Creek basin, which drains into the Teslin River (Figure 1). Whitefish species pairs have also been reported in Seaforth Lake (60°23'55"N, 133°32'29"W), Tatchun Lake (62°18'15"N, 136°6'44"W) and Teenah Lake (60°18'2"N, 133°25'15"W) in the Yukon Territory, but there is no published evidence of local adaptation (Mee et al. 2015). Therefore, one research recommendation would be to conduct additional studies on whitefishes in these lakes to fill knowledge gaps on local adaptation. A whitefish species pair was also found in Hanson Lake (64°0'40"N, 135°25'50"W) in the Yukon Territory, although it is now considered extirpated due to toxaphene treatment in 1962 to stock Rainbow Trout (*Oncorhynchus mykiss*) (Bodaly et al. 1988) and evidence of local adaptation was lacking (Bodaly et al. 1988; Mee et al. 2015).

Figure 1. Locations of Yukon Territory Lakes with whitefish species pairs discussed in this report. Modified from COSEWIC 2018.

Squanga Lake small- and large-bodied populations, Little Teslin Lake small- and large-bodied populations and Dezadeash lake small- and large-bodied populations are found only within their respective lake. Natural dispersal to other locations has not been observed (Sparling and Bodaly 2007). In addition, there is strong genetic evidence for reproductive isolation between small- and large-bodied forms within the same lake (Bodaly 1979; Mee et al. 2015). Distribution of DUs within the lakes is unknown.

Sampling effort

There has been no systematic search effort to document the distribution of Lake Whitefish or European Whitefish across Canada, let alone the distribution of whitefish pairs in Canada. The fish inventories that do exist (e.g., Ontario Lake Inventory, 1968–1981; current Ontario Broad-Scale Monitoring Program) do not typically examine the gill rakers and growth rates of whitefish, required to identify species pairs. The discovery of whitefish species pairs, including the ones in these reports, are the result of more detailed, localized research projects (Lindsey 1963; Bodaly

1979). For example, Bodaly (Bodaly 1979) found whitefish species pairs in five of 89 lakes sampled between 1968 and 1975 in the Yukon Territory and northern British Columbia.

Table 2. Sampling effort for six Yukon Lake DUs discussed in this report, including year and months of sampling, gear used and depth set (if relevant).

Location	Year (Month)	Gear (approx. depth)	Reference
Dezadeash Lake	1974 (June, July, August)	Gill nets (shallows); floating nets (>4.2 m)	Bodaly et al. 1988
	1992 (August)	Gill nets (7–15 m)	Bernatchez et al. 1996
	1991*	Angler survey	Foos et al. 2014
	1995	Angler survey	Foos et al. 2014
	2000*	Angler survey	Foos et al. 2014
	2001*	Angler survey	Foos et al. 2014
	2006	Angler survey	Foos et al. 2014
	2013	Angler survey	Foos et al. 2014
Little Teslin Lake	1975 (June, August)	Shallow nets (2 m); deep set nets (17 m); floating set nets (>17 m)	Bodaly et al. 1988
	1992 (August)	Gill net (7–15 m)	Bernatchez et al. 1996
Squanga Lake	1934		Lindsey 1963
	1945		Lindsey 1963
	1958		Lindsey 1963
	1960 (June)	Shallow nets (1–5 m); deep set nets (8–40 m); floating nets (12–24 m)	Lindsey 1963
	1992 (August)	Gill nets (7–15 m)	Bernatchez et al. 1996

* no fish were reported caught by anglers in these years.

Abundance

Whitefish in the three Yukon Territory Lakes discussed in this report were relatively abundant as of 1988 (Bodaly et al. 1988). Catch per unit effort (CPUE) for Squanga Lake (c. 1960) was estimated as 1.22, 1.68 and 3.62 in shallow, deep and floating nets respectively; CPUE overnight was estimated as 2.32 in floating nets only (Bodaly et al. 1988). Limited recent sampling in Yukon Territory lakes indicates that whitefish are abundant (COSEWIC 2018); although these samples were not distinguished by form.

As limited data are available for lakes in the Yukon Territory, fluctuations and trends in abundance cannot be determined. Both forms were known to be still extant in all three lakes as of 1992. There are no more recent form-specific data.

Element 3: Life-history parameters for whitefish

Limited information is available on life-history parameters for whitefish species pairs within Yukon Territory lakes, as sampling has been sporadic and data is gleaned from a few research projects which have not historically been focused on determination of such parameters. Known life-history parameters, as well as parameters gleaned from studies on non-Yukon whitefish populations, are listed in Table 3. Other important life-history parameters are unknown for this species; including parameters such as natural mortality, total mortality, recruitment etc. Age at maturity, maximum age and generation time for Squanga Lake have not been directly observed but are assumed to be similar to those of Little Teslin Lake, which has similar small and large body forms of Lake Whitefish and European Whitefish (Bodaly 1979).

Table 3. Known values for life-history parameters from small (s)- and large-bodied (l) whitefish from the 3 Yukon Lakes: Squanga (S), Little Teslin (LT) and Dezadeash (D).

Life-History Parameter	**Ss**	**Sl**	**LTs**	**LTl**	**Ds**	**Dl**
Age at maturity	2–3 years[1]	2–3 years[1]	2–3 years	2–3 years	4–5 years	4–5 years
Maximum age	6 years[1]	10 years[1]	6 years	10 years	7 years	10 years
Generation time	4 years[1]	7 years[1]	4 years	7 years	5 years	7 years
Fecundity[2]	25,000[2] eggs/kg	25,000[2] eggs/kg	25,000[2] eggs/kg	25,000[2] eggs/kg	25,000[2] eggs/kg	25,000[2] eggs/kg

[1]based on values for Little Teslin Lake
[2]estimate based on data from other whitefish (*C. clupeaformis*) populations (COSEWIC 2005)

In order to determine other life-history parameters such as natural and total mortality, and recruitment, additional studies will be necessary.

