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

Canadian Science Advisory Secretariat (CSAS)

Research Document 2015/033

Pacific Region

Identification of critical habitat for Coastrange Sculpin (Cultus Population) (*Cottus aleuticus*)

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June 2015

Canada

Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

ISSN 1919-5044

Correct citation for this publication:

Chiang, E., Pon, L., Selbie, D.T.,Hume, J.M.B., Woodruff, P., and Velema, G. 2015. Identification of critical habitat for Coastrange Sculpin (Cultus Population) (*Cottus aleuticus*). DFO Can. Sci. Advis. Sec. Res. Doc. 2015/033. vii + 23 p.

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ABSTRACT

This paper makes recommendation for the identification of critical habitat for the SARA listed, Coastrange Sculpin (Cultus Population), based on best available information. Coastrange Sculpin (Cultus Population), *Cottus aleuticus*, informally recognized as Cultus Pygmy Sculpin, is a neotenic form of the Coastrange Sculpin and found only in Cultus Lake in the southwestern corner of British Columbia, Canada. The recommendation of critical habitat satisfies the species recovery goal – “to ensure the long-term viability of the population in the wild.” Spatial extent, features and attributes of critical habitat are also recommended. Information with regards to the species, such as life history, biology, abundance, and threats are also reviewed and updated as appropriate.

Identification de l'habitat essentiel du chabot côtier (*Cottus aleuticus*) (population du lac Cultus)

RÉSUMÉ

Le présent document formule des recommandations en vue d'identifier l'habitat essentiel du chabot côtier (population du lac Cultus) en fonction de la meilleure information disponible. Le chabot côtier (population du lac Cultus) (*Cottus aleuticus*), connu officieusement sous le nom de chabot pygmée, est une forme néoténique du chabot côtier que l'on retrouve uniquement dans le lac Cultus, dans le coin sud-ouest de la Colombie-Britannique. La recommandation d'un habitat essentiel satisfera à l'objectif de rétablissement de l'espèce – « assurer la viabilité à long terme de la population à l'état sauvage ». Il est également recommandé de déterminer la répartition spatiale, les caractéristiques et les attributs de l'habitat essentiel. Les renseignements relatifs à l'espèce, par exemple son cycle biologique, sa biologie, son abondance et les menaces qui pèsent sur elle sont également passés en revue et mis à jour lorsque cela est approprié.

PREAMBLE

The Species At Risk Act (SARA) recognizes that a species' critical habitat is necessary for its survival and recovery. Every Recovery Strategy or Action Plan developed for a species listed on SARA as threatened or endangered must identify critical habitat to the extent possible, using best available information.

Critical habitat is defined under SARA as *"…the habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in an action plan for the species."*

Critical habitat functions, biophysical features and attributes should be clearly delineated as integral components of a critical habitat identification process. Recovery goal as indicated in the Recovery Strategy document are central to the overarching principle needs in identifying a species' critical habitat. The critical habitat identification process should be an iterative approach that is only complete when the recovery goal is achieved.

The recovery goal of the Coastrange Sculpin (Cultus Population), is *"… to ensure the long-term viability of the population in the wild. This taxon is likely to remain at an elevated risk due to the population's extremely limited distribution."* (NRTCPS 2007)

When critical habitat is identified, examples of "Activities Likely to Destroy Critical Habitat (ALTD CH)" should also be provided per requirements from SARA. This establishes a baseline to identify and communicate to Canadian public about the activities that are likely to cause critical habitat destruction.

This document provides recommendations for the identification of critical habitat for Coastrange Sculpin (Cultus Population) (*Cottus aleuticus*) to the extent possible based on best available information. As well, it provides examples of Activities Likely to Destroy Critical Habitat.

SPECIES INFORMATION

GENERAL DESCRIPTION

The Coastrange Sculpin (*Cottus aleuticus*) is found in coastal watersheds of western North America from Bristol Bay, Alaska to San Luis Obispo, California (Scott and Crossman 1973). It is a common riffle sculpin species in rivers and streams along the entire coastal British Columbia. Except in a few large river systems such as the Fraser and Skeena it is typically restricted to within about 100 km of the coast (McPhail 2007). Unlike the stream dwelling form of *C. aleuticus*, Coastrange Sculpin (Cultus Population) is only found in the deep areas (up to 40m) of a single lake - Cultus Lake, British Columbia (Ricker 1960; Woodruff 2010).

The general appearance of the Coastrange Sculpin (Cultus Population) is very similar to that of Coastrange Sculpin. As is the case with all Sculpins, *C. aleuticus* has morphological features that are adapted for bottom dwelling lifestyle, and lacks a swim bladder (McPhail 2007, Scott and Crossman 1973). However, Coastrange Sculpin (Cultus Population) differs from typical *C. aleuticus* in that it appears to be a dwarf form, maturing at a smaller size in the lake's pelagic environment (McPhail 2007, Cannings 1993, Scott and Crossman 1973, Ricker 1960). See figure 1 for general appearance of Coastrange Sculpin (Cultus Population) and figure 2 for its comparison to Coastrange Sculpin.

