COSEWIC
Assessment and Status Report

on the

Coastrange Sculpin
Cottus aleuticus

Cultus Lake population

in Canada

ENDANGERED
2019

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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COSEWIC 2000. COSEWIC assessment and status report on the Cultus pygmy sculpin *Cottus* sp. in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 9 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

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COSEWIC
Assessment Summary

Assessment Summary – November 2019

Common name
Coastrange Sculpin - Cultus Lake population

Scientific name
Cottus aleuticus

Status
Endangered

Reason for designation
This small-bodied freshwater fish is found in a single lake that drains into the lower Fraser River, in southwestern British Columbia. This area is undergoing increasing urbanization and recreational use. Every night, this unique population migrates from the lake bottom toward the lake surface to feed. A recent introduction of an exotic predator, Smallmouth Bass, is a serious concern to the long-term persistence of the sculpin. The species is also threatened by the cumulative impacts of aquatic invasive species, water pollution (eutrophication) and climate change. These threats reduce sculpin habitat by reducing oxygen in deep waters, and reducing surface water habitat due to increased predation from Smallmouth Bass.

Occurrence
British Columbia

Status history
Designated Special Concern in April 1997. Status re-examined and designated Threatened in November 2000 and in April 2010. Status re-examined and designated Endangered in November 2019.

COSEWIC
Executive Summary

Coastrange Sculpin
Cottus aleuticus

Cultus Lake population

Wildlife Species Description and Significance

The Coastrange Sculpin, Cultus Lake population is a population of vertically migrating, pygmy Coastrange Sculpin that inhabits the offshore habitat of Cultus Lake, southwestern British Columbia. Their general appearance is typical of Coastrange Sculpin; the head is broad and flat and the body tapers gradually to a moderately deep, laterally compressed tail section. There are two dorsal fins and the pectoral fins are large and fan-like. The Coastrange Sculpin, Cultus Lake population differ from typical Coastrange Sculpin in several traits including a smaller maximum size at maturity, the nighttime use of pelagic habitat into adulthood, a longer spawning period, several differences in morphology, and genetic differences at the microsatellite level. While other populations of Coastrange Sculpin commonly grow to over 80 mm in length, the Coastrange Sculpin, Cultus Lake population only grow to a maximum fork length of about 54 mm. Coastrange Sculpin, Cultus Lake population also are less dense and have larger head pores, more pectoral fin rays and shorter pelvic fins than typical Coastrange Sculpin, which may be advantageous for using pelagic waters. The Coastrange Sculpin, Cultus Lake population is an important component of the food web of Cultus Lake and is of great scientific interest as a case of postglacial evolution. Similar forms of pygmy, pelagic Coastrange Sculpin appear to have evolved independently in two interconnected lakes in Washington State, but in general the occurrence of adult sculpins that use the pelagic zone is extremely rare.

Distribution

Coastrange Sculpin occur in lakes and streams along the Pacific Coast of North America, from California to the Aleutian Islands. Coastrange Sculpin, Cultus Lake population is confined to Cultus Lake (49°03’ N, 122°59’ W) in the Fraser River watershed of southwestern British Columbia.

Habitat

Coastrange Sculpin mostly inhabit the fast water of streams but occasionally occur along the shorelines of lakes. The Coastrange Sculpin, Cultus Lake population have primarily been captured in the offshore habitat of Cultus Lake. Coastrange Sculpin normally undergo a switch from a surface water-oriented larval life stage to a bottom-oriented

juvenile lifestyle at about 32-35 days after hatching. Hydroacoustic and mid-water trawl surveys conducted to enumerate juvenile Sockeye Salmon in Cultus Lake have demonstrated that adult Coastrange Sculpin, Cultus Lake population continue to migrate vertically into surface waters of the lake at night. Anecdotal information indicates that Coastrange Sculpin, Cultus Lake population prefer hard substrates and cover, although they have also been photographed by SCUBA divers while partially buried in soft organic substrate. The Cultus Lake watershed is heavily developed for recreation, residential and agricultural uses, resulting in significant impacts to tributary and outlet streams and lake foreshore habitats. Cultus Lake is currently mesotrophic and is believed to be in the beginning stages of cultural eutrophication, as well as showing an increase in mean monthly temperatures due to climate change.

Biology

Generation times are about 2 to 5 years for Coastrange Sculpin and 3 years for Coastrange Sculpin, Cultus Lake population. While Coastrange Sculpin normally spawn between February and July, Coastrange Sculpin, Cultus Lake population is believed to spawn from late May or early June until August or even September, based on capture of mature individuals (Woodruff 2010; Ricker 1960). The diet of Coastrange Sculpin typically switches from zooplankton to aquatic insects and benthic invertebrates after the larval life stage. The diet of Coastrange Sculpin, Cultus Lake population, however, continues to be dominated by zooplankton into adulthood. In a survey of the diet compositions of Cultus Lake's piscivorous fish in the 1960s, Coastrange Sculpin, Cultus Lake population occurred regularly in the diet of Bull Trout, but only rarely in the diet of Coastal Cutthroat Trout and Coho Salmon, and not at all in the stomachs of Northern Pikeminnow. There is the potential for competition between Coastrange Sculpin, Cultus Lake population and juvenile Sockeye Salmon for zooplankton prey.

Population Sizes and Trends

The abundance of Coastrange Sculpin, Cultus Lake population is unknown. Trawl surveys conducted to assess the abundance of juvenile Sockeye Salmon in Cultus Lake from 1975 to 2017 suggest high catches per hour of sculpin from 1976-1980, followed by a decline in catches per hour until 1997, and an increase and stabilization of catch per hour from 1997-present. Monthly and seasonal minnow trapping surveys (2007-2017) show that the catch per unit effort (CPUE) among years remains approximately the same.

Threats and Limiting Factors

Due to the limited distribution of the Coastrange Sculpin, Cultus Lake population, it is very susceptible to ecological changes in Cultus Lake, such as the recent introduction of an aquatic invasive species and the impacts of development and eutrophication. The Coastrange Sculpin of Cultus Lake are increasingly threatened by the cumulative impacts of reduced hypolimnetic O_2 due to eutrophication, increased epilimnetic temperatures and predation by aquatic invasive predators, in particular the recently observed invasion of Smallmouth Bass.

Protection, Status and Ranks

NatureServe assigned Coastrange Sculpin, Cultus Lake population global, national and provincial status rankings of between critically imperilled and imperilled. The COSEWIC status for Coastrange Sculpin, Cultus Lake population was Threatened until it was reassessed in November 2019 and designated as Endangered. It is listed as Threatened on Schedule 1 of the Canadian *Species at Risk Act*. The BC Conservation Data Centre gives Coastrange Sculpin, Cultus Lake population its highest provincial rank of red. The provincial parkland surrounding much of Cultus Lake is protected by the provincial *Park Act* (1996), which sets management guidelines and restricts resource extraction.

TECHNICAL SUMMARY

Cottus aleuticus

Coastrange Sculpin, Cultus Lake population

Chabot de la chaîne côtière, Population du lac Cultus

Range of occurrence in Canada: British Columbia

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used)	3 years
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased	a. Not Applicable b. Not Applicable c. Not Applicable
Are there extreme fluctuations in number of mature individuals?	Unknown

Extent and Occupancy Information

Estimated extent of occurrence (EOO) 8 km^2 based on minimum convex polygon method but assigned 32 km^2 which is the IAO	32 km^2
Index of area of occupancy (IAO) (Always report 2x2 grid value).	32 km^2
Is the population “severely fragmented” i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a.No b.No

Number of "locations"* (use plausible range to reflect uncertainty if appropriate), based on three high-medium threats that affect all individuals	1
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of "locations"*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, observed and inferred decline in quality of habitat
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"*?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
	Unknown
Total	Unknown

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species?
Yes

i. Invasive non-native species
ii. Pollution (Household/urban, agricultural/forestry, airborne)
iii. Climate change (Droughts, temperature extremes)

The overall threats impact was assessed as High-Very High

What additional limiting factors are relevant?

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	Canadian endemic
Is immigration known or possible?	Not Applicable
Would immigrants be adapted to survive in Canada?	Not Applicable
Is there sufficient habitat for immigrants in Canada?	Not Applicable
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source (i.e., outside) population deteriorating?[+]	Not Applicable
Is the Canadian population considered to be a sink?[+]	Not Applicable
Is rescue from outside populations likely?	Not Applicable

Data Sensitive Species

Is this a data sensitive species?	No

Status History

Designated Special Concern in April 1997. Status re-examined and designated Threatened in November 2000 and in April 2010. Status re-examined and designated Endangered in November 2019.

Status and Reasons for Designation:

Status:	**Alpha-numeric codes:**
Endangered	B1ab(iii)+2ab(iii)
Reasons for designation: This small-bodied freshwater fish is found in a single lake that drains into the lower Fraser River, in southwestern British Columbia. This area is undergoing increasing urbanization and recreational use. Every night, this unique population migrates from the lake bottom toward the lake surface to feed. A recent introduction of an exotic predator, Smallmouth Bass, is a serious concern to the long-term persistence of the sculpin. The species is also threatened by the cumulative impacts of aquatic invasive species, water pollution (eutrophication) and climate change. These threats reduce sculpin habitat by reducing oxygen in deep waters, and reducing surface water habitat due to increased predation from Smallmouth Bass.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. No information is available on the number of mature individuals.
Criterion B (Small Distribution Range and Decline or Fluctuation): Meets Endangered, B1ab(iii)+2ab(iii), with very small EOO and IAO (both 32 km²), a single location, and observed and projected declines in quality of habitat.

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Criterion C (Small and Declining Number of Mature Individuals): Not applicable. No information is available on the number of mature individuals.
Criterion D (Very Small or Restricted Population): Not applicable. No information is available on the number of mature individuals.
Criterion E (Quantitative Analysis): Not applicable. Quantitative analyses have not been done.

PREFACE

Coastrange Sculpin, Cultus Lake population is a small fish endemic to a single lake (Cultus Lake) in southwestern British Columbia. The Coastrange Sculpin, Cultus Lake population was first assessed by COSEWIC in 1997 as Special Concern and was re-examined and assessed as Threatened in both 2000 and 2010. The major threat to the population is its restriction to a single, small lake located in a geographic area that is undergoing extensive and rapid residential and commercial development. Following the 2000 assessment, a recovery strategy was initiated and completed in 2007 under the leadership of Fisheries and Oceans Canada (Pacific Region) and the British Columbia Ministry of Environment. The recovery strategy identified several important information gaps that are required to be addressed to effect recovery of the species (i.e., long-term persistence of the species). These included information on habitat use across life stages and the identification of critical habitat, habitat availability, population abundance, population genetic and taxonomic studies and development of a stewardship group and long-term monitoring program. Co-ordination of efforts to recover the Cultus Lake Sockeye Salmon population (assessed as endangered by COSEWIC in 2003) was also listed as a priority. The progress report completed by Fisheries and Oceans Canada (2016) summarized results on population genetic and taxonomic studies, and included information on ongoing monitoring programs and new partnerships working towards addressing the remaining information gaps. The Action Plan for the Coastrange Sculpin, Cultus Lake population was finalized in 2017 (Fisheries and Oceans Canada 2017) and identified critical habitat and residence information, as well as listing recovery measures to be taken in order to support the recovery and persistence of the Cultus Lake population. A final Critical Habitat Order that prohibits the destruction of the critical habitat of the Cultus Lake population (i.e., the entirety of Cultus Lake up to the wetted boundary) was published in January 2019.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS (2019)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service
Environnement et Changement climatique Canada
Service canadien de la faune
Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Class: Actinopterygii

Order Scorpaeniformes

Family Cottidae

Genus: *Cottus*

Scientific Name: *Cottus aleuticus*

English Common Names: Coastrange Sculpin, Cultus Lake population 2004, Cultus Pygmy Sculpin, Cultus Lake Pygmy Sculpin

French Common Name: Chabot de la chaîne côtière, population du lac Cultus

The genus *Cottus* is a member of the sculpin family (Cottidae). Coastrange Sculpin, *Cottus aleuticus*, was originally described from Kodiak Island by Lockington (1880) as *Uranidea microstoma*. Gilbert (1895), however, placed this species in the genus *Cottus*, and because the species name *microstomus* was already assigned in this genus the name was changed to *Cottus aleuticus*. The only synonym is *Cottus protrustus* described by Schultz and Spoor (1933) from Unalaska Island, Alaska.