Habitat and Residence Requirements

Element 4: Habitat properties that whitefish needs for successful completion of all life-history stages

Lake Whitefish and European Whitefish are coolwater species (Scott and Crossman 1973). Spawning occurs in the fall, with variability from year to year within the same lake (Scott and Crossman 1973). Spawning occurs in shallow waters often over hard, sandy, or stony bottoms at depths of less than 7.6 metres, but there are reports of spawning in deeper waters. Some populations of Lake Whitefish are also known to migrate into streams for spawning (Dryer 1964). Some sampling in eastern lakes suggests that large- and small-bodied forms use the same spawning habitat (Chouinard and Bernatchez 1998) although spawn timing of the two forms may differ (Bodaly et al. 1988). Newly hatched larvae may also co-exist near their hatching sites and have a high degree of overlap in resource use (Chouinard and Bernatchez 1998). Young whitefish generally leave the shallow inshore water by early summer and move into deeper water (Scott and Crossman 1973). In general, as adults the small-bodied form occupy the limnetic zone and large-bodied form occupy the benthic zone at all water depths (Lindsey 1963; Bodaly 1979).

Lakes supporting whitefish were found to be well oxygenated, usually moderately high in total dissolved solids, moderately high in nutrient concentrations, and with extensive littoral areas, relative to many other Yukon lakes (Bodaly et al. 1988; McDermid et al. 2007). Squanga Lake has a length of 8.5 km and an average width of 1.2 km (Lindsey 1963). The lake is an average of 40 m deep (Bodaly et al. 1988); although, twenty-one percent of the lake's area is less than 3 m deep and a deep central trench 3.2 km long and roughly 183 m wide contains water over 30 m deep. In this lake, significant numbers of whitefish are found in associated creek environments during most times of the year (McDermid et al. 2007). Dezadeash has an area of 77.2 km^2, with a maximum depth of less than 10 m deep (Lindsey et al. 1981; Bodaly et al. 1988). Little Teslin lakes has an area of 3.2 km^2, of which over half is less than 10 m deep (Lindsey et al. 1981; Bodaly et al. 1988). Little else is known about the physical characteristics of whitefish habitat.

Element 5: Information on the spatial extent of the areas in whitefish distribution that are likely to have these habitat properties

Each of the six whitefish DUs discussed herein have distributions which are constrained to single lakes, and it is likely that each species pair originated within their respective lakes. In each of the lakes, both large and small bodied forms occupy the littoral zone as young-of-the-year. The large-bodied DUs in each lake occupy the benthic zone as adults, while the small-bodied DUs occupy the limnetic zone. It is unclear if other interconnected lakes have appropriate habitat properties to support whitefish.

Element 6: Presence and extent of spatial configuration constraints

The best available science suggests that the 6 DUs discussed herein do not migrate between locations within their respective watersheds but are confined to individual lakes. The sampling that has occurred to date has failed to find whitefish in other lakes that may share some connectivity with either Little Teslin Lake, Squanga Lake or Dezadeash Lake (e.g., Bodaly 1979; Lindsey et al. 1981; Bodaly et al. 1988). However, this sampling has not been exhaustive. These observations do suggest that barriers to habitat access exist; however, it is not clear whether those barriers are always physical, behavioural, or physiological, or due to a combination of factors.

Element 7: Evaluation of the concept of residence and application for whitefish

Residence is defined by SARA as “a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating” (DFO 2015). Unlike some salmonid and other fish species that construct redds, which are considered residences, whitefish are broadcast spawners and release eggs and milt at the surface of the water and then descend back to deeper waters. Therefore, based on the available knowledge of whitefish, the concept of residence does not apply.

Threats and Limiting Factors to the Survival and Recovery of Whitefish

Element 8: Threats to the survival and recovery of the whitefish

To identify the nature and magnitude of threats to the six DUs of whitefish species, a threats calculator was completed based on the IUCN-CMP (International Conservation Union-Conservation Measures Partnership) unified threats classification system (Salafsky et al. 2008) using the Threat Calculator tool developed by Nature Serve (2014).

The overall threat impact is considered to be High-Low for Yukon lakes for all DUs, indicating a wide range of uncertainty in regards to potential impact. The primary threat identified was that of invasive species. The High-Low designation indicates a potential population loss ranging from little change (1–10% decline over the next 3 generations) to substantial loss (31–70% over the next 3 generations) if threats are not moderated. Additional details on specific threat categories are given below (section numbers correspond to the threat number from the Threat Calculator tool) and the full threat assessment is presented in Appendix A.

Threat # 1. Residential & commercial development

There are campgrounds and holiday cottages present at each of the three lakes. Squanga Lake campground has 2 floating docks and a boat ramp. There is a private tourist lodge (Dalton Trail Lodge) located on the shores of Dezadeash Lake. Currently the impact from creation of new tourism and recreational areas is minimal and, due to the isolated location of these lakes, is not expected to increase greatly in the near future. Thus, the impact from these threats was considered to be Negligible in the Threat Calculator.

Threat # 3. Energy production & mining

There are substantial mining tenures along the southwestern end of Squanga Lake that extend into the lake (Government of Yukon 2020). Some of the area surrounding each of the three lakes is First Nations settlement land which includes rights to surface and subsurface resources (Government of Yukon 2020). However, there are currently no active mining operations or other forms of energy production around these lakes. Therefore, energy production and mining is not currently considered a threat.

Threat # 4. Transportation & service corridors

All three lakes are accessible by highways; Highway 1 (Alaska Hwy) runs adjacent to Squanga and Little Teslin lakes and Highway 3 (Haines Hwy) runs adjacent to Dezadeash Lake. Usage of these roads is low, with average daily traffic of 100 vehicles or less (2015). The impact of runoff and road salt is addressed in Threat #9 (see below). The impact of the proximity of these highways is unknown.

Threat # 5. Biological resource use

Summer and winter fishing is permitted in lakes throughout the Yukon Territory (Sparling and Bodaly 2007). Whitefish are caught in recreational and subsistence fisheries in Dezadeash Lake (Jessup 2012; Foos et al. 2014). Catches of whitefish by recreational anglers is generally considered to be low (Foos et al. 2014; Cameron Sinclair Yukon Government, Yukon 2020); First Nations are not required to report subsistence catches so this number is unknown. There are similar recreational and subsistence fisheries in Little Teslin and Squanga lakes. However, no population assessment has been made so it is not possible to determine the percentage of the populations affected by these fisheries and thus the impact of the threat is considered Unknown in the Threat Calculator.

Threat # 6. Human intrusion & disturbance

Use of motor boats is permitted in the three lakes. Motor boating often leads to increased turbidity, which can have a series of negative effects on fish habitats such as: displacement of adults and larvae; increased predation due to displacement and decreased visibility of individuals; and destruction of spawning grounds and food sources. While human activities are permitted in these lakes, there is no direct evidence to suggest that they pose a threat to the Yukon Territory lakes species pairs. In general, anthropogenic factors are not a known cause of concern to these species pairs due to the remoteness of the Yukon lakes watersheds, although humans could still have a negative effect on fish populations, should any future encroachment or pollution take place. In the Threats Calculator, the impact of this threat is considered Unknown but is likely negligible or not a threat.