A similar population of planktivorous dwarf *C. aleuticus* lives in Lake Washington, near Seattle, WA USA (Ikusemiju 1975). Both Cultus Lake and Lake Washington populations live in the off-shore waters of productive lakes; have enlarged cephalic pores, shorter pelvic fins, and a higher number of pectoral fin rays. Relative to the typical *C. aleuticus*, these morphological features could be adaptations for sensory perception and for maintaining position in the water column during a planktivorous lifestyle (Larson and Brown 1975). *C. aleuticus* in Lake Washington is highly distinct in microsatellite analyses compared to Coastrange Sculpin (Cultus Population), suggesting that they have had a separate origin from those in Cultus Lake and may be a result of parallel evolution. As well, Coastrange Sculpin (Cultus Population) is genetically distinct from the stream-dwelling Coastrange Sculpins found in the lake's tributary system at population level (Woodruff 2010).

Very little is known about the biology and habitat preferences of the Coastrange Sculpin (Cultus Population); nearly all of the research conducted on this species has been documented by Ricker (1960) and Woodruff (2010).

LIFE HISTORY

Typical *C. aleuticus* young become planktonic in lakes or estuaries after hatching and then take up a benthic lifestyle approximately one month later. Adults reach average total length between 3-4 inches (76-102 mm) while maximum of 115 mm have been reported at age of 4 years (Ricker 1960; Scott and Crossman 1973). In contrast, Coastrange Sculpin (Cultus Population) grows to total length of about 50 mm and do not migrate after hatching (Scott and Crossman 1973). They are adapted to complete their entire life cycle in the deep offshore waters of Cultus Lake (Ricker 1960).

Spawning by Coastrange Sculpin (Cultus Population) takes place in a female's third calendar year of life; likely beginning in late May or early June. By late June, spawning is in full swing and typically continues through July and August. However, a female carrying large eggs was found as late as September 11th (Ricker 1960). Fecundity in the Coastrange Sculpin is a function of female body size. Thus, females of the Coastrange Sculpin (Cultus Population) that mature as small as 37 mm, have relatively low fecundity between 50 – 150 eggs (McPhail 2007). In contrast, typical Coastrange Sculpin females mature at about 50 mm, and their fecundities range from about 200 – 1,000 eggs (Patten 1971).

BEHAVIOUR

Many sculpins have cryptic colourations, and typically avoid predators by reducing their movements and relying on crypsis for defence. Woodruff (2010) found that, in contrast to the typical cryptic response, Coastrange Sculpin (Cultus Population) tend to ascend into the water column when a known predator, Prickly Sculpin (*Cottus asper*), was present. As *C. asper* is a larger sculpin, it is also likely to out-compete Coastrange Sculpin (Cultus Population) for any refuge on the bottom (McNeely et al. 1990). It is unusual for Coastrange Sculpin to be found in large numbers in habitat occupied by Prickly Sculpin; in streams the two species tend to segregate spatially (Tabor et al. 2007). Woodruff (2010) suggested that predation and/or competition from sympatric *C. asper* in Cultus Lake might have been an important factor in the evolution of limnetic life history of the Coastrange Sculpin (Cultus Population).

GENERAL HABITAT USE

No Coastrange Sculpin (Cultus Population) has been observed in surveys along the shores of Cultus Lake or in its tributary streams (Ricker 1960; Woodruff 2010). Significant numbers however, have been observed in the stomachs of Bull Trout (*Salvelinus confluentus*) that forage in the deep, offshore waters of the lake (Ricker 1960) as well as in minnow traps suspended in the pelagic zone of the lake (Woodruff 2010). Coastrange Sculpin (Cultus Population) have also been incidentally captured in pelagic trawl surveys targeting Sockeye Salmon (*Oncorhynchus* *nerka*) in Cultus Lake (COSEWIC 2010). Based on these sampling results, Woodruff (2010) concluded that Coastrange Sculpin (Cultus Population) primarily occupy the deeper (>20m), offshore waters of the lake. Most fish captured in Woodruff's (2010) offshore minnow trapping efforts were found in traps set either on the bottom or within 10m of the bottom; the majority of captures occurred in the hypolimnion (20-40 m below the surface of the lake; Shortreed 2007; Figure 3). However, Coastrange Sculpin (Cultus Population) have also been caught in trawls as shallow as 4m on occasion. All capture data to date (Woodruff 2010, Ricker 1960, Hume, J., DFO. 2011. *unpul data*) are consistent with McPhail (2007) who suggested Coastrange Sculpin (Cultus Population) probably undertake diurnal vertical migrations. Larson and Brown (1975) and Ikusemiju (1975) also report a similar vertical migration pattern from the Lake Washington population. As such, it is reasonable to suggest that vertical migration is potentially an important trait of Coastrange Sculpin (Cultus Population).