Coastrange Sculpin are common in coastal streams along the Pacific coast. The Coastrange Sculpin, Cultus Lake population is a population derived from Coastrange Sculpin; they are morphologically similar to each other (relative to other freshwater *Cottus* species, McPhail 2007) and a mitochondrial DNA phylogeny is consistent with a postglacial divergence between Coastrange Sculpin, Cultus Lake population and Coastrange Sculpin (see **Spatial population structure and variability;** Woodruff 2010; Woodruff and Taylor 2013).

While Coastrange Sculpin commonly grow to over 80 mm in total length (McPhail 2007), Coastrange Sculpin, Cultus Lake population only grow to a maximum total length of 65 mm (Woodruff 2010 and unpublished data). Coastrange Sculpins normally undergo a switch from a pelagic larval life stage to a benthic juvenile life stage about 32-35 days after hatching (Scott and Crossman 1973). By contrast, mid-water trawl surveys conducted to enumerate juvenile Sockeye Salmon (*Oncorhynchus nerka*) in Cultus Lake have demonstrated that post-larval Coastrange Sculpin, Cultus Lake population (i.e., up to 65 mm in total length) continue to migrate into pelagic waters at night (J. Hume, pers. comm. 2006). Hydroacoustic surveys also conducted to enumerate juvenile Sockeye Salmon in Cultus Lake show much lower densities of sculpin-sized targets in the water column during the day than at night, indicating that Coastrange Sculpin, Cultus Lake population migrate upwards in the water column at night (J. Hume pers. comm. 2006). The planktivorous diet of adult Coastrange Sculpin, Cultus Lake population (Ricker 1960)—i.e., rather than the typical diet of benthic invertebrates for adult Coastrange Sculpin—supports the inference of a greater use of the pelagic habitat as a component of their life history. While Coastrange Sculpin normally spawn from about February through June (McPhail and Lindsey 1970;

Scott and Crossman 1973), Coastrange Sculpin, Cultus Lake population spawn from mid-May or early June until August or even September (Ricker 1960; Woodruff 2010).

The pygmy form of Coastrange Sculpin inhabiting the offshore habitat of Cultus Lake, within the lower Fraser River Valley in southwestern British Columbia, was first described by Ricker (1960). Another common name for this form, Cultus Lake Pygmy Sculpin, was first used by Coffie (1997). Similar pygmy populations of Coastrange Sculpin have been described from Lake Sammamish and Lake Washington (connected by the Sammamish River) in Washington State (Larson and Brown 1975). Cultus Lake is spatially isolated from the Lake Washington system and both systems have distinct freshwater connections to the sea; microsatellite analysis also suggested the two populations were distinct, suggesting that the Coastrange Sculpin, Cultus Lake population probably evolved independently from these other pelagic sculpins (Woodruff and Taylor 2013).

Morphological Description

The general appearance of the Coastrange Sculpin, Cultus Lake population is very similar to that of Coastrange Sculpin and typical of the genus *Cottus* (Figure 1, McPhail 2007). The head is broad and flat and the body tapers gradually to a moderately deep laterally compressed tail section. There are two dorsal fins, the first with spines and the second with soft rays. The pelvic fins are shorter in the Coastrange Sculpin, Cultus Lake population (Table 1) and thoracic in position. The pectoral fins are large and fan-like with a greater number of rays than in typical Coastrange Sculpin (Table 2). The anal fin is about the same length as the head. The caudal fin is slightly rounded. There is a simple well developed preopercular spine (i.e., on the posterior edge of the cheek) and the lateral line is complete. The preoperculo-mandibular pore canal (i.e., an extension of the lateral line system located along the bottom edge of the lower jaw) typically has pore counts of 10 on either side of a single pore on the tip of the chin. There are no scales anywhere on the body, but a patch of hair-like “prickles” is present behind each pectoral fin. Colouration is brown to grey with darker blotches, being lighter on the side and nearly white ventrally. There are usually two to four dark saddle-like markings on the sides under the dorsal fins and a light mark on the back just in front of the caudal fin.

Figure 1. Photograph of a Coastrange Sculpin (Cultus Lake population; P. Woodruff) ~ 50 mm total length. Arrows indicate approximate location of preoperculo-mandibular pore canal.

Table 1. Comparison of morphometric measurements between Coastrange Sculpin, Cultus Lake population (N = 20) and Coastrange Sculpin (N = 20).

Measurement type	Mean ± SD (mm)[1]	
	Coastrange Sculpin	Coastrange Sculpin, Cultus Lake population
Anal fin length	10.6±0.45	10.8±0.54
Body depth	6.1±0.26	6.2±0.34
Height of longest dorsal ray	4.6±0.30	4.6±0.26
Head depth	6.7±0.30	6.4±0.29
Head length	9.7±0.45	10.1±0.52
Interorbital width	1.2±0.14	1.1±0.14
Orbit length	2.3±0.16	2.36±0.13
Caudal peduncle depth	2.3±0.10	2.3±0.18
Length of pelvic fin	6.1±0.27	5.7±0.46
Caudal peduncle length	6.8±0.46	6.9±0.59
Snout length	2.4±0.18	2.3±0.17
Length of the 4th preoperculo-mandibular pore	0.12±0.02	0.22±0.07
Length of the 5th infraorbital pore	0.21±0.04	0.34±0.06

[1] Prior to estimating means and standard deviations for each fish type, the measurements of individual fish were size-adjusted to the overall mean standard length of 34.7 mm using allometric regression equations.

Table 2. Comparison of anal and pectoral fin ray counts between Coastrange Sculpin, Cultus Lake population (CLS, N = 20) and Coastrange Sculpin (CS, N = 20).

Fin type	Sculpin type	Fin ray counts			
		13	14	15	16
Anal fin	CS	1	14	5	0
	CLS	2	15	2	1
Pectoral fin	CS	0	1	19	0
	CLS	0	0	14	6

Coastrange Sculpin can grow as large as 145 mm in total length (Wydoski and Whitney 2003), with adults usually averaging at least 76 mm (Scott and Crossman 1973). In Frosst Creek, a tributary of Cultus Lake, Coastrange Sculpin commonly grow to 80 to 100 mm in total length (J. Taylor, pers. obs., Woodruff 2010). The vertically migrating pygmy form of Coastrange Sculpin found in Lake Washington reaches a maximum total length of about 67 mm (58 mm standard length, Larson and Brown 1975). Data on the size of Coastrange Sculpin, Cultus Lake population come from examination of the stomach contents of Dolly Varden and/or Bull Trout (*Salvelinus malma/S. confluentus,* collectively referred to as “char” below) caught from Cultus Lake (Ricker 1960) and the length frequency distribution of sculpins caught in mid-water trawl surveys (J. Hume, unpublished data) and minnow trap surveys (Woodruff 2010). The maximum length of Coastrange Sculpin, Cultus Lake population found in the stomach contents of char was about 50 mm total length (Ricker 1960). Since these char were also eating much larger prey, including some Prickly Sculpin (*Cottus asper*) in the 100 to 200 mm range, it is unlikely that they would have been avoiding larger Coastrange Sculpin, Cultus Lake population if they were present (Ricker 1960). The vast majority of the sculpin caught in mid-water trawl surveys conducted in Cultus Lake (i.e., 98%) have been in the size range 9 to 52 mm total length.

The species identification of the trawl-caught sculpins from Cultus Lake began in 1999. Since 1999, the sculpins caught have ranged from 9 to 54 mm in fork length and were all identified as Coastrange Sculpin, Cultus Lake population; Ikusemiju (1975) also captured pelagic sculpin up to 54 mm in Lake Washington trawls. It is believed that the few larger sculpins (up to 132 mm) caught in trawl samples prior to 1999 were Prickly Sculpin; these fish were caught when the net occasionally touched bottom, and represent approximately 2% of the total catch (J. Hume, pers. comm. 2006). The species identity of these larger sculpins, however, should be confirmed by examining the preserved catch samples stored at the Fisheries and Oceans Canada Cultus Lake laboratory. Minnow trap surveys conducted from May-October in the limnetic area of Cultus Lake caught *C. aleuticus* ranging from 15mm to 65mm total length; larger Prickly Sculpin were also caught (Woodruff 2010).

The Coastrange Sculpin, Cultus Lake population differs from typical Coastrange Sculpin in a number of morphological and meristic traits (Tables 1, 2), most predominantly in the length of the pelvic fin (shorter) and the size of various cephalic pores (larger, J. Taylor, unpublished data). When summarized by principal component analysis (PC), plotting of scores along PC axes 1 and 2 indicates the presence of two morphotypes of fish (Figure 2). The variable explaining the most variation in Component 2 was cephalic pore length. Additional variables making smaller but still notable contributions to PC 2 included pelvic fin length, interorbital width, head depth and head length. The average value of PC 2 was significantly greater for Coastrange Sculpin, Cultus Lake population compared to Coastrange Sculpin (*t*-test, $P<0.0001$) implying that the two fish types have different average body shapes. Compared to Coastrange Sculpin, the average Coastrange Sculpin, Cultus Lake population had a larger average cephalic pore length (by 73%), a narrower interorbital length (8%), shorter pelvic fins (8%), and a head that was longer (5%) and less deep (4%, Table 1). Coastrange Sculpin, Cultus Lake population showed greater buoyancy (had an average density of less than 1 $g \cdot cm^3$) than Coastrange Sculpin (E. Taylor, pers. comm., unpublished data).

Coastrange Sculpin, Cultus Lake population tend to have higher pectoral fin ray counts compared to Coastrange Sculpin. Both fish types had a modal pelvic ray count of 15; however, 30% of Coastrange Sculpin, Cultus Lake population had a pectoral fin ray count of 16 while none of the Coastrange Sculpins had a pectoral fin ray count greater than 15 (Table 2, chi-square test, $P = 0.02$). Anal fin ray count frequencies did not differ significantly between the two sculpins (Table 2, chi-square test, $P = 0.4$).

The qualitative differences in morphology identified as distinguishing Coastrange Sculpin, Cultus Lake population from Coastrange Sculpin—i.e., larger average cephalic pore length, narrower interorbital length, shorter pelvic fins length, and higher pectoral fin ray counts—were also identified as distinguishing the pygmy and normal forms in the Lake Washington study (Larson and Brown 1975). Lake Washington Pygmy Sculpins also had longer, but shallower heads than normal Coastrange Sculpin; however, this difference was not statistically significant. The most substantial difference in morphology between the pygmy forms and Coastrange Sculpin in both systems was larger cephalic pores for the pygmy forms. Large pores can indicate feeding on smaller prey items (such as

microcrustaceans and small insect larvae; Vega and Viozza 2016). The relative difference in pore size between the pygmy forms and normal Coastrange Sculpin, however, was much greater in the Lake Washington system (200-300% larger) compared to the Cultus Lake system (73% larger).

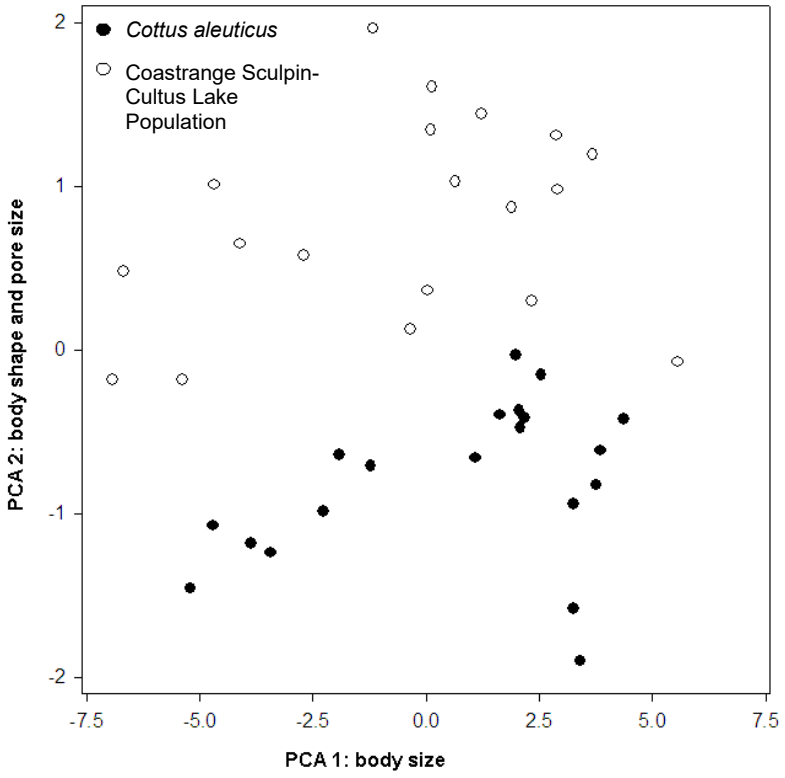

Figure 2. The results of a principal component analysis (PCA) comparing morphology between Coastrange Sculpin, Cultus Lake population and Coastrange Sculpin (J. Taylor, unpublished data).