Threat # 8. Invasive & other problematic species, genes & diseases

Invasive species are a threat for each of the whitefish DUs. Introductions of other fish species have shown to negatively impact whitefish populations in other locations. For example, Cisco (*Coregonus artedii*) and small-bodied Lake Whitefish typically do not co-exist as they have similar niches (Trudel et al. 2001); the introduction of Cisco into Opeongo Lake, Ontario in the 1940s likely contributed to the decline of the small-bodied form of whitefish in that lake (Cucin and Faber 1984). Similarly, the introduction of Rainbow Smelt (*Osmerus mordax*) in Ontario lakes has been an issue of concern since the late 1980s, as this species has been shown to outcompete Lake Whitefish and prey on its larvae (Evans and Loftus 1987). Therefore lakes with introduced fish species which occupy similar ecological niches, are at risk of losing ecologically unique lake pairs that are irreplaceable if lost.

Invasive invertebrates, such as the Spiny Waterflea (*Bythotrephes longimanus*), are also a potential threat (Leung and von Finster 2016). There was a loss of one of the whitefish species pairs (or possibly a collapse of both species into a hybrid form) in Como Lake, Ontario following the introduction of Spiny Waterflea (Reid and Parna 2017). In Lake Como, it is thought that the presence of this abundant, new prey source may have increased whitefish growth rates leading to a breakdown of size-assortative mating between the large- and small-bodied forms and subsequent loss of the small-bodied form (Reid and Parna 2017).

Other invasive species with potential to alter aquatic habitats, such as Didymo algae (*Didymosphenia geminate*), Zebra Mussels (*Dreissena polymorpha*) Quagga Mussels (*Dreissena bugensis*) and New Zealand Mud Snail (*Potamophyrgus antipodarum*), have been identified as potentially problematic in Yukon watersheds (Leung and von Finster 2016). For example, Didymo, which already exists in the Yukon, can form large blooms that may compromise spawning habitat for some fish species or alter the composition of invertebrate communities thereby altering aquatic food webs (Leung and von Finster 2016). There has been no direct assessment of the impacts of these species on whitefish.

Invasive species can be introduced through use of live bait. Although the use of live bait fish is not permitted in the Yukon Territory, there is the potential for illegal baitfish use and dumping of bait and other organisms (e.g., invertebrates, pathogens) given the lakes popularity for angling, boating and proximity to roads. Other sources of invasive species introductions include improperly cleaned boats, fishing gear and felt soled fishing boots.

In the Threats Calculator, the impact of this threat depends on identity of the introduced species and is assessed as High-Low for the six Yukon Territory DUs.

Threat # 9. Pollution

Road salt or toxic spills from the Alaska Highway (Hwy. 1) adjacent to Squanga and Little Teslin lakes, and Haines Road (Hwy. 3) adjacent to Dezadeash Lake, could wash into the lakes. However, anthropogenic factors are not a known cause of concern to the whitefish species pairs due to the remoteness of the lakes in the Yukon Territory, although humans could still have a negative effect on fish populations, should any future encroachment or pollution take place. In the Threats Calculator, the impact of this threat is currently considered to be Negligible.

Threat # 11. Climate change & severe weather

The effects of climate change are of concern for many freshwater fish species in Canada and a potential concern for whitefish populations. In the boreal forests of Northern Canada, warming is already occurring and is predicted to increase average temperatures by 2–5°C within the next century (Price et al. 2013). Climate change is expected to exacerbate the impact of other unknown, but potential threats such as droughts and increased forest fires. For example, several models predict changes in precipitation patterns in the southern Yukon with an overall increase in precipitation. However, studies disagree as to the seasonality of that shift with some predicting increased summer droughts coupled with wetter winters (Tam et al. 2019) and other predicting increased rainfall in the summer and autumn (Price et al. 2013). Changes to precipitation patterns may have seasonal impacts on lake water levels and thermal regimes. Climate change is also predicted to result in more frequent and larger forest fires (ACIA 2004; McCoy and Burn 2005), which could also impact lake sediment and nutrient inputs. In addition, as climates warm, loss of permafrost may impact lake volume, water chemistry, and ecosystem function (Price et al. 2013; Larouche 2015; Rey et al. 2019). The southern Yukon region around

Squanga, Little Teslin and Dezadeash Lakes is characterized by thin (<2 m thick), discontinuous areas of permafrost (Burn 1994; Smith 2010); these areas are predicted to thaw under most climate change scenarios (Burn 1994; Price et al. 2013).

While the effects of climate change are a concern for the six whitefish DUs in the Yukon Territory, due to the uncertain nature of future changes to global climates, the uncertain timeframe over which changes will occur, and a lack of experimental information on the specific impacts of these potential changes to whitefish populations, this threat is assessed as Unknown in the Threat Calculator.

Element 9: Activities most likely to threaten the habitat properties identified in elements 4–5

Activities most likely to impact habitat include fishing related impacts (including shoreline degradation, disturbances caused by motor boats, and introductions of invasive species). However, there is currently no evidence that these types of activities are currently impacting whitefish habitat for DUs in Squanga, Little Teslin or Dezadeash Lakes. Angling activity is generally low in all three locations and whitefish are not typically the target of the recreational fishery (Foos et al. 2014). Catches of whitefish for subsistence by First Nations may occur, but are also likely not currently impacting whitefish habitat. There are currently no active mining operations or other forms of energy production around these lakes (Government of Yukon 2020).

Element 10: Natural factors that will limit the survival and recovery of whitefish

The limited distribution of each of these DUs is the greatest natural factor limiting survival and/or recovery. Each of the species pairs is found in only a single lake, where they likely originated. Small, closed populations are vulnerable to genetic risks such as losses in fitness due to inbreeding. The genetic diversity and the degree of inbreeding in within the six DUs covered by this report is currently unknown.