Woodruff (2010) captured Coastrange Sculpin (Cultus Population) during every month from May to October, with the highest catches occurring in July and August, which included young of the year. Catch success varied both spatially and temporally, suggesting that habitat use likely changed from season to season, although there are no further data regarding winter habitat. By-catch data from Cultus Lake annual Sockeye trawls show wide variations on each of the survey dates. Since each trawl is set at different depths, this variation may suggest some sort of spatial patchiness of the Coastrange Sculpin (Cultus Population).

Typical *C. aleuticus* are not known to utilize sandy substrate; preferring instead coarse gravel and cobble substrate (McPhail 2007; Tabor et al. 2007). Substrate preference is not known for Coastrange Sculpin (Cultus Population) specifically, although it is reasonable to expect that the fish also prefer similar substrate types such as coarse gravel and cobble.

While the spawning habitat of the Coastrange Sculpin (Cultus Population) is also unknown, another lacustrine sculpin species, *C. extensus,* has been found to use rocky, cobble or boulder substrate (Ruzycki et al. 1998). Also, *C. aleuticus* found in coastal streams use gravel riffles for spawning purposes (Ricker 1960). It is reasonable to infer that Coastrange Sculpin (Cultus Population) spawning habitat is likely to be similar to other lacustrine sculpin species – rough substrates such as gravel, cobbles and boulders.

FOOD ITEMS

Unlike the stream-resident forms of *C. aleuticus* that forage primarily on benthic organisms, the main prey of the Coastrange Sculpin (Cultus Population) is Cladoceran zooplankton with *Daphnia* being the most prevalent (Ricker 1960). Diet of Coastrange Sculpin (Cultus Population) also consisted of Chironomid midges, *Epischura*, *Ostracods*, *Bosmina* and *Cyclops*, (Ricker, 1960). *Daphnia* biomass in Cultus Lake constitutes 72% of total plankton (Shortreed 2007). In Cultus Lake, *Daphnia* are generally found in highest densities in the vicinity of the thermocline (metalimnion) at night (Shortreed, 2007). As previously mentioned, Coastrange Sculpin (Cultus Population) probably undertakes diurnal migrations in the water column. This migration likely is for feeding on zooplankton preys that mainly consists of *Daphnia*. (McPhail, 2007 and Hume, J., DFO. *unpubl data*).

CURRENT ABUNDANCE

There is currently no reliable estimate of the abundance of Coastrange Sculpin (Cultus Population) in Cultus Lake. The only available estimate of 3,000 - 10,000 individuals originates from Cannings (1993) and has no apparent quantitative basis. COSEWIC Status Report (2010) suggested a slight downward trend of approximately 4% based on the by-catch data from annual Cultus Sockeye surveys from 1975 to 2004. There are a number of caveats pertaining to this dataset, which are detailed in COSEWIC (2010) and briefly described in the following. First, the capture data was based on by-catch of a survey designed for Cultus Sockeye Salmon, which targeted specific depths based on hydroacoustic indications of abundance. Second, the mesh size of the trawl net was large for the average size of Coastrange Sculpin (Cultus Population) and therefore may have resulted in size selection bias. Third, the trawls were almost always conducted in the middle of the lake along the long axis, and typically in the northern portion of the lake; leaving much of the lake unsampled. Finally, trawls were mostly shorter prior to 1985 at less than 30min when Sockeyes were denser and trawls of 30 minutes or longer did not start until the late 1980s.

THREATS

INVASIVE SPECIES

The introduction of invasive species has been described as one of the most prevalent threats for at-risk freshwater fish in Canada (Dextrase and Mandrak 2006). Invasive species have the potential to significantly impact the survival and conservation of Coastrange Sculpin (Cultus Population). This is exacerbated by the endemic nature of the species. A well known example of such an occurrence is the introduction of Brown Bullhead (*Ameriurus nebulosus*) in Hadley Lake, B.C., which led to the extinction of the unique Threespine Stickleback Species Pairs (*Gasterosteus* spp, Species at Risk Public Registry).

Invasive Fish and Invertebrate Species

To date, no invasive fish species have been found in Cultus Lake (COSEWIC 2010). However, Brown and Yellow Bullhead (*A. natalis*), Yellow Perch (*Perca flavescens*) and Bass species (*Micropterus spp.)* have been found in the lower Fraser Valley area (Nowosad 2010; Koopmans 2006; Dunphy 2006). These invasive species are of particularly concern due to their relatively close proximity to Cultus Lake (COSEWIC 2010). Due to the intense use of the lake by recreational boaters, it is also possible that invasive invertebrate species such as Zebra Mussel (*Dreissena polymorpha*) or Quagga Mussels (*Dreissena rostriformis bugensis*) find their way into Cultus Lake.