Population Spatial Structure and Variability

Woodruff (2010) and Woodruff and Taylor (2013) compared mitochondrial and microsatellite DNA variation in Coastrange Sculpin, Cultus Lake population samples collected using mid-water trawls and from minnow traps suspended mid-water in the lake to Coastrange Sculpin samples from inlet and tributary streams and to Cultus samples from several populations outside the Cultus Lake drainage. The mitochondrial DNA data consisted of about 500 base pairs of sequence from the displacement loop (d-loop) region. Coastrange Sculpin, Cultus Lake population and Coastrange Sculpin from tributaries of Cultus Lake and from outside the drainage formed a monophyletic lineage relative to sequences from the Prickly Sculpin and the difference between the two species was about 4.8%. By contrast, Coastrange Sculpin, Cultus Lake population sequences were

intermingled amongst an array of other Coastrange Sculpin samples and average sequence divergence ranged from 0.5 – 0.9%. These data clearly indicate that Coastrange Sculpin, Cultus Lake population has very close genetic affinities to Coastrange Sculpin and suggest that the two types of *C. aleuticus* have diverged only very recently (i.e., post-Wisconsinan glaciation or within the last ~10,000 years, Woodruff 2010; Woodruff and Taylor 2013).

Although Coastrange Sculpin, Cultus Lake population and Coastrange Sculpin are clearly closely related phyletically, they are not genetically identical. The microsatellite DNA data were summarized by the statistic "F_{ST}" which represents the proportion of total genetic variation assayed across the eight loci that is attributable to differences between pairwise comparisons (Hartl and Clark 1989). These data demonstrate that Coastrange Sculpin, Cultus Lake population is genetically distinct from Coastrange Sculpin at two of the three other areas within the Cultus Lake drainage (Table 3). In fact, although the F_{ST} values are low (but typical for sculpins collected from adjacent freshwater habitats—see Taylor and Gow 2008; Whiteley *et al.* 2009), the difference between Coastrange Sculpin, Cultus Lake population and the stream-resident samples from Frosst Creek (F_{ST} =0.011) is comparable to the difference between two samples (Norrish Creek and the Squamish River) that are from two systems located some 70 km apart.

Table 3. Comparisons of pairwise F_{ST} values between samples of Coastrange Sculpin, Cultus Lake population and Coastrange Sculpin from Cultus Lake and several localities outside the Cultus Lake drainage.

F_{ST} values are estimated by Weir and Cockerham's (1984) θ and are based on allelic variation across eight microsatellite loci (see Woodruff 2010). Coastrange Sculpin, Cultus Lake population represent mid-water trawl and minnow trap samples that were pooled after no significant difference in F_{ST} between them was observed ($P < 0.1$). CLS = Coastrange Sculpin, Cultus Lake population, FC = Frosst Creek, EB = Entrance Bay, MB = Maple Bay, NC = Norns Creek, SR = Squamish River, MR = Manquam River, CR = Cheakamus River, LW = Lake Washington (Washington State, USA). Boldface comparisons represent those within the Cultus Lake watershed. Sample sizes ranged from 25 (Entrance Bay) to 67 (Squamish River) and those values that are underlined are not significantly greater than 0 (from 500 permutations).

CLS	**FC**	**EB**	**MB**	NC	SR	MR	CR	LW
CLS -								
FC 0.011	-							
EB 0.008	<u>0.008</u>	-						
MB <u>0.005</u>	<u>0.004</u>	<u>0.000</u>	-					
NC 0.022	0.036	0.041	0.039	-				
SR 0.039	0.048	0.050	0.047	0.011				
MR 0.028	0.043	0.047	0.042	0.007	<u>0.004</u>			
CR 0.045	0.058	0.052	0.049	0.011	<u>0.001</u>	<u>0.003</u>		
LW 0.041	0.055	0.063	0.061	0.038	0.043	0.031	0.047	-

Woodruff (2010) and Woodruff and Taylor (2013) also examined the behaviour of Coastrange Sculpin, Cultus Lake population in terms of their position in the water column in experimental “depth tanks”. The percentage of total time observed that Coastrange Sculpin, Cultus Lake population spent swimming off the bottom was compared to Coastrange Sculpin from two “typical” stream-dwelling populations. These tests demonstrated that Coastrange Sculpin, Cultus Lake population spent more time swimming off the bottom of the depth tanks (as assessed by analysis of variance, followed by Tukey-Kramer post hoc pairwise tests; F= 4.31, df = 2, p = 0.0176) than sculpins from the stream-dwelling populations, but differences were only statistically significant when all populations were tested in the presence of the Prickly Sculpin—a larger, sympatric congener that may compete with and is believed to prey on Coastrange Sculpin, Cultus Lake population.

Designatable Units

Although closely related to Coastrange Sculpin, the Coastrange Sculpin, Cultus Lake population is eligible as a designatable unit (DU) within *C. aleuticus* under the “discrete” and “significance” criteria because it is (a) genetically distinct from adjacent populations of *C. aleuticus* in the Cultus Lake watershed (as discussed above within the **Morphological Description** and **Spatial Population Structure and Variability** sections**)** and (b) it is a unique part of the evolutionary and ecological legacy of *C. aleuticus* in Canada given its very unusual life history and significant morphological and behavioural differentiation, as expanded upon below within the **Special Significance** section.

Special Significance

The Coastrange Sculpin, Cultus Lake population is probably a postglacially derived form of Coastrange Sculpin (*Cottus aleuticus*). This is suggested by the glacial history of the area (Cultus Lake only became accessible after the retreat of the Wisconsinan ice sheets some 8-10,000 years ago) and by mitochondrial DNA data that clearly show that Coastrange Sculpin, Cultus Lake population and Coastrange Sculpin exhibit widespread sharing of mtDNA sequence haplotypes (Woodruff 2010; Woodruff and Taylor 2013). Thus, they represent examples of rapid, and possibly ongoing, vicariant evolution. While the Coastrange Sculpin, Cultus Lake population is endemic to Cultus Lake, similar forms of pelagic pygmy Coastrange Sculpins appear to have evolved independently in two Washington State lakes (Larson and Brown 1975). Cultus Lake and its biota have been closely studied for many years; the Cultus Lake lab operated by Fisheries and Oceans Canada has maintained long-term data sets from the 1930s, and there is a very diverse native fish community within the lake. The Cultus Lake population provides an excellent example of parallel evolution (e.g., Colosimo *et al.* 2005; Jones *et al.* 2012). Coastrange Sculpin, Cultus Lake population is morphologically and behaviourally distinct from adjacent stream samples: they are characterized by significantly larger cephalic pore size and significantly more pectoral fin rays; they are more buoyant (have lower density); they mature at a significantly smaller size; and they utilize the pelagic zone of the lake where they are planktivorous. The genetic bases for these latter indicators of discreteness are not established; however, these distinctions are plausibly interpreted as adaptations for a limnetic (open-water), planktivorous lifestyle, given the probable role of cephalic pores in

sensory perception, and the larger pectoral fins and smaller overall body size in maintaining position in the open water in a group of fishes (all Cottidae) that lack a swim bladder (Bailey and Bond 1953).

Consequently, the Coastrange Sculpin, Cultus Lake population occupies an ecological setting (pelagic zone of a lake) that is highly unusual if not unique for *C. aleuticus* in Canada and is generally very rare in sculpins. Except for two highly divergent species in Lake Baikal, Russia (family Comephoridae), cottoid fishes are benthic as adults (Hunt *et al.* 1997). As summarized by Woodruff (2010), extensive open-water trawling surveys designed to help enumerate limnetic populations of Sockeye Salmon and Kokanee (*Oncorhynchus nerka*) in 100 British Columbia lakes since 1975 rarely, if ever, capture *C. aleuticus* in the pelagic zones of these lakes and Cultus Lake is the only lake where mature *C. aleuticus* are captured consistently in mid-water by trawling or by minnow traps suspended in the open water (see **Search Effort** section; Woodruff 2010). Taken together, the genetic distinctiveness of Coastrange Sculpin, Cultus Lake population, their occupancy of an unusual ecological setting and associated phenotype represent an important component of the evolutionary legacy of *C. aleuticus* as a whole.

DISTRIBUTION

Global Range

Coastrange Sculpin, Cultus Lake population is endemic to a single lake in Canada: Cultus Lake in southwestern British Columbia. Its presumed ancestor, Coastrange Sculpin, occurs in lakes and streams along the Pacific Coast of North America (Figure 3) and is distributed continuously from San Luis Obispo County California, north to the Bristol Bay region, Alaska, and westward in the Aleutian Island chain as far as Kiska. There is apparently an isolated population that occurs in the Kobuk River, just north of the Arctic Circle, in the Chukchi Sea drainage, 800 km north of the Bristol Bay population in Southern Alaska (Scott and Crossman 1973).

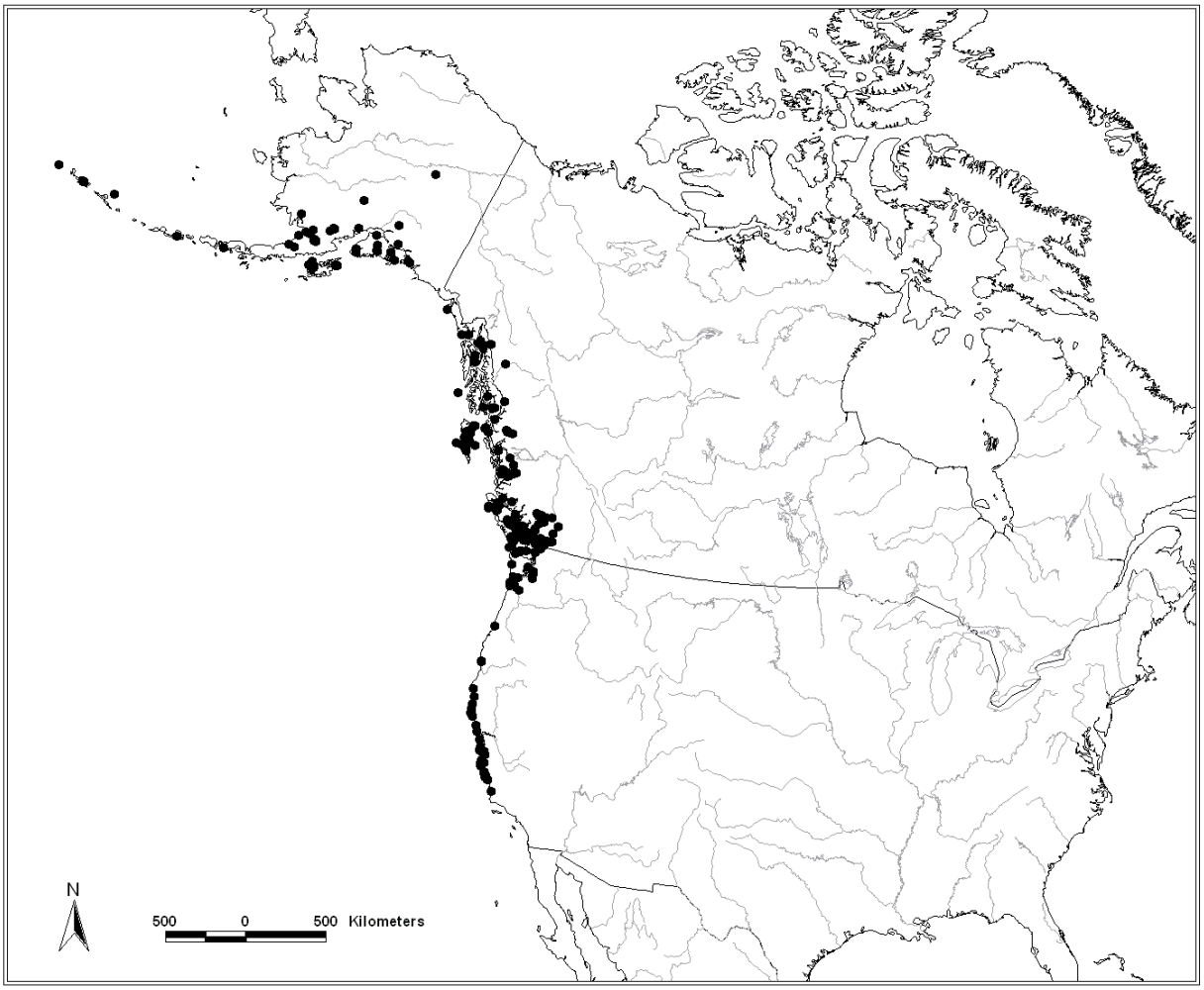

Figure 3. Global distribution of Coastrange Sculpin based on 262 occurrence records obtained from the WFC (2006) and GBIF (2006).