Element 11: Discussion of the potential ecological impacts of the threats identified in element 8 to the target species and other co-occurring species, current monitoring efforts and knowledge gaps

The primary threat to whitefish DUs is the potential introduction of invasive species and it is possible that these introductions would affect other co-occurring species as well if they significantly alter the habitat or modify established food webs. Based on information regarding introductions of other fish species in other northern lakes, the small-bodied form seems particularly vulnerable to interspecific competition (Cucin and Faber 1984; Trudel et al. 2001). However, introduction of novel prey species could have negative impacts on the target species (e.g., collapse of whitefish species pairs), and/or positive impacts on co-occurring native species, such as Lake Trout (*Salvelinus namaycush*) and Northern Pike (*Esox lucius*) which have been shown to benefit from introductions of potential novel prey species (Evans and Loftus 1987).

Other invasive species have the potential to alter aquatic habitats, such as Didymo algae, Zebra Mussels, Quagga Mussels and New Zealand Mud Snail (Leung and von Finster 2016). For example, Didymo, which is an invasive species in the Yukon, can form large blooms that may compromise spawning habitat for whitefish DUs and co-occurring species or alter the composition of invertebrate communities thereby altering aquatic food webs (Leung and von Finster 2016). However, the impact of these species on whitefish and co-occurring species is unknown.

Monitoring efforts for fish populations in Squanga, Little Teslin and Dezadeash Lakes is relatively low. Angling surveys occur in Dezadeash Lake every 5 years; previous surveys occurred in 1991, 1995, 2000, 2001, 2006 and 2013 (Foos et al. 2014) and another survey is scheduled for 2020 (Cameron Sinclair, Yukon Government, Yukon 2020). This survey provides information about the recreational fishery in Dezadeash Lake, including for target (primarily Lake Trout, Arctic Grayling (*Thymallus arcticus*) and Northern Pike) and non-target (i.e., whitefish) species. A few of these fish are also sampled for sex, length and weight but this sampling is limited by angler cooperation and occurs primarily on Lake Trout (Foos et al. 2014). Harvest levels for Lake Trout in Dezadeash Lake are considered sustainable; harvest rates and sustainable yield have not been estimated for other fish species in this lake (Foos et al. 2014).

Angling surveys have not been undertaken for Squanga or Little Teslin Lakes. However, a survey for Burbot (*Lota lota*) was carried out in Squanga Lake in 2013 (Barker et al. 2014). Burbot abundance was lower than predicted based on lake size, which suggests that Burbot populations may be depleted in this lake (Barker et al. 2014). Estimates of the abundance of other species is not currently available for Squanga or Little Teslin Lakes.

Recovery Targets (Elements 12–15)

Due to limited information available for these six whitefish DUs, more studies are required to fully address elements 12–15, which pertain to proposing abundance and distribution targets (element 12), project expected population trajectories (element 13), provide advice on the degree of suitable habitat meets the demands of the species (element 14), and the probability that the proposed recovery targets can be achieved (element 15).

A potential recovery goal could be to ensure the persistence of self-sustaining populations for each whitefish DU within the current distribution range. However, the population size necessary to achieve this goal is currently unknown; there is currently not sufficient data about past or present abundance and productivity of any of the six DUs discussed herein to establish quantitative abundance targets necessary for long-term viability. Squanga Lake and Little Teslin Lake have not been monitored for angler harvest (Cameron Sinclair, Yukon Government, Yukon 2020). While Dezadeash has been surveyed in the past, it is not clear if whitefish were identified to small- vs. large-bodied type and because whitefish are not targeted in the recreational fishery there were few observations of this species in those surveys. There is not currently sufficient information about the population parameters necessary to determine population abundance, natural and total mortality, or age/size composition, and population trajectories are unknown. There is also no carrying capacity information available for these lakes. Additional sampling and monitoring must be carried out to provide robust data for use in setting quantitative recovery goals. Therefore, given the limited data and restricted geographic distribution of these whitefish DUs, it is proposed that current spatial distribution and species pairs in Squanga Lake, Little Teslin Lake and Dezadeash Lake be maintained.

The available habitat should continue to meet the demands of these six whitefish DUs at the current (unknown) level of abundance unless there are unexpected changes to the lakes.

Given the limited data, probabilities of meeting different targets cannot be provided for these six DUs. However, a general assumption is these DUs are currently maintaining their spatial distribution and species pairs within each lake, but further studies are required to confirm this general assumption.

Scenarios for Mitigation of Threats and Alternatives to Activities (Elements 16–19)

Due to limited information available for these six whitefish DUs, more studies are required to fully address elements 16–19, which pertain to developing an inventory of feasible mitigation measures and reasonable alternatives to activities that are threats to the species and its habitat (element 16), developing an inventory of activities that could increase productivity (element 17), determining if current habitat supply may be insufficient to achieve recovery targets (element 18) and estimating the reduction on mortality rate expected by each proposed mitigation measure or identified alternatives (element 19).

The primary threat to each whitefish DU is the potential introduction of invasive species into the relevant lake (Squanqa Lake, Little Teslin Lake or Dezadeash Lake). One potential source of introductions is the use of live bait and/or bait dumping. Current fishing regulations in the Yukon Territory prohibit the use of live-bait fish and these measures should continue to be strictly enforced. Invasive invertebrates and invasive plants can be introduced through incompletely cleaned boats or fishing gear, and particularly felt-soled waders (Leung and von Finster 2016). Educating the public about correctly cleaning, drying and disinfecting equipment, and encouraging the use of alternatives to felt-soled waders and other porous materials have been suggested as mitigation measures for reducing spread of some types of invasive species (Leung and von Finster 2016). Monitoring Squanga, Little Teslin and Dezadeash Lakes, as well as other lakes in the area, for invasive species will aid in mitigation measure.

Collecting additional abiotic data, and biological information could aid in the determination of the factors regulating population dynamics, is therefore recommended. However, it is unknown if these DUs are currently at or near their carrying capacities and probabilities of meeting different targets cannot be provided at this time. Additions studies are required to provide more detailed science advice on these elements.

Allowable Harm Assessment (elements 20–22)

Due to limited information available for these six whitefish DUs, more studies are required to fully address elements 20–22, which pertain to projecting population trajectories (element 20), recommending parameter values for population productivity (element 21) and evaluating the maximum human induced mortality and habitat destruction that a species can sustain without jeopardizing its survival or recovery (element 22).

Current population sizes and trends are unknown for the six Yukon Lakes whitefish DUs discussed in this report. Therefore, it is not currently possible to determine the amount of mortality or habitat destruction that can be sustained without jeopardizing survival.