Invasive Aquatic Plant Species – Eurasian Water Milfoil

The invasive aquatic macrophyte, Eurasian water milfoil (*Myriophyllum spicatum L.*) (EWM) was first noted in Cultus Lake in 1977. Annual milfoil surveys during the fall from 1977 to 1991 showed that EWM was widespread within the lake. Infestation increased steadily from 12.7 ha in 1977 to 21.5 ha in 1991, or from 17% to 29% of the 74 ha littoral area (Truelson 1992). This increase occurred in spite of EWM control efforts. A hydroacoustic based survey was conducted in 2004, which reported a 26% increase (26.7 ha total) in EWM coverage for the same area examined in the previous survey (Stables 2005). Anecdotal reports also suggest that the current EWM abundance is higher than during the 1990s, though opinions vary. At Cultus Lake, EWM is most common from 1 to 4 m deep (Mossop and Bradford. 2004).

EWM can affect the Cultus Lake environment through several mechanisms, including altering predation dynamics in shallow waters of the lake, and affecting water quality in terms water temperature and dissolved oxygen levels during summer months (Unmuth et al. 2000). It can also alter the movement of sediment into deeper water and contribute to the accumulation of sediment deposits along the shoreline. Lastly it can out-compete and replace the native vegetation in the lake (Truelson 1992). EWM was identified as a threat for the COSEWIC listed

Cultus Sockeye Salmon (COSEWIC 2003). Continued control of water milfoil in Cultus Lake was identified as a potential recovery activity for the Cultus Lake Sockeye population (DFO 2008).

The potential effects of EWM on the Coastrange Sculpin (Cultus Population) are unknown. If the Coastrange Sculpin (Cultus Population) uses shallow waters with EWM growth for part of its life cycle, the presence of EWM could potentially exert negative pressure on the species from the increasing sediment deposition in the littoral environment and potentially smothering the cobble/gravel bottom substrates. However, no direct evidence is available for this potential scenario. As well, COSEWIC (2010) speculated that, due to increased Northern Pikeminnow (*Ptchocheilus oregonensis*) abundance by way of increased EWM cover, there may be a potentially higher predation pressure on Coastrange Sculpin (Cultus Population). However, this possibility may be reduced by the predator control program targeting Northern Pikeminnow as part of recovery measure for Cultus Sockeye Salmon (see discussion below in section 4.2). Alternatively, the presence of EWM may also provide cover, refuge and spawning grounds if Coastrange Sculpin (Cultus Population) utilizes shallower waters (Harvey 2007).

Few life history trends of Coastrange Sculpin (Cultus Population) can be inferred from the capture data from Woodruff (2010). The vast majority of captures occurred at depths of 20m or more. There is a slight pattern of congregation toward the southern end of the lake, where eight gravid females and one male were captured from May – July 2008 (Figure 3). It is reasonable to conclude that EWM does not appear to directly affect the species given existing life history information.

ALTERED PREDATION RATES

The Coastrange Sculpin (Cultus Population) appears to be a key prey item for Bull Trout and less so for other species in Cultus Lake, including Prickly Sculpin, Northern Pikeminnow, Coho Salmon (*Oncorhynchus kisutch*), Coastal Cutthroat Trout (*Oncorhynchus clarkii*) and Cultus Sockeye Salmon (NRTCPS 2007, Ricker 1960, Woodruff 2010).

Changing predation dynamics in Cultus Lake are difficult to quantify. Cultus Sockeye Salmon has seen a dramatic decline since the 1970s, with recent generational (4 year) average of about 1,000 spawners per year (5% of historical values; Bradford et al. 2011). It was speculated that the decline could shift predation pressure to Coastrange Sculpin (Cultus Population) (Woodruff 2010, COSEWIC 2010). As part of the recovery efforts for the Cultus Sockeye Salmon, there had been a predator removal program focusing on Northern Pikeminnow. In 2004, the adult population of the Northern Pikeminnow was estimated at approximately 60,000 individuals (Bradford et al. 2007). The predator removal program has removed over 40,000 adults from the lake by purse seining, and the most recent efforts has shown decreasing catch efficiencies to less than 2,000 fish. However during the same time, the by-catch data of Coastrange Sculpin (Cultus Population) from juvenile sockeye trawls does not show a marked trend. This suggest that either: 1) predation from Northern Pikeminnow may not be a significant pressure on the population of Coastrange Sculpin (Cultus Population), as also suggested by Ricker (1960); or 2) Sockeye trawl by-catch data is not indicative to the population trend of Coastrange Sculpin (Cultus Population). Further, it is also interesting to note that Northern Pike Minnow has been caught in the deep waters of the lake (~40m; L. Pon, DFO, Cultus Lake Research Laboratory. pers. obs. 2011), indicating potential long-term co-existence of this predator with Coastrange Sculpin (Cultus Population). Land Use, Water Use and Lake Water Quality

Lake Water Quality and Nutrient Levels

Many studies and stakeholders have raised concerns over the increasing land and water use in the Cultus Lake watershed and its potential to lead to lake eutrophication (Shortreed 2007, Woodruff 2010, COSEWIC 2010, Marion Robinson, Cultus Lake Aquatic Stewardship Strategy, Cultus Lake BC, pers. comm. 2010). Cultus Lake watershed, including Columbia Valley, has had many different land use activities including agricultural, forestry, residential and recreational utilization. Cultus Lake itself is a popular summer vacation spot in the Lower Fraser Valley and receives an estimated 3 million visitors per year (Robinson 2011)