Canadian Range

In Canada, Coastrange Sculpin occur in streams and lakes along the Pacific Coast of British Columbia, including some tributaries to Cultus Lake (Figures 3-4). Watersheds in which Coastrange Sculpin occur include the Fraser River in the south; north in such rivers as the Skeena, Nass, and Stikine; and on Vancouver island and Haida Gwaii. Coastrange Sculpin, Cultus Lake population is endemic to the offshore habitat of Cultus Lake (49°03' N, 122°59' W) in southwestern British Columbia (Figure 4). Cultus Lake is located within the Chilliwack River drainage of the lower Fraser River watershed.

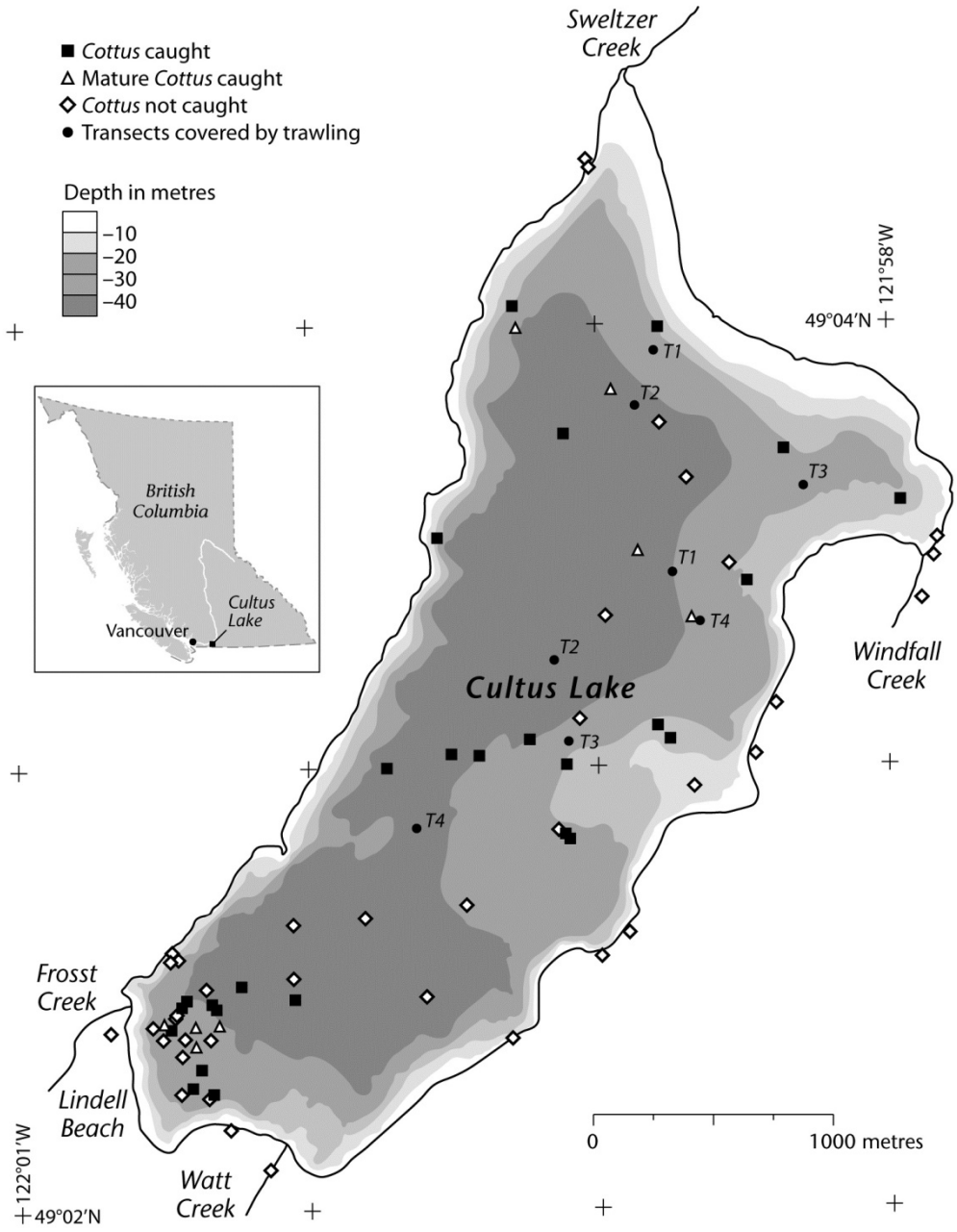

Figure 4. Bathymetric map of Cultus Lake with 10 m depth contours (modified from Shortreed 2007) showing capture sites and trawl locations. Inset shows the location of Cultus Lake within the boxed area in British Columbia. Mature *Cottus* were identified by the presence of eggs or testes. Trawl transects are denoted by T1-T4 (i.e., Trawls 1-4).

Extent of Occurrence and Area of Occupancy

Fisheries and Oceans Canada (2017) have identified the critical habitat for the Coastrange Sculpin, Cultus Lake population as the entire Cultus Lake (6.3 km^2). The index of area of occupancy (IAO) is 32 km^2 based on a 2 x 2 km grid (Figure 5). The extent of

occurrence (EOO) is 8 km^2 based on the minimum convex polygon around Cultus Lake; however, because the EOO cannot be lower than the IAO, the EOO is therefore the same as the IAO at 32 km^2.

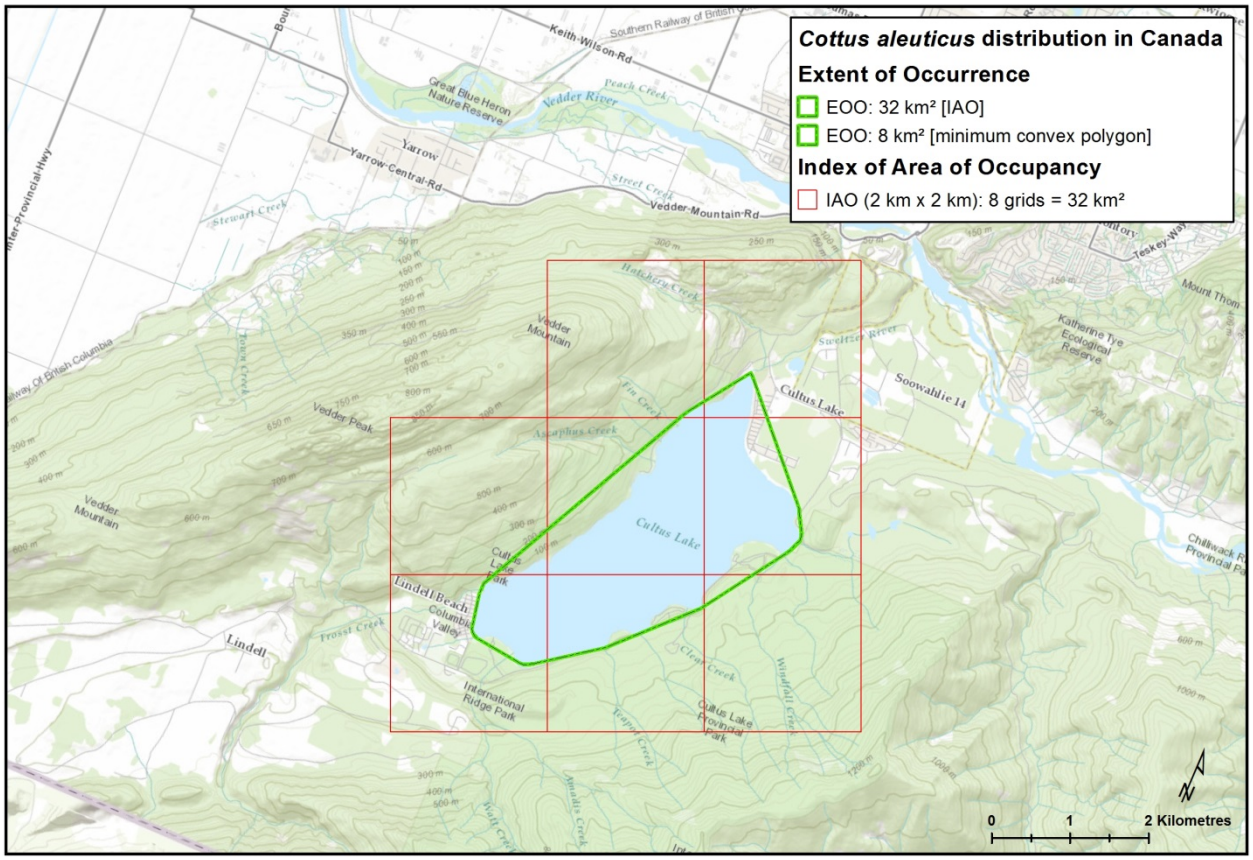

Figure 5. Index of area of occupancy (IAO) and extent of occurrence (EOO) for Coastrange Sculpin, Cultus Lake population.

Search Effort

The presence of Coastrange Sculpin, Cultus Lake population in Cultus Lake is known from their occurrence in both stomach samples taken from piscivorous fish (Ricker 1960) and mid-water trawl sets performed to enumerate juvenile Sockeye Salmon (J. Hume, unpublished data). The trawl surveys have been conducted up to three times per year since 1975. Between 1975 and 2017, the total trawling effort was 228 sets taken over more than 75 hours, and the catch was 926 Coastrange Sculpin, Cultus Lake population. Tow net sampling has revealed the presence of similar vertically migrating pygmy forms of Coastrange Sculpin in two Washington State lakes (Larson and Brown 1975). Multiple minnow traps have been set by Woodruff (2010; Figure 4) and DFO Lakes Research Program (unpublished data; Figure 6).Traps were set from 2007-2008 (Woodruff 2010) and then in 2012 and 2014-2017 (DFO Lakes Research Program, unpublished data). Coastrange Sculpin, Cultus Lake population have been captured in these traps as well.

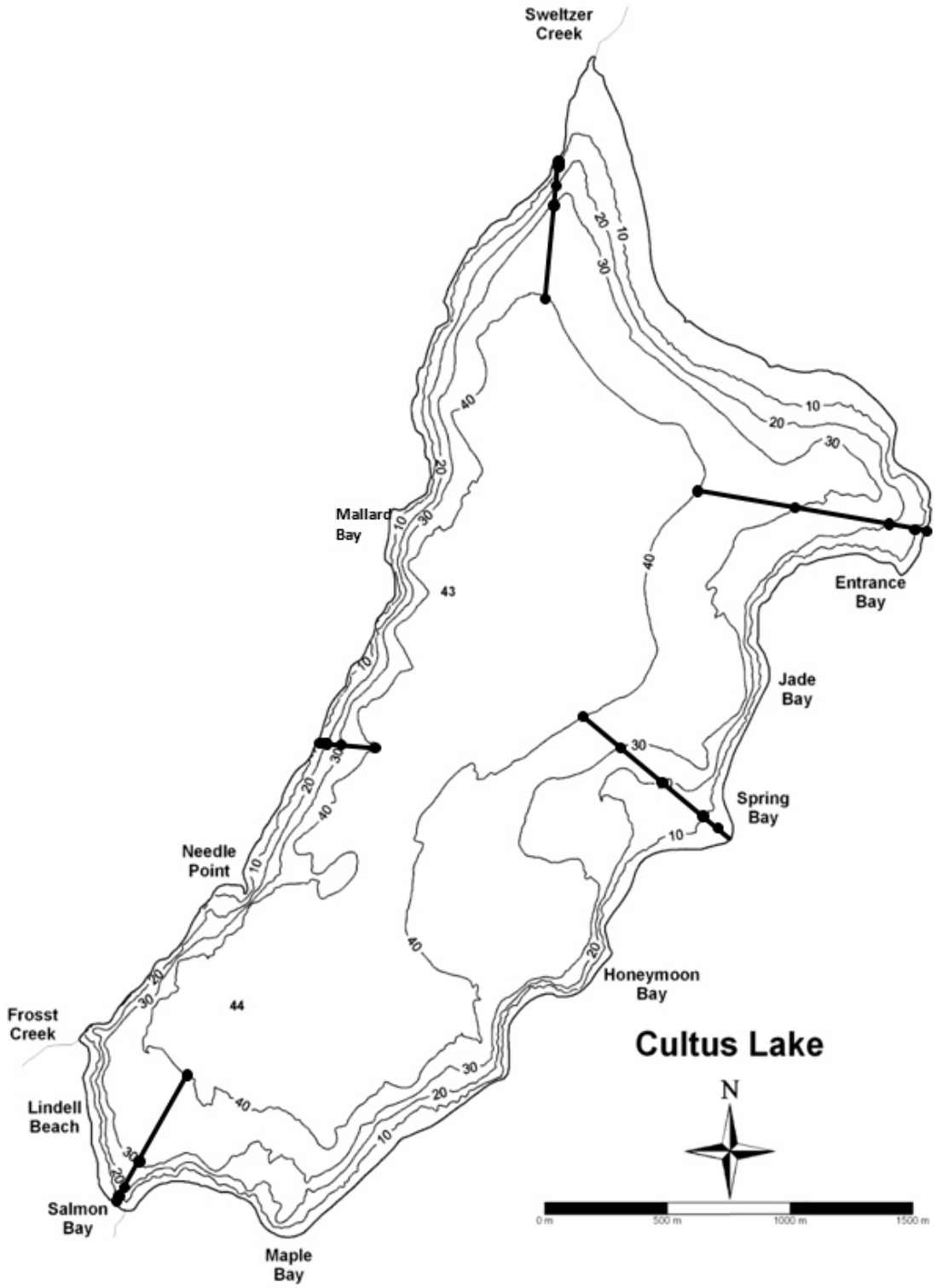

Figure 6. Map of Cultus Lake showing approximate location of minnow trap lines used by DFO Lakes Research Program for minnow trapping study.