Conclusions

To support implementation of the *Species at Risk Act* (SARA) Fisheries and Oceans Canada (DFO) develops a Recovery Potential Assessment (RPA) to provide information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery.

In 2018, eight Designatable Units (DUs) of whitefish were assessed as Threatened in Canada, and two more were determined to be Extinct, by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This RPA pertains to six of those DUs; those found in the Yukon Territory in Squanga, Little Teslin and Dezadeash Lakes. This RPA provides descriptions of the known status of these DUs, an overview of the biology and habitat requirements, and an assessment of the threats and factors which contribute to the Threatened status and may limit recovery. These DUs occur as species pairs (a large- and a small-bodied form occur in each of the three lakes mentioned above) with highly constrained distributions. The major threat to the DUs was determined to be the potential introduction of invasive species. These DUs are further at risk due to their limited distribution which means that activities or natural factors that affect an entire lake have the potential to severely impact an entire DU.

This RPA provides up-to-date information and discusses associated uncertainties of the 22 elements listed in the Terms of Reference for this Science Response Process. However, no quantitative advice can be provided at this time on a number of elements, including biological traits, population dynamics and abundance, population trajectories, probabilities of meeting different targets and allowable harm. Therefore, it is recommended to conduct additional studies to address these knowledge gaps.

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Appendix: Threat Calculator for Whitefish Species Pairs

*Table A1: European Whitefish (*Coregonus lavaretus*) – Squanga Lake small-bodied population and Lake Whitefish (*C. clupeaformis*) – Squanga Lake large-bodied population.*

Overall Threat Impact Calculation Help

Threat Impact		Level 1 Threat Impact Counts high range	low range
A	Very High	0	0
B	High	1	0
C	Medium	0	0
D	Low	0	1
	Calculated Overall Threat Impact:	High	Low
	Assigned Overall Threat Impact:	**BD = High - Low**	

Threats Calculator Table

Threat[a]		Impact[b] (calculated)		Scope[c] (next 10 Yrs.)	Severity[d] (10 Yrs. or 3 Gen.)	Timing[e]	Comments
1	Residential & commercial development	-	Negligible	Negligible (<1%)	Negligible (<1%)	High - Low	-
1.1	Housing & urban areas	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing development around lake
1.2	Commercial & industrial areas	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing development around lake
1.3	Tourism & recreation areas	-	Negligible	Unknown	Negligible (<1%)	High (Continuing)	campground with 2 floating docks and boat ramp; cottages
2	Agriculture & aquaculture	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-

Threat[a]		Impact[b] (calculated)		Scope[c] (next 10 Yrs.)	Severity[d] (10 Yrs. or 3 Gen.)	Timing[e]	Comments
2.1	Annual & perennial non-timber crops	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
2.2	Wood & pulp plantations	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
2.3	Livestock farming & ranching	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
2.4	Marine & freshwater aquaculture	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
3	Energy production & mining	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-
3.1	Oil & gas drilling	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no active renewable energy resources
3.2	Mining & quarrying	-	Not Calculated (outside assessment timeframe)	Unknown	Unknown	Low (Possibly in the long term, >10 yrs/3 gen.)	substantial mining tenures; extending into the lake; no active mining
3.3	Renewable energy	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no active renewable energy resources
4	Transportation & service corridors	-	Unknown	Unknown	Unknown	Unknown	-
4.1	Roads & railroads	-	Unknown	Unknown	Unknown	Unknown	Hwy. 1 runs near the Lake; Road salt accounted for in 9.4
4.2	Utility & service lines	-	Unknown	Unknown	Unknown	Unknown	-
4.3	Shipping lanes	-	-	-	-	-	not applicable
4.4	Flight paths	-	Unknown	Unknown	Unknown	Unknown	-
5	Biological resource use	-	Unknown	Unknown	Unknown	Unknown	-
5.1	Hunting & collecting terrestrial animals	-	Unknown	Unknown	Unknown	Unknown	-
5.2	Gathering terrestrial plants	-	Unknown	Unknown	Unknown	Unknown	-
5.3	Logging & wood harvesting	-	Not a Threat	Negligible (<1%)	Neutral or Potential Benefit	Insignificant/Negligible (Past or no direct effect)	no activity
5.4	Fishing & harvesting aquatic resources	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no commercial fishing; some First Nations subsistence fishing - no requirements to report this catch

Threat[a]		Impact[b] (calculated)		Scope[c] (next 10 Yrs.)	Severity[d] (10 Yrs. or 3 Gen.)	Timing[e]	Comments
6	Human intrusions & disturbance	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	-
6.1	Recreational activities	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	some recreational fishing; extent is unknown
6.2	War, civil unrest & military exercises	-	Negligible	Negligible (<1%)	Unknown	Insignificant/Negligible (Past or no direct effect)	-
6.3	Work & other activities	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	some ongoing research, unknown impact
7	Natural system modifications	-	Unknown	Pervasive - Restricted (11-100%)	Unknown	Moderate - Insignificant/Negligible	-
7.1	Fire & fire suppression	-	Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs./3 gen.)	fire regime for this area is unknown but likely similar to the adjacent Teslin region which has a history of low frequency, large fires (TTFMP); controlled burns and other fire suppression measures are in place near Whitehorse but this is unlikely to affect this area
7.2	Dams & water management/use	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-
7.3	Other ecosystem modifications	-	Negligible	Negligible (<1%)	Unknown	Insignificant/Negligible (Past or no direct effect)	-
8	Invasive & other problematic species & genes	B D	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	-
8.1	Invasive non-native/alien species/diseases	B D	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	potential introduction via baitfishes or invertebrate planktivores; impact depends upon species introduced and could be slight; introduced cisco (or similar fish) are likely to have a greater impact on the small-bodied form; a variety of invasive species have been identified as potentially problematic (Leung et al 2016).
8.2	Problematic native species/diseases	-	Unknown	Unknown	Unknown	Unknown	-
8.3	Introduced genetic material	-	Unknown	Unknown	Unknown	Unknown	-
8.4	Problematic species/diseases of unknown origin	-	Unknown	Unknown	Unknown	Unknown	-