Lake water quality in the context of nutrient level has been identified as a central issue for both Cultus Sockeye Salmon and the Coastrange Sculpin (Cultus Population) (NRTCPS 2007, COSEWIC 2003). Several lines of evidence demonstrate an increasing trend in Cultus Lake nutrient loading. Shortreed (2007) reported that Cultus Lake had relatively high dissolved oxygen (DO) concentrations averaging 9.9 mg/L (108% saturation) at the surface and average hypolimnetic DO, which was slightly lower at 8.9mg/L (71% saturation). In the fall, hypolimnetic DO began to decline and was reduced to 6.1 mg/L (~50% saturation) by late December. After only a few weeks however, lake overturn occurred and DO was again >10 mg/L throughout the water column. When compared with data from Ricker (1937) for the period between 1927 – 1935 (Figure 4), seasonal surface DO concentration were virtually identical between the two studies, but hypolimnetic (30m depth) DO was substantially lower in the 2007 data. The declines in oxygen levels near bottom sediments have also been noted more recently. Intra-gravel oxygen levels near Lindell Beach area was found to be below 5mg/L compared to other sites (Hume, J. *unpul. data*. 2005.). The depleted oxygen may explain the abandonment of this area as spawning site for Cultus Sockeye Salmon, but also may be related to naturally anoxic groundwater seepage from the Columbia Valley aquifer (J. Hume, DFO. Cultus Lake Research Laboratory. pers. obs., 2011). Hypolimnetic oxygen depletion is classically associated with increased lake productivity and decomposition of organic matter during summer lake thermal stratification (Wetzel 2001). In Cultus Lake, this is likely attributed to increased productivity input from anthropogenic sources (Shortreed 2007).

Ongoing paleolimnological investigation by DFO Cultus Lake Research Laboratory further supports the view that lake nutrient load is increasing. Unpublished time series data reveal increases in $\delta^{15}N$ and chlorophyll *a* (algal pigment) in the lake sediments over the past ca. 140 years, particularly since ca. 1950 (Dan Selbie, DFO, Cultus Lake Salmon Research Laboratory, Cultus Lake, BC. and Peter Leavitt, Department of Biology, University of Regina, Regina, SK, *unpubl data*). While increased $\delta^{15}N$ in Sockeye nursery lakes can be related to the returns of Sockeye and its nutrient sources (Selbie et al. 2009), the Cultus Lake Sockeye run has declined over this same period. The likely explanation for the observed nutrient loading trend is the potential inputs from the lake catchment area associated with anthropogenic land uses (e.g. increased human land use, sewage effluence, agricultural run-off) and possibly water fowl activity. The net effect of increasing lake nutrient level and associated oxygen depletion remains a significant concern to the Coastrange Sculpin (Cultus Population) as data begins to show lake areas with low oxygen levels (Figure 5).

Land Use

The land use pattern in the Cultus Lake watershed likely plays a significant role in the nutrient loading concerns. Land ownerships surrounding the lake shoreline include BC Provincial Crown, BC Parks, the Cultus Park Board, and private land holders.

Historically, Cultus Lake watershed experienced forestry resource activities. However, a sizeable portion of the watershed has been designated as Provincial Park since 1948. As well, several streams on the Cultus Lake side of Vedder Mountain have been designated with Provincial Wildlife Habitat Area status that affords protection from forestry practices. There are no current or planned forestry activities directly in the Cultus Lake watershed (British Columbia Ministry of Natural Resource Operation, iMap application, 2011). Approximately 85% of the Columbia Valley in the south end of the Cultus Lake watershed is in provincial Agricultural Land Reserve (ALR) Zoning. Agricultural land use includes livestock production (cattle, swine, poultry and deer) and horticultural production (nurseries, tree farms and raspberries). During a land use survey in 1997, of the approximately 978 hectares of surveyed land in the Columbia Valley, approximately 27% (260 hectares) is forested or undeveloped (non-arable), approximately 21% (122 hectares) is used as rural residential or hobby farm, and 52% (506 hectares) is used for agricultural purposes (Zubel 2000).

The community of Lindell Beach is located on the southwestern shore of Cultus Lake, just outside of the ALR in the Columbia Valley. It consists of residential and recreational properties, with commensurate land use that includes a golf course and trailer park. Old residential septic sewage systems and golf courses have been cited as potential sources of nutrient inputs to Cultus Lake in that area (Shortreed 2007, Woodruff 2010, Marion Robinson, Cultus Lake Aquatic Stewardship Strategy, Cultus Lake, BC, pers. comm., 2011., NRTCPS 2007). The effect of Lindell Beach land use on lake nutrient level input remains unknown, but is one of the objectives of the ongoing Cultus Lake Nutrient Loading Project currently underway with cooperation from the local stewardship group - Cultus Lake Aquatic Stewardship Strategy (CLASS).