In the last 30 years, Fisheries and Oceans Canada has conducted acoustic and mid-water trawl surveys to enumerate juvenile Sockeye Salmon in over 100 British Columbia lakes containing anadromous Sockeye Salmon (J. Hume and K. Hyatt, pers. comm. 2006; Hume and MacLellan 2010; Woodruff 2010). In most of these lakes, there were virtually no sculpins caught. The majority of the sculpins caught have not been identified to species and they generally reach too large a size to be considered pygmy forms (J. Hume, pers. comm. 2006). Since 1999, larger sculpins caught from lakes of the Fraser River system (i.e., larger than 35 mm in total length) have been identified to species and most of these have been Prickly Sculpin (J. Hume, pers. comm. 2006). In addition to Cultus Lake, only four other lakes have been identified as being potential sites for pygmy Coastrange Sculpin occurrence: Seton Lake, Tuya Lake, Red Bluff Lake and Pitt Lake. In Seton Lake, only one Coastrange Sculpin of 35mm was captured, while the sizes of the other Sculpin captured (<20mm) indicate young of the year. While there is a high catch rate of Sculpins in Tuya Lake (Mathias 2000), no Coastrange Sculpin have been identified in that system (only Prickly Sculpin and Slimy Sculpin; Beere 2002). Mature-sized *C. aleuticus* fish (i.e., > 40 mm; Ruzycki *et al.* 1998) were caught in the water column in only three lakes: Cultus Lake, Red Bluff Lake and Pitt Lake (Table 4). Sculpins were caught more often in Cultus Lake than in the other two lakes, and the catches consisted of a range of size and age classes. Both Red Bluff and Pitt Lakes are deeper than Cultus Lake (80 m and 143 m maximum depths, respectively) and are also less productive (Slaney 1988; Bodtker *et al.* 2007), making them less likely to support a pelagic population. The species identification of Sculpin in Red Bluff Lake has not been confirmed; however, this lake is within the *C. aleuticus* range. The number of mature-sized fish in Cultus Lake is a conservative estimate, as only an average and range of sizes were included, due to the large number of sculpin caught in each trawl; the lengths of all fish were recorded for the other systems, due to the small number of sculpins caught per survey, and so these numbers are an exact count. Large numbers of mature-sized sculpins have only been caught in the water column of Cultus Lake, compared with the other lakes surveyed by DFO for Sockeye Salmon and by the Province of BC for Kokanee assessments.

Table 4. The number of mature-sized (> 40 mm total length) sculpin caught in DFO mid-water Sockeye trawls throughout the province of BC. Of the 62 total lakes surveyed, mature-sized sculpin were only caught in the water column of three lakes. Due to the large number of sculpins caught in Cultus Lake in some of the trawls, lengths were not recorded for all fish, and so the number of mature fish caught in Cultus Lake is a conservative estimate. The Sculpin caught in Pitt and Red Bluff lakes were not all identified to species, so it is possible that other species (i.e., *C. aspen*) are included, and this number is likely an overestimate of mature *C. aleuticus* sampled from those lakes.

Lake Name	Total number of surveys	Number of surveys where sculpin caught	Number of mature-sized sculpin caught
Cultus	89	64	48
Pitt	41	16	3
Red Bluff	1	1	4

HABITAT

Habitat Requirements

Coastrange Sculpin generally inhabit medium- or large-sized streams with a moderate to rapid current, but may also occur in lakes (Wydoski and Whitney 2003). They are usually found on gravel or cobble substrates in streams but, in lakes, are often found on sand or even mud substrates (McPhail and Lindsey 1970). They may move downstream to estuaries and are tolerant of brackish water (McPhail and Lindsey 1970). Coastrange Sculpin are known to spawn in stream habitats with rocky substrate.

Coastrange Sculpin, Cultus Lake population is believed to be restricted to the offshore habitat of Cultus Lake based on their common capture in mid-water Sockeye Salmon trawl surveys (J. Hume, unpublished data) and their presence in the stomach contents of piscivorous fish caught from Cultus Lake (Ricker 1960). Neither Coastrange Sculpin, Cultus Lake population nor Coastrange Sculpin were previously caught by Ricker (1960) during extensive seining of shoreline habitats in Cultus Lake, although the larger Prickly Sculpin was captured regularly. Recent shore seining by DFO Lakes Research Program has captured Coastrange Sculpins (size range 25-40 mm) along various portions of the shoreline; genetic work is ongoing to determine which population these fish belong to. Minnow trapping of benthic offshore habitats of Cultus Lake have resulted in the capture both of Coastrange Sculpin, Cultus Lake population and Prickly Sculpin, but only Coastrange Sculpin, Cultus Lake population were captured in mid-water minnow traps (Woodruff 2010). Minnow traps set during daylight hours did not capture any Sculpin. Anecdotal reports indicate that Coastrange Sculpin, Cultus Lake population prefer hard substrates for resting and dens, including human-made objects such as beer bottles (P. Woodruff, unpublished data; D. Carlisle, unpublished report), although SCUBA divers have also observed them partially buried in soft organic sediment. In laboratory conditions, sculpins from the Cultus Lake population could be found on any hard surfaces provided in the tank (including upside down on floating wood pieces at the surface, halfway up the tank in the vicinity of pumps, filters and other tank apparatus, etc.; P. Woodruff, unpublished data). Direct evidence of spawning has not been observed for Coastrange Sculpin, Cultus Lake population, but breeding is believed to occur in the deeper waters of the lake (Ricker 1960) or on shoals off the mouths of inlet creeks (Woodruff 2010; D. Carlisle, unpublished report). The critical habitat for the Coastrange Sculpin, Cultus Lake population was identified to be the entire Cultus Lake (Fisheries and Oceans Canada 2017) and a final Critical Habitat Order that prohibits the destruction of the critical habitat of the Cultus Lake population (i.e., the entirety of Cultus Lake up to the wetted boundary) was published in January 2019.

Coastrange Sculpin normally undergo a switch from a pelagic larval life stage to a benthic juvenile lifestyle at about 32-35 days after hatching (Scott and Crossman 1973). Hydroacoustic and mid-water trawl surveys in Cultus Lake, confirmed with more recent minnow trapping, have demonstrated that post-larval Coastrange Sculpin, Cultus Lake population (i.e., up to 54 mm in fork length) continue to migrate vertically into mid- and surface waters of the lake at night (J. Hume, unpublished data). The Lake Sammamish and

Lake Washington forms of pygmy Coastrange Sculpin also migrate vertically into mid- and surface waters of the lake at night (Ikusemiju 1967).

Cultus Lake has a surface area of 6.3 km^2, a drainage basin of 65 km^2, and a mean and maximum depth 32 m and 44 m, respectively. It is steep-sided and has a littoral area (i.e., the zone where light penetrates to the bottom) of only 12% of the total surface area. Like most coastal British Columbia lakes, Cultus Lake is a warm monomictic lake (i.e., it is thermally stratified except during the winter overturn) with a strong and prolonged thermocline. Summer temperatures in the surface layer (the epilimnion) exceed 20°C while bottom temperatures in the fall average less than 7°C; winter surface temperatures ranged from 5.2-7.6°C (Shortreed 2007). Cultus Lake is mesotrophic and has relatively high water clarity (i.e., Secchi disk depths average 10 to 11 m).

Cultus Lake supports a very diverse native fish community that includes Sockeye Salmon, Chinook Salmon (*O. tshawytscha*), Coho Salmon (*O. kisutch*), Chum Salmon (*O. keta*), Pink Salmon (*O. gorbuscha*); Coastal Cutthroat Trout (*O. clarkii clarkii*), both Steelhead and Rainbow Trout (*O. mykiss*), Dolly Varden, Bull Trout, Coastrange Sculpin, Cultus Lake population, Prickly Sculpin, Threespine Stickleback (*Gasterosteus aculeatus*), Largescale Sucker (*Catostomus macrocheilus*), Longnose Dace (*Rhinichthys cataractae*), Mountain Whitefish (*Prosopium williamsoni*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Peamouth Chub (*Mylocheilus caurinus*), Redside Shiner (*Richardsonius balteatus*) and Western Brook Lamprey (*Lampetra richardsoni*). Smallmouth Bass (*Micropterus dolomieu*) have recently been discovered in Cultus Lake.

Habitat Trends

Streams and lakes suitable as habitat for Coastrange Sculpin populations are common along the Pacific Coast of North America and there is no reason to believe that the availability of suitable habitat has changed appreciably over time. The Cultus Lake watershed is heavily developed for recreation, residential and agricultural uses, resulting in significant impacts to tributary and outlet streams and lake foreshore habitats (COSEWIC 2003). Water quality was initially assessed as excellent in 1996 (MWLAP 1996); unfortunately, it now appears that cultural eutrophication has been accelerating in recent years (Putt 2014) and lake temperatures are also increasing (Sumka 2017). Eutrophication is having a negative impact on hypolimnetic oxygen concentrations, and is reducing the area available for deep-water refuges, potentially forcing fish into the upper water column (Putt 2014).

BIOLOGY

Most of the available information regarding Coastrange Sculpin, Cultus Lake population biology comes from the initial published study of this population by Ricker (1960). Woodruff (2010) and Woodruff and Taylor (2013) provide information on the genetics and behaviour of this fish. The remaining information available regarding Coastrange Sculpin, Cultus Lake population comes from trawl and acoustic surveys

conducted in Cultus Lake to enumerate Sockeye Salmon (J. Hume, unpublished data). Studies from Washington State (Ikusemiju 1967; Larson and Brown 1975) provide information about the other two known occurrences of pygmy Coastrange Sculpin.

Life Cycle and Reproduction

Coastrange Sculpin typically mature at age two to three years (i.e., for females; Bond 1963; Patten 1971) and can live to a maximum of age eight (Wydoski and Whitney 2003). Using length frequency distribution data, Ricker (1960) estimated that Coastrange Sculpin, Cultus Lake population mature at age three (i.e., females) and live to maximum of age four. Males of both normal Coastrange Sculpin and Coastrange Sculpin, Cultus Lake population may begin to spawn a year earlier than females. Generation times are probably about two to five years for Coastrange Sculpin and three years for Coastrange Sculpin, Cultus Lake population. The minimum size at maturity for females is about 37 mm total length for Coastrange Sculpin, Cultus Lake population (Ricker 1960) and ranges from 41 to 49 mm total length for other Coastrange Sculpin populations (Bond 1963, Patten 1971, Wydoski and Whitney 2003). Ricker (1960) recorded mature males of Coastrange Sculpin, Cultus Lake population as small as 29 mm.

While Coastrange Sculpin normally spawn between February and July (McPhail and Lindsey 1970; Scott and Crossman 1973; Wydoski and Whitney 2003), Coastrange Sculpin, Cultus Lake population is believed to spawn from mid-May or early June until August or even September (Ricker 1960; Woodruff 2010). Although direct evidence of Coastrange Sculpin, Cultus Lake population spawning has not been observed, gravid females and mature males have been captured from May to August (Woodruff 2010). Coastrange Sculpin deposit adhesive egg masses on the undersides of rocks (Scott and Crossman 1973). One male Coastrange Sculpin may spawn with, and guard the eggs from, multiple females (Scott and Crossman 1973). The ripe egg size of Coastrange Sculpin is usually less than 1.5 mm (Scott and Crossman 1973). The average diameter of formalin-hardened ripe Coastrange Sculpin, Cultus Lake population eggs is about 0.8 mm (Ricker 1960). The fecundity of Coastrange Sculpin can range from 100 eggs for a 49 mm fish to 1,764 eggs for a 101 mm fish (Patten 1971). Since adult Coastrange Sculpin, Cultus Lake population are smaller, their fecundity is probably lower, and they likely have smaller eggs.