Threat[a]		Impact[b] (calculated)		Scope[c] (next 10 Yrs.)	Severity[d] (10 Yrs. or 3 Gen.)	Timing[e]	Comments
8.5	Viral/prion-induced diseases	-	Unknown	Unknown	Unknown	Unknown	-
8.6	Diseases of unknown cause	-	Unknown	Unknown	Unknown	Unknown	-
9	Pollution	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs./3 gen)	-
9.1	Domestic & urban waste water	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs./3 gen)	road salt; some camp grounds but impact of waste water is unknown
9.2	Industrial & military effluents	-	-	-	-	-	not applicable
9.3	Agricultural & forestry effluents	-	-	-	-	-	not applicable
9.4	Garbage & solid waste	-	Unknown	Unknown	Unknown	Unknown	some camp grounds and cottages near lakes but impact of garbage/solid waste is unknown
9.5	Air-borne pollutants	-	Unknown	Unknown	Unknown	Unknown	-
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	-
10	Geological events	-	Unknown	Unknown	Unknown	Unknown	-
10.1	Volcanoes	-	Unknown	Unknown	Unknown	Unknown	-
10.2	Earthquakes/tsunamis	-	Unknown	Unknown	Unknown	Unknown	-
10.3	Avalanches/landslides	-	Unknown	Unknown	Unknown	Unknown	-
11	Climate change & severe weather	-	Unknown	Pervasive (71-100%)	Unknown	High - Low	-
11.1	Habitat shifting & alteration	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-
11.2	Droughts	-	Not Calculated (outside assessment timeframe)	Pervasive (71-100%)	Unknown	Low (Possibly in the long term, >10 yrs/3 gen)	possible seasonal droughts; predictions are for overall average wetter conditions in this location (Tam 2019)
11.3	Temperature extremes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	-
11.4	Storms & flooding	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-
11.5	Other impacts	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-

[a] **Threat numbers** are provided for Level 1 threats (whole numbers) and Level 2 threats (numbers with decimals)

[b] **Impact** indicates the degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on severity and scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment time (e.g., timing is insignificant/negligible [past threat] or low [possible threat in long term]); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[c] **Scope** indicates the proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[d] **Severity** indicates the level of damage, within the scope, to the species from the threat that can reasonably be expected within a 10-year or 3-generation timeframe. For this species a 10-year timeframe was used. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit > 0%).

[e] **Timing** indicates whether a threat is continuing (High); expected in the future (could happen in the short term [< 10 years or 3 generations]) or is now suspended but could come back in the short term (Medium); expected only in the future (could happen in the long term) or now suspended but could come back in the long term (Low); or occurred only in the past and is unlikely to return, or has no direct effect (Insignificant/Negligible).

Table A2: European Whitefish (Coregonus lavaretus) – Little Teslin Lake small-bodied population and Lake Whitefish (C. clupeaformis) – Little Teslin Lake large-bodied population

Overall Threat Impact Calculation Help

Threat Impact		Level 1 Threat Impact Counts: high range	low range
A	Very High	0	0
B	High	1	0
C	Medium	0	0
D	Low	0	1
	Calculated Overall Threat Impact:	High	Low
	Assigned Overall Threat Impact:	**BD = High - Low**	

Threats Calculator Table

Threat[a]		Impact[b] (calculated)		Scope[c] (next 10 Yrs.)	Severity[d] (10 Yrs. or 3 Gen.)	Timing[e]	Comments
1	Residential & commercial development	-	Negligible	Negligible (<1%)	Negligible (<1%)	High - Low	-
1.1	Housing & urban areas	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing development around lake
1.2	Commercial & industrial areas	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing development around lake
1.3	Tourism & recreation areas	-	Negligible	Unknown	Negligible (<1%)	High (Continuing)	campground; cottages
2	Agriculture & aquaculture	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-
2.1	Annual & perennial non-timber crops	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
2.2	Wood & pulp plantations	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake

Threat[a]		Impact[b] (calculated)		Scope[c] (next 10 Yrs.)	Severity[d] (10 Yrs. or 3 Gen.)	Timing[e]	Comments
2.3	Livestock farming & ranching	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
2.4	Marine & freshwater aquaculture	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
3	Energy production & mining	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-
3.1	Oil & gas drilling	-	Not Calculated (outside assessment timeframe)	Unknown	Unknown	Low (Possibly in the long term, >10 yrs./3 gen)	no active drilling; oil pipeline easement parallels the Alaska Hwy (hwy. 1) (Teslin Forest Management Plan); potential for oil and gas exploration but none to date (Teslin FMP)
3.2	Mining & quarrying	-	Not Calculated (outside assessment timeframe)	Unknown	Unknown	Insignificant/Negligible (Past or no direct effect)	no active mining
3.3	Renewable energy	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no active renewable energy resources
4	Transportation & service corridors	-	Unknown	Unknown	Unknown	Unknown	
4.1	Roads & railroads	-	Unknown	Unknown	Unknown	Unknown	Hwy 1 runs near the Lake; Road salt accounted for in 9.4
4.2	Utility & service lines	-	Unknown	Unknown	Unknown	Unknown	-
4.3	Shipping lanes	-					not applicable
4.4	Flight paths	-	Unknown	Unknown	Unknown	Unknown	-
5	Biological resource use	-	Unknown	Unknown	Unknown	Unknown	-
5.1	Hunting & collecting terrestrial animals	-	Unknown	Unknown	Unknown	Unknown	-
5.2	Gathering terrestrial plants	-	Unknown	Unknown	Unknown	Unknown	-
5.3	Logging & wood harvesting	-	Not a Threat	Negligible (<1%)	Neutral or Potential Benefit	Insignificant/Negligible (Past or no direct effect)	no activity
5.4	Fishing & harvesting aquatic resources	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no commercial fishing; some First Nations subsistence fishing - no requirements to report this catch
6	Human intrusions & disturbance	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	