At the north end of Cultus Lake, septic leachates from residential areas likely also contribute to elevated lake nutrient loading. Liquid waste management is currently the focus of the community and regional district, and the local area plans - Electoral Area E, Columbia Valley and Cultus Lake Strategic Planning (2010) both address this issue (M. Robinson, Cultus Lake Aquatic Stewardship Strategy, Cultus Lake, BC, pers. comm., 2011, and L. Grant, Fraser Valley Regional District, pers. comm., 2011).

Land developments for cottage/residential use have increased in the recent time as well. The newest project consists of a community of ~200 cottages with a planned expansion of another 150 units. There is an expectation that the development will increase by 50% to 100% in the Lindell Beach area (R. McDermit, Fraser Valley Regional District, pers. comm., 2011). The ALR commission and the local community have had a strong policy against sub-division and/or removal of ALR in the Columbia Valley (L. Grant, Fraser Valley Regional District, pers. comm., 2011). As a result, land use pattern in the Columbia Valley is not expected to change greatly and the developmental pressures on the lake will likely continue to come from Lindell Beach area. Furthermore, the cottage community development projects are now required to submit sewage management plans with adequate treatment capacity. Although the treatment facilities do not represent a perfect solution, they will help to control nutrient loading issue from the new projects in the interim (R. McDermit, Fraser Valley Regional District, pers. comm., 2011).

Increased nutrient loading into groundwater from agricultural activities in the Lower Fraser Valley has been well documented (Environment Canada 2004). Pristine groundwater in the Fraser Valley typically contains 0.15 mg/L Total Nitrogen. The background threshold level used in the Zubel (2000) groundwater investigation was 3 mg/L NO3-N although no reason was given for this threshold value. Regardless, Zubel (2000) found more than 20 groundwater sites showing nitrate-nitrogen levels greater than the background with 2 “hotspots” in the Columbia Valley. With groundwater travel speed at an estimated 260 m/year (Zubel 2000), it is almost certain that the groundwater nutrient inputs occur in Cultus Lake. Zubel (2000) also found a significant groundwater mound (groundwater divide) that occurs in the central part of the valley. As a result, it is highly likely that half of the Columbia Valley groundwater flow travels south toward the Canada-USA border while the other half travels north toward Cultus Lake. This groundwater mound effectively diverts half of the potential nutrient input from groundwater source in the Columbia Valley away from Cultus Lake. Zubel (2000) concluded that nitrate-nitrogen input as a result of agricultural activities was “not an overly excessive amount and that minor adjustment of manure management activities will ensure excess nutrients applied to the soil will not leach into the groundwater." However, the results and the effectiveness of such management activities are unclear and surface water sources may still be of significant importance in nutrient loading to Cultus Lake.

Lake Water Use

Concerns exist over the water use in Cultus Lake, both in terms of recreational boating and water extraction (NRTCPS 2007). The lake shoreline has been altered by the construction of wharves and piers but mainly in the Lindell Beach area (COSEWIC 2003). The various activities associated with water-oriented recreation have primarily altered shallow littoral areas. Wave actions from boaters have been consistently identified as a concern by the local community. However, it is unlikely to affect the survival and recovery of Coastrange Sculpin (Cultus Population), given the capture information available from Woodruff (2010). Note that this conclusion can change if life history information of the species shows utilization of shallow waters. Likewise, lake water extractions, as identified and discussed in the NRTCPS (2007), do not likely pose significant threat to the survival and recovery of the species.

POTENTIAL CONTAMINANTS FROM RECREATIONAL POWER BOATS

Although no quantitative data exists, it is commonly accepted that Cultus Lake receives heavy recreational boat traffic in the busy summer months between June to September. Recent user survey (Robinson 2011) indicates 27% (n=167) of lake users are recreational power boaters. The associated pollution from this heavy use has been identified as a potential threat to the Coastrange Sculpin (Cultus Population) by Harvey (2007) and the local community (Robinson 2011).

During a site visit in August 2011, approximately 120 powered water crafts were observed on the lake (E. Chiang, DFO. Cultus Lake. pers. obs. 2011). Recreational power boat traffic had been known as a source of pollutants that include polycyclic aromatic hydrocarbons (PAHs) in aquatic environments (Mastran et al. 1994, Rice et al. 2008, Lico 2004, Heald et al. 2005, and Jackivicz and Kuzminski, 1973). The intensity of the release is well correlated to the seasonality and intensity of recreational motorboat use. Rice et al. (2008) used passive samplers at locations in and around Auke Lake, southeast Alaska to show dramatically high PAH levels along with intense recreational usage from power boats and personal water crafts during busy seasons. Mastran et al. (1994) also tracked the correlated boating activities with total PAH concentrations in water samples along a large reservoir. As such, PAHs are contaminants of potential concern for the Cultus Pygmy Sculpin.