Coastrange Sculpin feed largely at night, mainly on aquatic insects and benthic invertebrates (particularly molluscs), but in the autumn they may feed extensively on Pacific salmon and trout (*Oncorhynchus* spp.) eggs (McPhail and Lindsey 1970; Scott and Crossman 1973). Larval Coastrange Sculpin feed on plankton in lakes (Wydoski and Whitney 2003). Adult Coastrange Sculpin, Cultus Lake population is also planktivorous, with a diet that includes *Daphnia* sp., chironomid midge larvae and pupae, *Epipishura*, Ostracoda, *Bosmina*, and *Cyclops* (Ricker 1960). Additionally, one Coastrange Sculpin, Cultus Lake population of 37 mm in length consumed a smaller sculpin (*Cottus* sp.) of 14 mm in length (Ricker 1960). Shortreed (2007) found *Daphnia* at high densities around the thermocline at night (average depth 16 m). Stomach content analysis from the pelagic Sculpin in Lake Washington indicated that they feed on ostracods, chironomid larvae, *Cyclops*, Mysids, *Daphnia*, and chironomid pupae (Ikusemiju 1975).

Physiology and Adaptability

Coastrange Sculpin are primarily a freshwater species, although they can also occur in brackish or salt water (Moyle 1967; McPhail and Lindsey 1970; Brown *et al.* 1995). There is no information available regarding the physiological requirements or tolerances of Coastrange Sculpin, Cultus Lake population.

Although Coastrange Sculpin are common in lakes and streams throughout most of the Pacific Coast of North America (Scott and Crossman 1973), vertically migrating pygmy forms of Coastrange Sculpin are only known from Cultus Lake, and Lake Sammamish and Lake Washington in Washington State. It is possible that these three lakes have distinctive environmental characteristics responsible for the evolution and persistence of these unusual Coastrange Sculpin populations.

Dispersal and Migration

In streams, the pelagic larvae of Coastrange Sculpin drift downstream before settling as benthic juveniles in lower stream reaches (Brown *et al.* 1995). Upstream and tributary populations of Coastrange Sculpin are believed to be maintained by the upstream migration of juveniles (Brown *et al.* 1995). Moyle (1967) suggested that the wide coastal distribution of Coastrange Sculpin is related to their having pelagic larvae that are able to disperse through salt water.

Coastrange Sculpin, Cultus Lake population is only known to occur in the offshore habitat of Cultus Lake, where they migrate vertically into surface waters of the lake at night. They are unlikely to actively move, or to be passively carried by currents, into the lake's inlet or outlet streams. Indeed, salmon fry traps operated at the outlet of Cultus Lake (Sweltzer Creek) during spring have caught Prickly Sculpin, but not Coastrange Sculpin, Cultus Lake population (Ricker 1960). Electrofishing in Sweltzer Creek resulted in the capture of Prickly Sculpin, but no Coastrange Sculpin of either population (P. Woodruff, pers. comm.). Dispersal to another lake is unlikely because there are no other lakes remaining within the Cultus Lake watershed and the discharge from Cultus Lake does not pass through any other lakes during its 112 km course to the Pacific Ocean.

Interspecific Interactions

In a survey of the diet compositions of Cultus Lake's piscivorous fish, Coastrange Sculpin, Cultus Lake population occurred regularly in the diet of char (*Salvelinus* spp.), but only rarely in the diet of Coastal Cutthroat Trout and Coho Salmon and not at all in the stomachs of Northern Pikeminnow (Ricker 1960). One potential explanation for the observed difference among fish types in the frequency of Coastrange Sculpin, Cultus Lake population occurrence in diet samples could be that char tend to forage more offshore and deeper than the other three species (Ricker 1960). A study of stomach contents for Sockeye Salmon caught in Cultus Lake (Ricker 1937) found that while planktonic crustaceans composed the majority of the food items consumed by juvenile Sockeye

Salmon, larval sculpins had been consumed by 8% of age three Sockeye Salmon (i.e., maturing males) that had probably "residualized" within the lake (i.e., never migrated to the sea as is typical for Sockeye Salmon).

The Coastrange Sculpin, Cultus Lake population is a planktivore that is sometimes preyed on by piscivorous fish; however, another potentially important interspecific interaction for this sculpin is its competition with juvenile Sockeye Salmon for planktonic crustacean prey.. Both Coastrange Sculpin, Cultus Lake population and juvenile Sockeye Salmon in Cultus Lake prey mostly on planktonic crustaceans, with *Daphnia* being the most important prey type by volume (Ricker 1960; COSEWIC 2003). In the autumn sculpin also consume salmon eggs. Cultus Lake is one of the more productive Sockeye Salmon nursery lakes in British Columbia, with a large *Daphnia* population (Shubert *et al.* 2002); however, intraspecific competition for planktonic crustacean prey has been shown to reduce juvenile Sockeye Salmon growth in years of large Sockeye Salmon abundance, particularly during late summer (Ricker 1937). It is possible that interspecific competition also occurs between juvenile Sockeye Salmon and Coastrange Sculpin, Cultus Lake population in the lake, particularly in years of higher juvenile salmon abundance.

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

Fish were collected from the offshore area of Cultus Lake. For detailed trawling methods please see Hume and MacLellan (2000) or MacLellan and Hume (2010). In addition to this open-water trawling, the shoreline was sampled by Woodruff (2010) using minnow traps deployed from shore, while the pelagic area was sampled using minnow traps suspended off the bottom of the lake by a float, 10 m apart, and at depths that ranged from 10-40 m. Fisheries and Oceans Canada also surveyed the lake using minnow traps, set at 5 m intervals, to a maximum depth of 40 m (Figure 6; DFO Lakes Research Program, unpublished data). The minnow traps were baited with Sockeye Salmon (as Sockeye Salmon carcasses are present in the lake at spawning time) and Cyalume yellow 12 hour "glow sticks" which have been shown to help attract Deepwater Sculpin, *Myoxocephalus thompsonii* (Sheldon *et al*. 2008). The collection localities were determined using a GPS unit (Garmin 12 GPS) and mapped using ArcMap in ArcGIS (ESRI). Mature female fish were identified by the presence of eggs. One mature male was identified by the presence of testes.

Abundance

The current abundance of Coastrange Sculpin, Cultus Lake population is unknown.

Fluctuations and Trends

The mid-water trawl data from Cultus Lake were analyzed to look for time series trends in Coastrange Sculpin, Cultus Lake population catch rate. It is important to note that the trawling done in Cultus Lake is designed to target age-0 Sockeye Salmon fry in the lake and not sculpins. Trawl depths and duration are targeted on Sockeye Salmon through the use of hydroacoustics and are designed to get a representative sample of fish in the layer that has Sockeye Salmon-sized targets. It is not a representative sample of all fish in the water column and as such may not accurately represent the sculpin population in the lake at the time of sampling.

The Cultus Lake trawl time series is summarized in Figure 7. Data selection for the time series included all trawls with 0 catches of sculpin as well as the following criteria: 1) only trawls from April – October were included, inclusive; 2) the time series used here began in 1976 corresponding to when sculpin were initially captured in the survey, and 3) only trawls greater than 2 minutes duration were included. No winter trawls were included. It is unclear whether variation is due to catchability and detection probability.

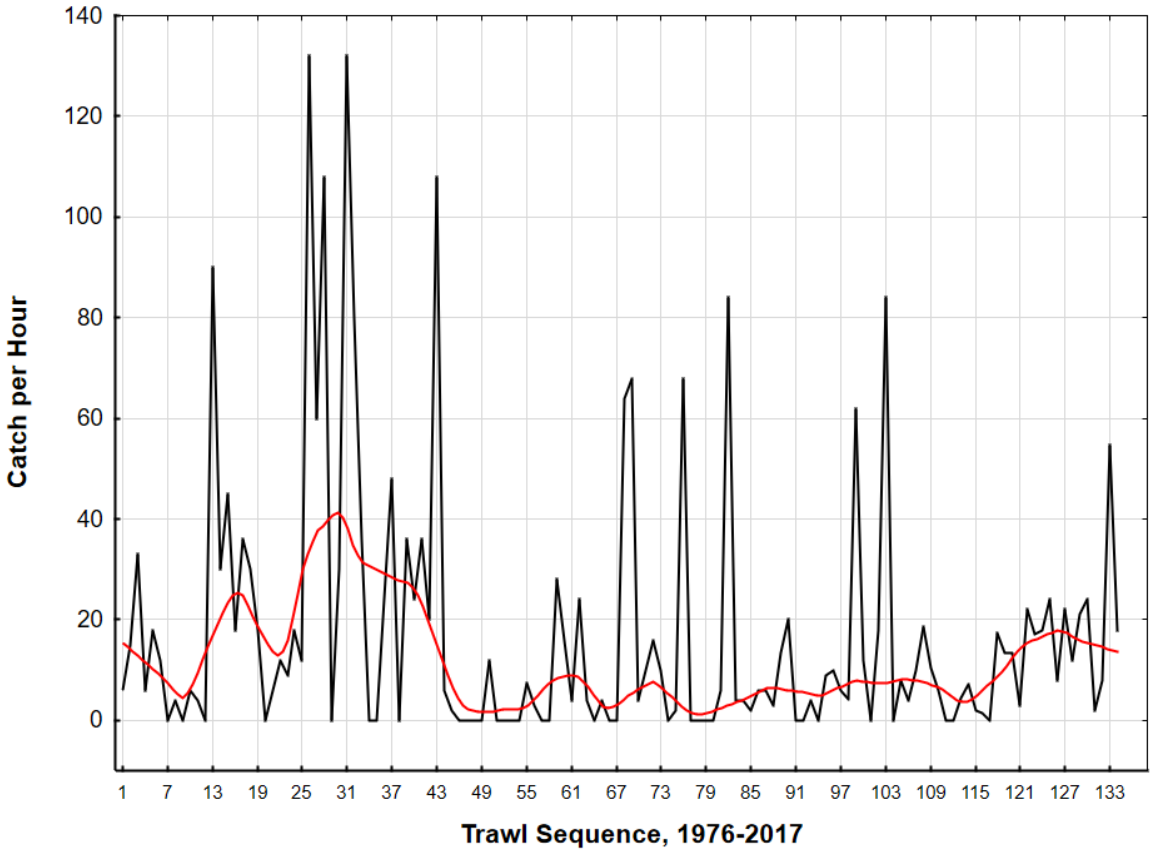

Figure 7. The trawl sequence of catch per hour (black) for Coast Range Sculpin, Cultus Lake population. The lowess fit (red; bandwidth = 0.1) presents a smoothed trendline in the time series.

Locally weighted scatter plot smoothing (lowess) was used to summarize the trend in catch per hour. Lowess weights neighbouring data at any point and estimates a polynomial regression at that point (to capture ups and downs in the time series). The stiffness or bandwidth lowess refers to the proportion of data defined as the neighbourhood. This method, and others like it, captures or smooths a trend in otherwise highly variable time series.

In this case, Figure 7 has a bandwidth of 0.1 meaning 10% of the data is used to estimate local patterns for any point. A bandwidth of 0.25 includes more neighbouring data but smooths many of the ups and downs in the trend for this length of time series.

Figure 7 shows that sculpin trends were up in the early stages of the time series (through 1980), declined in the early 1980s (1981-1982) and have levelled out since then until the last decade with a rise in catch per hour through to 2017. The lowess fit at a bandwidth of 0.1 captures some of the upward and downward trends through the total time series including near the end.

Minnow trap sampling was conducted in order to catch Sculpins for genetic and behavioural analysis (Woodruff 2010; Woodruff and Taylor 2013) and to determine presence/absence (DFO Lakes Research Program). As this sampling is the only targeted effort that has been completed for the Cultus Lake population, the data has been included in this report. Catch per unit effort (CPUE) of Coastrange Sculpin, Cultus Lake population from minnow traps ranged from a low of 0.55 fish per hour in April 2016, to a high of 6.1 fish per hour in late July 2015, likely due to the presence of young of the year *C. aleuticus* (Figure 8; P. Woodruff, unpublished data; DFO Lakes Research Program, unpublished data). Minnow trap catches in the spring showed an increase over time; catches in July showed a decrease in one year, followed by a significant increase; catches in the fall remained similar between years (a slight decrease in October, followed by a slight increase in November sampling; Figure 8). But due to the selective nature of the spatial and temporal minnow trapping design, we can not infer annual trends in CPUE from this data.