Threat[a]		Impact[b] (calculated)		Scope[c] (next 10 Yrs.)	Severity[d] (10 Yrs. or 3 Gen.)	Timing[e]	Comments
6.1	Recreational activities	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	some recreational fishing; extent is unknown
6.2	War, civil unrest & military exercises	-	Negligible	Negligible (<1%)	Unknown	Insignificant/Negligible (Past or no direct effect)	-
6.3	Work & other activities	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	some ongoing research, unknown impact
7	Natural system modifications	-	Unknown	Pervasive - Restricted (11-100%)	Unknown	Moderate - Insignificant/Negligible	
7.1	Fire & fire suppression	-	Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs./3 gen)	this area has a history of low frequency, large fires (TTFMP); controlled burns and other fire suppression measures are in place near Whitehorse but this is unlikely to affect this area
7.2	Dams & water management/use	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-
7.3	Other ecosystem modifications	-	Negligible	Negligible (<1%)	Unknown	Insignificant/Negligible (Past or no direct effect)	-
8	Invasive & other problematic species & genes	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	-
8.1	Invasive non-native/alien species/diseases	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	potential introduction via baitfishes or invertebrate planktivores; impact depends upon species introduced and could be slight; introduced cisco (or similar fish) are likely to have a greater impact on the small-bodied form; a variety of invasive species have been identified as potentially problematic (Leung et al 2016).
8.2	Problematic native species/diseases	-	Unknown	Unknown	Unknown	Unknown	-
8.3	Introduced genetic material	-	Unknown	Unknown	Unknown	Unknown	-
8.4	Problematic species/diseases of unknown origin	-	Unknown	Unknown	Unknown	Unknown	-
8.5	Viral/prion-induced diseases	-	Unknown	Unknown	Unknown	Unknown	-
8.6	Diseases of unknown cause	-	Unknown	Unknown	Unknown	Unknown	-

Threat[a]		Impact[b] (calculated)		Scope[c] (next 10 Yrs.)	Severity[d] (10 Yrs. or 3 Gen.)	Timing[e]	Comments
9	Pollution	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs./3 gen)	-
9.1	Domestic & urban waste water	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs./3 gen)	road salt; some camp grounds but impact of waste water is unknown
9.2	Industrial & military effluents	-					not applicable
9.3	Agricultural & forestry effluents	-					not applicable
9.4	Garbage & solid waste	-	Unknown	Unknown	Unknown	Unknown	some camp grounds and cottages near lakes but impact of garbage/solid waste is unknown
9.5	Air-borne pollutants	-	Unknown	Unknown	Unknown	Unknown	-
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	-
10	Geological events	-	Unknown	Unknown	Unknown	Unknown	-
10.1	Volcanoes	-	Unknown	Unknown	Unknown	Unknown	-
10.2	Earthquakes/tsunamis	-	Unknown	Unknown	Unknown	Unknown	-
10.3	Avalanches/landslides	-	Unknown	Unknown	Unknown	Unknown	-
11	Climate change & severe weather	-	Unknown	Pervasive (71-100%)	Unknown	High - Low	-
11.1	Habitat shifting & alteration	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-
11.2	Droughts	-	Not Calculated (outside assessment timeframe)	Pervasive (71-100%)	Unknown	Low (Possibly in the long term, >10 yrs./3 gen)	possible seasonal droughts; predictions are for overall average wetter conditions in this location (Tam 2019)
11.3	Temperature extremes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	-
11.4	Storms & flooding	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-
11.5	Other impacts	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-

[a] **Threat numbers** are provided for Level 1 threats (whole numbers) and Level 2 threats (numbers with decimals)

[b] **Impact** indicates the degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on severity and scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds

to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment time (e.g., timing is insignificant/negligible [past threat] or low [possible threat in long term]); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[c] **Scope** indicates the proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[d] **Severity** indicates the level of damage, within the scope, to the species from the threat that can reasonably be expected within a 10-year or 3-generation timeframe. For this species a 10-year timeframe was used. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit > 0%).

[e] **Timing** indicates whether a threat is continuing (High); expected in the future (could happen in the short term [< 10 years or 3 generations]) or is now suspended but could come back in the short term (Medium); expected only in the future (could happen in the long term) or now suspended but could come back in the long term (Low); or occurred only in the past and is unlikely to return, or has no direct effect (Insignificant/Negligible).

Table A3: European Whitefish (Coregonus lavaretus) – Dezadeash Lake small-bodied population and European Whitefish (Coregonus lavaretus) – Dezadeash Lake large-bodied population

Overall Threat Impact Calculation Help

		Level 1 Threat Impact Counts	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	1	0
C	Medium	0	0
D	Low	0	1
	Calculated Overall Threat Impact:	High	Low
	Assigned Overall Threat Impact:	**BD = High - Low**	

Threats Calculator Table

Threat[a]		Impact[b]		Scope[c] (next 10 Yrs)	Severity[d] (10 Yrs or 3 Gen.)	Timing[e]	Comments
1	Residential & commercial development	-	Negligible	Negligible (<1%)	Negligible (<1%)	High - Low	-
1.1	Housing & urban areas	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing development around lake
1.2	Commercial & industrial areas	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing development around lake
1.3	Tourism & recreation areas	-	Negligible	Unknown	Negligible (<1%)	High (Continuing)	campground, cottages, private tourist lodge (Dalton Trail Lodge)
2	Agriculture & aquaculture	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-

Threat[a]		Impact[b]		Scope[c] (next 10 Yrs)	Severity[d] (10 Yrs or 3 Gen.)	Timing[e]	Comments
2.1	Annual & perennial non-timber crops	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
2.2	Wood & pulp plantations	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
2.3	Livestock farming & ranching	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
2.4	Marine & freshwater aquaculture	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no ongoing activities around lake
3	Energy production & mining	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-
3.1	Oil & gas drilling	-	Unknown	Unknown	Unknown	Unknown	no active oil and gas exploration/drilling ()
3.2	Mining & quarrying	-	Not Calculated (outside assessment timeframe)	Unknown	Unknown	Insignificant/Negligible (Past or no direct effect)	no active mining
3.3	Renewable energy	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	no active renewable energy resources
4	Transportation & service corridors	-	Unknown	Unknown	Unknown	Unknown	
4.1	Roads & railroads	-	Unknown	Unknown	Unknown	Unknown	Hwy. 3 runs near the Lake; Road salt accounted for in 9.4
4.2	Utility & service lines	-	Unknown	Unknown	Unknown	Unknown	-
4.3	Shipping lanes	-					not applicable
4.4	Flight paths	-	Unknown	Unknown	Unknown	Unknown	-
5	Biological resource use	-	Unknown	Unknown	Unknown	High - Low	-
5.1	Hunting & collecting terrestrial animals	-	Unknown	Unknown	Unknown	Unknown	-
5.2	Gathering terrestrial plants	-	Unknown	Unknown	Unknown	Unknown	-