Most PAHs tend to be relatively non-volatile and poorly soluble; they will become incorporated into bottom sediments, primarily by removal from the water column through their association with particulate matter (Government of Canada 1994). The amount of PAHs released by a motorboat is typically a function of fuel mixture, engine design, age, operating speed and efficiency (Jackivicz and Kuzminski, 1973). In addition, motorboats also tend to release PAHs and other organic pollutants through fuel and oil product leakages (Mastran et al. 1994).

Much research has demonstrated the greatly enhanced toxicity of PAHs in water as the result of near ultraviolet radiation. (Oris et al. 1990, Weinstein and Oris 1999, Mekenyan et al., 1994). Toxic effects include reduced growth, decreased reproduction rates, and acute lethality in wide variety of aquatic species such as algae, duckweed, oligochaetes, chironomids, daphnids, brine shrimp, myside shrimp, mollusk larvae, fish and amphibians (McDonald and Chapman 2002).

Moles and Marty (2005) investigated a series of physiological effect on Prickly Sculpin (*Cottus asper*) in Auke Lake, Alaska where high levels of PAHs in water and sediment originate from intense recreational boating activities. This decline of lake salmon stock has also been attributed to this pollution level (Rice et al. 2008). They used a series of physiological metrics such as length/mass ratio, hematology, histology, and parasitism to compare Prickly Sculpin in Auke Lake and neighbouring lakes where PAHs levels in water and sediments are found to be nil. The results uncovered indication of physiological effect of chronic exposure to PAH contamination. Sculpins sampled from Auke Lake had lower condition factor, gastrointestinal indices, and lymphocytes than fish from neighbouring lakes. Furthermore, there is higher prevalence of parasite, microscopic lesions in livers and lower proportion of juvenile sculpins in Auke Lake.

Some sampling of benthic sediment in Cultus Lake that target the spawning grounds of Cultus Sockeye Salmon took place in November, 2007 (Kelly 2008). These preliminary sediment chemistry results showed some slightly elevated PAHs (Acenaphthene and Fluorene) when compared to Interim Sediment Quality Guideline published by Canadian Council of Ministers of the Environment (CCME-ISQG) and no exceedance when compared to Generic Numerical Sediment Criteria for sensitive sites (BC-SedQCss) under Province of British Columbia Contaminated Sites Regulations. The CCME-ISQG are screening tools and based on probability of adverse effect from available data and the exceedances to screening values do not represent real and immediate adverse biological effect (CCME 1999). As such, the slight exceedances of CCME-ISQG are likely not expected to result in significant adverse effect to aquatic ecosystem.

Heavy recreational motor boating is a well documented source of pollution in aquatic ecosystem (Mastran et al. 1994, Rice et al. 2008, Lico 2004, Heald et al. 2005, and Jackivicz and Kuzminski, 1973). Whether or not the pollution from heavy motor boat use may or may not affect Coastrange Sculpin (Cultus Population) will likely persist without further site-specific investigation. Overall, the existing sediment data likely indicates to no significant adverse impact. However further investigation is warranted as existing data missed the areas of highest potential concern – the littoral areas near the Cultus Lake Park and the boat launches in Entrance Bay. Since the study from Kelly (2008) targeted spawning grounds for Cultus Sockeye Salmon, the data set also did not target deeper benthic areas of Cultus Lake that is the primary habitat of Cultus Pygmy Sculpin. Further site specific investigation into aquatic contaminants in Cultus Lake should therefore focus on:

1) potential of recreational motor boat traffic contamination into littoral areas in heavy use seasons,
2) environmental fate of contaminants such as PAHs in the deep benthic areas, and
3) the potential toxicological implications to Coastrange Sculpin (Cultus Population).

APPROACH TO IDENTIFYING CRITICAL HABITAT

The identification of critical habitat in the context of SARA involves specifying the geospatial location of the critical habitat; and describing the known biophysical functions, features and attributes required to carry out life processes necessary for its survival or recovery.

The geospatial component and biophysical functions, features and attributes of the Coastrange Sculpin (Cultus Population) critical habitat were derived from published research. Through a technical workshop that took place in February 2011, inputs from experts from the University of British Columbia (UBC), Fisheries and Oceans Canada (DFO - Cultus Lake Salmon Research Laboratory, Pacific Biological Station, and Pacific Region headquarters), Environment Canada, British Columbia Parks and the British Columbia Ministry of Natural Resource Operations (MNRO) were incorporated as foundation to this critical habitat identification effort.

CRITICAL HABITAT: GEOSPATIAL FEATURES

The distribution of the Coastrange Sculpin (Cultus Population) is restricted to Cultus Lake in southwestern British Columbia. Located approximately 10 km south of the City of Chilliwack, in the eastern Fraser Valley, Cultus Lake is a small lake with a surface area of 6.3 km^2. The lake has a littoral zone area of approximately 0.9 km^2, a mean depth of 31 m, and a maximum depth of 44 m (Shortreed, 2007). Frosst Creek, located at the southwest end of Cultus Lake, is the largest tributary, although numerous other ephemeral and permanent streams contribute to lake inflows. Sweltzer Creek, located at the northern end of Cultus Lake, is the only outlet. It flows approximately 3 km before joining the Chilliwack River, a tributary of the lower Fraser River. The residence time of Cultus Lake is relatively short, averaging 1.8 years. The depth of the thermocline in Cultus Lake averages approximately 16m during the thermal stratification period, typically from late April, early May to late November (Shortreed, 2007).