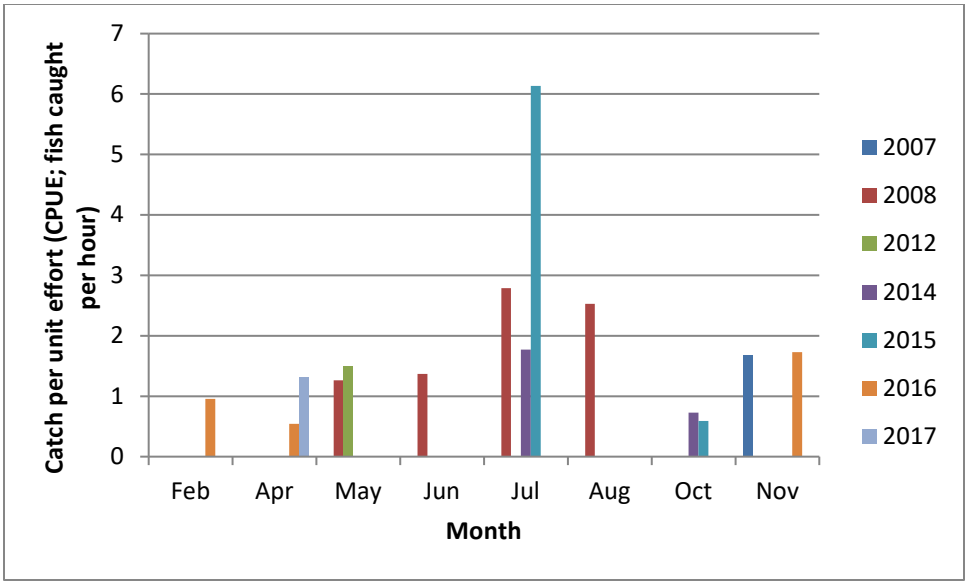

Figure 8. Catch per unit effort by year and month for minnow trap surveys in Cultus Lake (Woodruff 2010; DFO Lakes Research Program, unpublished data).

Rescue Effect

Because Cultus Lake is located 112 km up the Fraser River system and the Fraser and Sammamish/Lake Washington watersheds are separated by about 190 km of ocean, it is highly unlikely that there would be natural exchange of individuals between the Washington State and British Columbia populations. This inference is consistent with highly significant genetic differences between sculpins from the two areas. There is less of a separation between Cultus Lake and Pitt Lake; however, the presence of a pelagic Sculpin in Pitt Lake has not been determined.

THREATS AND LIMITING FACTORS

Threats

The primary threats to this populations were all assessed as high to medium impact and included invasive species, pollution (household sewage and urban wastewater, agricultural and forestry effluents, and airborne pollutants) and climate change (droughts and temperature extremes).

Invasive species

Aquatic invasive species can impact whole freshwater ecosystems in a multitude of ways, including through competition, predation and habitat alteration (Havel *et al.* 2015). Invasive freshwater fish have been found to be one of the main causes of biodiversity loss and the decline of native freshwater fish species (Hermoso *et al.* 2011). Smallmouth Bass

(*Micropterus dolomieu*) are now known to occur in Cultus Lake. Smallmouth Bass were captured for the first time in Cultus Lake in May 2018. Since that time, control methods have been implemented, including nest suppression and adult capture. In Lake Sammamish, which also has a pelagic *C. aleuticus* population, sculpin were the preferred item in age 1-3 Smallmouth Bass (Pflug and Pauley 1984). It is currently uncertain what effect Smallmouth Bass will have on the Cultus Lake population. Smallmouth Bass and Cultus Lake sculpin habitats do overlap seasonally and predation is anticipated; bass stomach contents are currently being analyzed to assess the intensity of predation on sculpin.

Predation from introduced Brown Bullhead (*Ameiurus nebulosus*) led to the extinction of the endemic Threespine Stickleback species pair located in Hadley Lake, British Columbia (COSEWIC 2001). Brown Bullhead and the closely related Yellow Bullhead (*A. natalis*) have also been introduced to the lower Fraser River system where they are common in sloughs and creeks closely associated with the main river (Nowosad 2010). There has been recent expansion of introduced Yellow Perch (*Perca flavescens*) and bass species (*Micropterus* spp.) in lakes of southern British Columbia (Dunphy 2006; Koopmans 2006), Furthermore, niche modelling shows generally high environmental suitability of the Lower Mainland region for several centrarchid and percid predators (e.g., Bradford *et al.* 2008). These occurrences and models, coupled with the observation that several invasive fishes and amphibians have been recorded within the Lower Mainland (including the Vedder River into which Cultus Lake drains via Sweltzer Creek) for more than 50 years (Nowosad 2010), suggest that introduction of more vertebrate exotic predators or competitors into Cultus Lake is a very real possibility.

<u>Pollution</u>

Eutrophication/anoxia from atmospheric/domestic, agricultural activities

Another developing threat is the impact of recreational, residential and agricultural development on the lake's offshore water quality (see **Habitat trends** section). The lake's parks currently receive about 1.5 million visitors annually, making Cultus Lake one of the most heavily utilized lakes in British Columbia (COSEWIC 2003). Poorly performing septic tanks, inputs from agricultural and domestic fertilizers, sedimentation from land-based activities, and poor groundwater quality have all been identified as concerns and have the potential to degrade the lake to some degree (Schubert *et al.* 2002). It is apparent that cultural eutrophication is now occurring with Cultus Lake (Putt 2014); this increase in nutrients will have a negative effect on water quality and increase the anoxic areas located at depth in the lake. The effects of eutrophication can force fish to occupy areas higher up in the water column, resulting in increased predation risk and detrimental water temperatures (Putt 2014). There will be a decrease in hypolimnetic oxygen, reducing the quality of deepwater habitat; increased anoxia at depth can lead to internal nutrient loading from lake sediments that becomes a self-sustaining cycle (Putt 2014). Freshwater sculpin have a low tolerance to hypoxia (Mandic *et al*. 2009).

Climate Change

Droughts (water levels) and temperature

While previous limnological data suggested little change had occurred over the past 70 years (COSEWIC 2003; Shortreed 2007), it is now apparent that the thermal dynamics of the lake are changing (Sumka 2017). Warmer temperatures may prolong stratification, increasing algal production and hypolimnetic oxygen depletion, further reducing habitat for the Cultus Lake population (Putt 2014). It is predicted that there will be increasing temperatures and a decline in summer precipitation and snowfall due to climate change, further affecting water levels in Cultus Lake (http://plan2adapt.ca/tools/planners).

Overall threats impact

Overall threats impact was assessed as Very High to High and can be characterized as the synergetic impacts of invasive species, eutrophication and climate change. The species is threatened by a worsening temperature and oxygen squeeze which is altering their vertical distribution consequently increasing their vulnerability to predation by the newly invaded Smallmouth Bass.

Limiting Factors

Population trends in potential competitors and predators

The demonstrated decline and potential extinction of the Cultus Lake Sockeye Salmon population (COSEWIC 2003) could affect the survival of Coastrange Sculpin, Cultus Lake population. The number of Sockeye Salmon returning to Cultus Lake has declined since the late 1960s with a particularly drastic decline (92%) during the 1990s (COSEWIC 2003). The primary reasons for this decline are over-exploitation by fisheries, recent increases in the level of pre-spawn mortality associated with early migration and climate-driven reductions in marine survival (COSEWIC 2003). Deteriorating water quality conditions in Cultus Lake, leading to low overwinter survival, could also be contributing to this decline (DFO Lakes Research Program 2019, pers. comm.). The potential impact of decreased Sockeye Salmon abundance on the survival of Coastrange Sculpin, Cultus Lake population is unclear. Because juvenile Sockeye Salmon and Coastrange Sculpin, Cultus Lake population may compete for zooplankton prey, decreases in juvenile Sockeye Salmon abundance could increase the survival of Coastrange Sculpin, Cultus Lake population; however, there appears to be sufficient number of zooplankton available at this time. Then again, returning Sockeye Salmon can contribute a large proportion of the available phosphorus and nitrogen in Sockeye Salmon nursery lakes (Gende *et al*. 2002), which may elevate zooplankton densities. Consequently, reduced Sockeye Salmon abundance might decrease the abundance of prey for Coastrange Sculpin, Cultus Lake population; as of 2019, cultural eutrophication was seen as a threat to Cultus Lake, and therefore additional nutrients are not a limiting factor. Comparisons of limnological information collected from Cultus Lake in 2001-2007 with data collected in the 1930s and 1960s suggest, however, that there has been no marked change in either water quality (COSEWIC 2003; Shortreed

2007), or zooplankton abundance and community structure (Schubert *et al*. 2002), over the past 70 years, although it does appear that the lake is currently in the early stages of cultural eutrophication (Putt 2014). During years of reduced juvenile Sockeye Salmon abundance, Ricker (1941) noted a shift in diet composition of the predacious fish community in Cultus Lake away from juvenile Sockeye Salmon towards other prey species, including Prickly Sculpin and Coastrange Sculpin, Cultus Lake population. Therefore, another consequence of reduced Sockeye Salmon abundance could be a switch in the diet of the lake's piscivorous fish community away from juvenile Sockeye Salmon and towards Coastrange Sculpin, Cultus Lake population, thereby reducing Coastrange Sculpin, Cultus Lake population survival.

Northern Pikeminnow numbers in Cultus Lake were estimated to be between 62,000-71,000 by Bradford *et al*. (2007). It is not known whether the large numbers of Pikeminnow are due to the presence of introduced Eurasian Milfoil (*Myriophyllum spicatum*) in the lake's littoral zone which has increased to cover about 73% of the lake's surface littoral area that is < 6 m in depth (Schubert *et al*. 2002; Shortreed 2007). Adult Northern Pikeminnow in Cultus Lake occupy both limnetic and littoral zones, and prey mostly on fish (Ricker 1941); however, Coastrange Sculpin, Cultus Lake population were not found in the stomach contents of 240 Northern Pikeminnow sampled from Cultus Lake during the 1930s (Ricker 1941, 1960). Since 2006, there has been a targeted reduction of Northern Pikeminnow, with approximately 60,000 fish removed from the lake. Recent dramatic reductions in the abundance of juvenile Sockeye Salmon (COSEWIC 2003) could, however, lead to a shift in the diet of Northern Pikeminnow towards Coastrange Sculpin, Cultus Lake population (Ricker 1941; National Recovery Team for Cultus Pygmy Sculpin 2007). In addition, given the high abundance of Northern Pikeminnow in Cultus Lake, even a small increase in the average rate of predation on Coastrange Sculpin, Cultus Lake population might have a significant effect on survival. With the targeted harvest on Northern Pikeminnow, there has been anecdotal information that Trout and Char numbers are increasing (L. Pon, 2019, pers. comm.). Char (Bull Trout) were considered to be the major predator on the Cultus Lake population by Ricker (1960). Further eutrophication in Cultus Lake will reduce the quality of deep-water thermal refuges (Putt 2014).

Number of Locations

Coastrange Sculpin, Cultus Lake population, is only found in one location as they use most habitats within Cultus Lake. The three main threats (invasive species, pollution and climate change) will affect all individuals of this population.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

COSEWIC assigned a status of Threatened to the Coastrange Sculpin, Cultus Lake population in 2000 and 2010. It was then designated as Endangered when it was reassessed in November 2019. It has been listed as Threatened under Schedule 1 of the federal *Species at Risk Act* since 2003. A final Critical Habitat Order that prohibits the

destruction of the critical habitat of the Cultus Lake population (i.e., the entirety of Cultus Lake up to the wetted boundary) was published in January 2019.

The provincial parkland surrounding much of Cultus Lake is protected by the provincial *Park Act* (1996) of BC, which sets management guidelines and restricts resource extraction. Cultus Lake Municipal Park is managed under the *Cultus Lake Park Act* (1932), which prohibits private land ownership, but the park functions as a resort community rather than a conservation area.

Non-Legal Status and Ranks

NatureServe (2018) assigned Coastrange Sculpin, Cultus Lake population global, national and provincial status rankings of between critically imperilled and imperilled (G1G2, N1N2 and S1S2, respectively). The BC Conservation Data Centre gives Coastrange Sculpin, Cultus Lake population its highest provincial rank (red). The Coastrange Sculpin, Cultus Lake population is not listed in the IUCN Red List of Threatened Species; *C. aleuticus* is listed as stable/least concern (IUCN 2018).