Threat[a]		Impact[b]		Scope[c] (next 10 Yrs)	Severity[d] (10 Yrs or 3 Gen.)	Timing[e]	Comments
5.3	Logging & wood harvesting	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	Forest Resources Permits issued - collection for personal use only (see COSEWIC 2018)
5.4	Fishing & harvesting aquatic resources	-	Unknown	Unknown	Unknown	High (Continuing)	no commercial fishing; there is an aboriginal subsistence fishery in the lake (Foos 2014, Jessup 2012); however, without a population assessment it is not possible to determine the percentage of the population affected
6	Human intrusions & disturbance	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
6.1	Recreational activities	-	Not a Threat	Pervasive (71-100%)	Neutral or Potential Benefit	High (Continuing)	angling survey suggests whitefish are caught in small numbers as incidental catch; in surveys from 1995, 2001, 2006, and 2013 all angled whitefish were released - related mortality is unknown (Foos 2014); possible impact of ice fishing is unknown
6.2	War, civil unrest & military exercises	-	Negligible	Negligible (<1%)	Unknown	Insignificant/Negligible (Past or no direct effect)	-
6.3	Work & other activities	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	some ongoing research, unknown impact
7	Natural system modifications	-	Unknown	Pervasive - Restricted (11-100%)	Unknown	Moderate - Insignificant/Negligible	
7.1	Fire & fire suppression	-	Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs/3 gen)	the type of stands present in this region are subject to an annual burn rate of 0.39 (on average) (see COSEWIC 2018); controlled burns and other fire suppression measures are in place near Whitehorse but this is unlikely to affect this area
7.2	Dams & water management/use	-	Negligible	Negligible (<1%)	Negligible (<1%)	Insignificant/Negligible (Past or no direct effect)	-

Threat[a]		Impact[b]		Scope[c] (next 10 Yrs)	Severity[d] (10 Yrs or 3 Gen.)	Timing[e]	Comments
7.3	Other ecosystem modifications	-	Negligible	Negligible (<1%)	Unknown	Insignificant/Negligible (Past or no direct effect)	-
8	Invasive & other problematic species & genes	B D	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	-
8.1	Invasive non-native/alien species/diseases	B D	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	potential introduction via baitfishes or invertebrate planktivores; impact depends upon species introduced and could be slight; introduced cisco (or similar fish) are likley to have a greater impact on the small-bodied form; a variety of invasive species have been identified as potentially problematic (Leung et al 2016).
8.2	Problematic native species/diseases	-	Unknown	Unknown	Unknown	Unknown	-
8.3	Introduced genetic material	-	Unknown	Unknown	Unknown	Unknown	-
8.4	Problematic species/diseases of unknown origin	-	Unknown	Unknown	Unknown	Unknown	-
8.5	Viral/prion-induced diseases	-	Unknown	Unknown	Unknown	Unknown	-
8.6	Diseases of unknown cause	-	Unknown	Unknown	Unknown	Unknown	-
9	Pollution	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs./3 gen)	-
9.1	Domestic & urban waste water	-	Negligible	Small (1-10%)	Negligible (<1%)	Moderate (Possibly in the short term, < 10 yrs./3 gen)	road salt; some camp grounds but impact of waste water is unknown
9.2	Industrial & military effluents	-	-	-	-	-	not applicable
9.3	Agricultural & forestry effluents	-	-	-	-	-	not applicable
9.4	Garbage & solid waste	-	Unknown	Unknown	Unknown	Unknown	some camp grounds and cottages near lakes but impact of garbage/solid waste is unknown
9.5	Air-borne pollutants	-	Unknown	Unknown	Unknown	Unknown	-
9.6	Excess energy	-	Unknown	Unknown	Unknown	Unknown	-

Threat[a]		Impact[b]		Scope[c] (next 10 Yrs)	Severity[d] (10 Yrs or 3 Gen.)	Timing[e]	Comments
10	Geological events	-	Unknown	Unknown	Unknown	Unknown	-
10.1	Volcanoes	-	Unknown	Unknown	Unknown	Unknown	-
10.2	Earthquakes/tsunamis	-	Unknown	Unknown	Unknown	Unknown	-
10.3	Avalanches/landslides	-	Unknown	Unknown	Unknown	Unknown	-
11	Climate change & severe weather	-	Unknown	Pervasive (71-100%)	Unknown	High - Low	-
11.1	Habitat shifting & alteration	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-
11.2	Droughts	-	Not Calculated (outside assessment timeframe)	Pervasive (71-100%)	Unknown	Low (Possibly in the long term, >10 yrs./3 gen)	possible seasonal droughts; predictions are for overall average wetter conditions in this location (Tam 2019)
11.3	Temperature extremes	-	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	-
11.4	Storms & flooding	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-
11.5	Other impacts	-	Unknown	Pervasive (71-100%)	Unknown	Unknown	-

[a] **Threat numbers are provided for Level 1 threats (whole numbers) and Level 2 threats (numbers with decimals)**

[b] **Impact** indicates the degree to which a species is observed, inferred, or suspected to be directly or indirectly threatened in the area of interest. The impact of each threat is based on severity and scope rating and considers only present and future threats. Threat impact reflects a reduction of a species population or decline/degradation of the area of an ecosystem. The median rate of population reduction or area decline for each combination of scope and severity corresponds to the following classes of threat impact: Very High (75% declines), High (40%), Medium (15%), and Low (3%). Unknown: used when impact cannot be determined (e.g., if values for either scope or severity are unknown); Not Calculated: impact not calculated as threat is outside the assessment time (e.g., timing is insignificant/negligible [past threat] or low [possible threat in long term]); Negligible: when scope or severity is negligible; Not a Threat: when severity is scored as neutral or potential benefit.

[c] **Scope** indicates the proportion of the species that can reasonably be expected to be affected by the threat within 10 years. Usually measured as a proportion of the species' population in the area of interest. (Pervasive = 71–100%; Large = 31–70%; Restricted = 11–30%; Small = 1–10%; Negligible < 1%).

[d] **Severity** indicates the level of damage, within the scope, to the species from the threat that can reasonably be expected within a 10-year or 3-generation timeframe. For this species a 10-year timeframe was used. Usually measured as the degree of reduction of the species' population. (Extreme = 71–100%; Serious = 31–70%; Moderate = 11–30%; Slight = 1–10%; Negligible < 1%; Neutral or Potential Benefit > 0%).

[e] **Timing** indicates whether a threat is continuing (High); expected in the future (could happen in the short term [< 10 years or 3 generations]) or is now suspended but could come back in the short term (Medium); expected only in the future (could happen in the long term) or now suspended but could come back in the long term (Low); or occurred only in the past and is unlikely to return, or has no direct effect (Insignificant/Negligible).

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