Habitat Protection and Ownership

The aquatic habitat of Cultus Lake (i.e., below the high watermark) is provincial Crown land. Most of Cultus Lake's shoreline (92%), but not the aquatic habitat *per se*, is within either Cultus Lake Provincial Park (2561 ha along the east and west shores) or Cultus Lake Municipal Park (640 ha along the north shore). The federal *Fisheries Act* (1985) regulates activities that impact fish and fish habitat in all waters of Canada and must be applied by all levels of government. The provincial *Park Act* (1996) provides management guidelines and restricts resource extraction within provincial parks, thereby providing some level of protection against habitat degradation or loss for the adjacent terrestrial habitat. Cultus Lake Municipal Park is managed under a unique provincial statute, the *Cultus Lake Park Act* (1932), which gives the City of Chilliwack tenure over the park, but prohibits the City from selling property. The Cultus Lake electoral area consists of over 2,000 residents. Cultus Lake Municipal Park functions as a resort community with approximately 1,000 year-round residents. The small private resort/residential community of Lindell Beach is at the south end of the lake with approximately 150 residents. South of Lindell Beach is the Columbia Valley, a light agricultural area that extends south across the United States border. Frosst Creek, the largest tributary of Cultus Lake, drains this agricultural area (including the United States portion) before entering Cultus Lake at Lindell Beach.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

P. Woodruff obtained her BSc in Biology from the University of Victoria and her MSc in Zoology from the University of British Columbia. She has worked on marine mammals, migratory wetland birds, Kokanee Salmon and Sockeye Salmon, and various freshwater fish species at risk in British Columbia.

COLLECTIONS EXAMINED

Preserved Coastrange Sculpin, Cultus Lake population samples stored at the Cultus Lake Salmon Research Laboratory, the laboratory of Dr. Eric Taylor at the University of BC, and the Beatty Biodiversity Museum were examined as part of the preparation of this and previous reports.

Appendix: Threats Calculator.

Species or Ecosystem Scientific Name	*Cottus aleuticus*	**Element ID**		**English Name**	Coastrange Sculpin, Cultus Lake population
Version Date:	1/23/2019	YYYY-MM-DD (Ctrl + ";" for today's date)			
Assessors:	Patricia Woodruff, John R. Post, Dwayne Lepitzki, Sue Pollard, Mark Ridgeway, Constance O'Connor, Lucas Pon, Daniel Selbie, Greg Wilson, Benoit Laliberté and Marie-France Noel				
References:	COSEWIC 2019 (draft); Putt 2010; Sumka 2017; telecon 23 January 2019				
Generation Time:	3 years				

Overall Threat Impact Calculation Help:		**Level 1 Threat Impact Counts**	
Threat Impact		**high range**	**low range**
A	Very High	0	0
B	High	3	0
C	Medium	0	3
D	Low	0	0
Calculated Overall Threat Impact:		**Very High**	**High**
Assigned Overall Threat Impact:		**AB = Very High - High**	

Impact Adjustment Reasons:	It is unknown what overall effect (positive or negative) that eutrophication will have on the food web. Excess Phosphorus loading could result in the lake becoming Nitrogen-limited, which could encourage the growth of blue-green algae and other inedible phytoplankton species.
Overall Threat Comments	As Coastrange Sculpin, Cultus Lake population, is only found in one location, any threat could affect the entire population. Smallmouth Bass, an invasive non-native fish species that is known to prey on sculpin, has recently been discovered in Cultus Lake and could spread throughout the lake within the next 10 years. The compounding problems of increasing temperatures with climate change, coupled with increasing nutrients from atmospheric sources and residential and agricultural areas, are causing eutrophication in the lake, leading to longer stratification periods, anoxic conditions and lower oxygen levels at depth. Hypoxia at depth is believed to be one of the more serious threats to the persistence of the Cultus Lake population. It is conceivable that there could be a massive rapid eutrophication of Cultus Lake within the next 10 years. The current abundance of the Cultus Lake population is unknown. The current abundance trend is unknown: trawl surveys, where Coastrange Sculpin, Cultus Lake population were caught as bycatch, indicated a declining population; targeted minnow trap surveys indicate a more stable population. Time frame for severity and timing also 10 years, given 3 year generation time. Provincial parkland surrounding much (92%) of Cultus Lake under *Provincial Parks Act* sets management guidelines and restricts resource extraction.

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments (Limit of 2000 characters in each row. Avoid using ampersand '&'.)**
1	Residential & commercial development						Not applicable, this population is found in the offshore areas
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						
1.3	Tourism & recreation areas						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments (Limit of 2000 characters in each row. Avoid using ampersand '&'.)
2	Agriculture & aquaculture						Not applicable, this population is found in the offshore areas
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						
3	Energy production & mining						Not applicable, this population is found in the offshore areas; also, *Provincial Parks Act* restricts resource extraction
3.1	Oil & gas drilling						
3.2	Mining & quarrying						
3.3	Renewable energy						
4	Transportation & service corridors						Not applicable within the lake itself.
4.1	Roads & railroads						
4.2	Utility & service lines						
4.3	Shipping lanes						Dredging occurs in the outlet stream of Sweltzer Creek; however, only Prickly Sculpin (*Cottus asper*) have been found there, during electrofishing surveys and the operation of the sockeye smolt fence.
4.4	Flight paths						
5	Biological resource use		Negligible	Pervasive (71-100%)	Negligible or <1% pop. decline	High (continuing)	Sculpin have been caught as bycatch in Sockeye Salmon trawls; however, the sculpin are not always at the depth that is targeted for salmon juveniles. Sculpin have been released alive from the trawl net and from minnow traps.
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						
5.3	Logging & wood harvesting						

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments (Limit of 2000 characters in each row. Avoid using ampersand '&'.)
5.4	Fishing & harvesting aquatic resources		Negligible	Pervasive (71-100%)	Negligible or <1% pop. decline	High (continuing)	Sculpin are occasionally caught as bycatch in trawls for Sockeye Salmon juveniles. Both trawling and minnow trap capture appear to have low or no associated mortality. Minnow trapping during the summer, with the associated high temperatures, appears to be the only time when minnow trapping might be lethal.
6	Human intrusions & disturbance		Negligible	Pervasive - large	Negligible or <1% pop. decline	High (continuing)	Recreational SCUBA divers and non-lethal minnow trap surveys are likely not threats to the persistence of the Cultus Lake sculpin population. Military diving exercises are not believed to be a threat, but require further clarification on what locations the divers are using. Projects looking at matting to remove Eurasian milfoil are not believed to have a significant impact on Cultus Lake sculpin populations.
6.1	Recreational activities						There are recreational SCUBA divers that are interested in the benthic habitat and the Cultus Lake population of sculpin; their actions are not believed to be a threat.
6.2	War, civil unrest & military exercises		Negligible	Pervasive - large	Negligible or <1% pop. decline	High (continuing)	CFB Chilliwack uses the lake to conduct military diving exercises (such as the placement and removal of dummy mines); it is not known what locations they use in the lake (DFO Cultus Lake to seek further clarification).
6.3	Work & other activities						Minnow trapping does not appear to be lethal, unless undertaken during summer when surface temperatures reach lethal levels. There are some projects using impervious matting on invasive Eurasian Milfoil which extend down to 8m depth, it is not known if this project would have any significant effect on the Cultus Lake sculpin population.
7	Natural system modifications		Negligible	Negligible (<1%)	Negligible or <1% pop. decline	High (continuing)	
7.1	Fire & fire suppression		Negligible	Negligible (<1%)	Negligible or <1% pop. decline	High (continuing)	Water is extracted for fighting fires; however, this action removes warm surface water during the day in the summer, and so is unlikely to impact the Cultus Lake sculpin population.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments (Limit of 2000 characters in each row. Avoid using ampersand '&'.)
7.2	Dams & water management/use						There is a lot of groundwater extraction (mainly through the use of wells) but there has been no evidence of the lake level dropping. It is unknown what effect the use of groundwater has compared with the effects from evaporation and the loss of tributary stream inflow during the summer. There is an application for an independent power project in Frosst Creek, which should not effect water flow into the lake.
7.3	Other ecosystem modifications		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	It is not known what impact eutrophication will have on the food web dynamics of Cultus Lake: currently, it appears that zooplankton such as *Daphnia sp.* may be enhanced due to the increased nutrients in the system. It is not known how insect larvae and the benthic food web may be affected, as eutrophication and climate warming can lead to more deoxygenation in the benthic environment, as well as a greater abundance of organic debris (possibly causing smothering of habitat?). There is a pilot project underway that is using impervious mats to halt the growth and spread of milfoil; the effects of this project on the food web of the Cultus Lake population are unknown. Guano from migratory gull species (Glaucous-wing and Herring Gulls) is responsible for excess phosphorus in Cultus Lake (Putt 2014). It is not known if the gulls are also bringing contaminant or pathogen loads into Cultus Lake, and what the impact or magnitude of these loads might be. It is not known what effect the removal of large numbers of Northern Pikeminnow will have on the food web of Cultus Lake.
8	Invasive & other problematic species & genes	BC	High - Medium	Pervasive - large	Serious - moderate	High (continuing)	Smallmouth Bass, a non-native invasive species, are now present in Cultus Lake; these fish are known to prey upon sculpin species. With the reduction of Sockeye Salmon in Cultus Lake, it is unknown whether predators will switch to sculpins as prey.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments (Limit of 2000 characters in each row. Avoid using ampersand '&'.)
8.1	Invasive non-native/alien species	BC	High - Medium	Pervasive - large	Serious - moderate	High (continuing)	Smallmouth Bass, both juvenile and adults, have been discovered in the north end of Cultus Lake and are known to prey on sculpin species. There is currently no impediment to stop the bass from spreading throughout the lake, possibly within the next 10 years. It is believed that the bass will interact with the Cultus Lake sculpin population, especially during the shoulder seasons when they are more in contact with the cold-water fish; Smallmouth Bass will go down to 15-20m depth in winter, but they are believed to stop foraging when the temperature is below 10oC.
8.2	Problematic native species		Unknown	Pervasive (71-100%)	Unknown	High (continuing)	It is unknown what effect the reduction or build-up of Sockeye Salmon will have on the Cultus Lake sculpin, and whether predators such as Bull Trout or Northern Pikeminnow will switch to consume more sculpin as prey. Cultus Sockeye Salmon fry are being stocked into Cultus Lake. Both Sockeye Salmon and the Cultus Lake Population of Sculpins feed on zooplankton and have a similar trophic overlap , although there appears to currently be a healthy population of zooplankton, so no bottom-up carrying capacity effect. It is not known whether the Cultus Lake Population of Sculpin are still feeding regularly on zooplankton. Northern Pikeminnow numbers were thought to be increasing, the status of Bull Trout and other predatory fish is unknown.
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin						
8.5	Viral/prion-induced diseases						
8.6	Diseases of unknown cause						
9	Pollution	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	Increasing nutrients from atmospheric, urban, residential and agricultural activities are leading to increased eutrophication, with larger anoxic areas (Putt 2014). It is believed that anoxia is a key threat to the persistence of the Cultus Lake population of sculpin, and will require a project looking at the aerobic scope of this fish.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments (Limit of 2000 characters in each row. Avoid using ampersand '&'.)
9.1	Household sewage & urban waste water	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	Increasing nutrients from household sewage and septic tanks are leading to eutrophication in the lake (Putt 2014)
9.2	Industrial & military effluents						
9.3	Agricultural & forestry effluents	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	Increasing nutrients from agricultural activities are leading to eutrophication in Cultus Lake (Putt 2010).
9.4	Garbage & solid waste						
9.5	Air-borne pollutants	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	Air pollution from urban areas is responsible for atmospheric deposition of excess nutrients (Putt 2010).
9.6	Excess energy						
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/tsunamis						There have been constant tremors, unknown what, if any, effect from an earthquake.
10.3	Avalanches/landslides						Some sedimentation has entered the lake from landslides.
11	Climate change & severe weather	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	Increasing temperatures lead to longer periods of stratification, and more instances of anoxic conditions at depth (Sumka 2017)
11.1	Habitat shifting & alteration						There appears to have been some seasonal redistribution of fish within Cultus lake, due to temperature and hypoxia events increasing.
11.2	Droughts	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	There have been, and likely will continue to be, longer drought periods, with a 14% decrease in water input to the lake.
11.3	Temperature extremes	BC	High - Medium	Pervasive (71-100%)	Serious - moderate	High (continuing)	Models indicate that increasing temperatures lead to longer periods of stratification (Sumka 2017). The surface temperatures of the lake are increasing and the heat storage of the lake has increased, with likely negative effects on metabolic rates , trophic links and foraging opportunities.
11.4	Storms & flooding						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al*. (2008).							