The majority of Coastrange Sculpin (Cultus Population) sampled in the Woodruff (2010) study were captured on or within 10 m of the lake bottom. Mid-water trawls (targeting Cultus Sockeye Salmon) in Cultus Lake have incidentally captured some juveniles of the species at depths as shallow as 4m (Pon, L. and Hume, J. *unpul data*.). The overall distribution pattern of Coastrange Sculpin (Cultus Population) is consistent with the distribution information from an analogous planktivorous pelagic coast-range sculpin population in Lake Washington (Ikusemiju, 1975). Namely the vertical species range aligns with deeper waters near thermocline and the highest concentration of zooplanktons.

Riparian zones have in the past been identified as part of a critical habitat for SARA listed aquatic species. Richardson et al. (2010) offered perspectives on the typical identification of riparian zones as part of SARA critical habitat. Specifically, riparian zones provide functions that include shading for temperature-sensitive species, control of channel complexity and sediment inputs through bank stabilization, input of large wood and allochthonous energy sources, and filtering of nutrients and toxins from adjacent land. As such, there is a de facto consensus that riparian buffers are essential for aquatic system heath and maintenance of aquatic and other species. However, based on current life history information, it is highly unlikely that reasonable rationale exists to consider riparian zones surrounding Cultus Lake for the critical habitat of Coastrange Sculpin (Cultus Population).

The known geographic range of Coastrange Sculpin (Cultus Population) does not exceed the wetted boundaries of Cultus Lake. For the past 30 years, DFO has conducted acoustic and mid-water trawl surveys in vast number of B.C. lakes containing anadromous Sockeye Salmon. The majority of the lakes contain no Sculpins, and for those lakes that do, the by-catches have been generally identified to be too large to be pygmy forms of Coastrange Sculpin (J. Hume, affilation & Location, pers. obs.,2011, COSEWIC 2010). The geospatial extent of this species' critical habitat, as the result, may be smaller, but likely not larger, than the Cultus Lake. It is reasonable to infer that Cultus Lake supports all essential life functions of the species. Therefore, the recovery goal of long term population viability can be met by the preservation of aquatic habitat in Cultus Lake. The geospatial extent of the critical habitat for Coastrange Sculpin (Cultus Population) is identified as the entirety of Cultus Lake up to its wetted boundary (Figure 6).

CRITICAL HABITAT: BIOPHYSICAL FUNCTIONS, FEATURES, AND ATTRIBUTES

As indicated previously, the concept of habitat function and the associated features and attributes form integral components of critical habitat identification process. It is reasonable to assume that Cultus Lake has historically provided all essential functions for the Coastrange Sculpin (Cultus Population) to evolve and thrive. The following table has the recommended critical habitat function, features and attributes for Coastrange Sculpin (Cultus Population).

Table 1 Biophysical Functions, Features, and Attributes of critical habitat for the Coastrange Sculpin (Cultus Population)

Function	Feature(s)	Attribute(s)
Spawning	Benthic environment (inferred)	Benthic substrate size – Coarse substrates such as cobble or gravel. Oxic benthic condition
Rearing	Benthic environment (inferred)	Benthic substrate size – Coarse substrates such as cobble or gravel. Oxic benthic condition
	Water column (inferred)	Lake water quality that maintains the structural and functional lake ecosystem characteristics necessary for the persistence of Coastrange Sculpin (Cultus Population). Maintenance of water clarity sufficient to retain the deep euphotic zone of Cultus Lake.
Feeding	Water column (observed)	Lake water quality that maintains the structural and functional lake ecosystem characteristics necessary for the persistence of Coastrange Sculpin (Cultus Population). Maintenance of water clarity sufficient to retain the deep euphotic zone of Cultus Lake.
Predator Refuge	Water column (inferred)	Unknown but water clarity may play an important role.

CRITICAL HABITAT FEATURE – BENTHIC ENVIRONMENT

Similar to all sculpins, the Coastrange Sculpin (Cultus Population) does not possess a swim bladder, and is thus negatively buoyant (Scott and Crossman, 1973; McPhail, 2007). The benthic environment of Cultus Lake is the primary habitat for the Coastrange Sculpin (Cultus Population) and supports life functions such as spawning, rearing and to a lesser extent feeding (Ricker 1960; Woodruff, 2010). The associated critical habitat attributes are the benthic substrate composition and the oxygen levels.

The exact type of substrate preference, as benthic habitat attribute, is unknown. Based on several lines of evidence, it can be reasonably inferred that Coastrange Sculpin (Cultus

Population) likely favour coarse substrates for spawning and rearing purposes. Stream-based Coastrange Sculpin tend to spawn on gravel substrate within riffles, and are often found on coarse gravel and cobble substrates (Ricker 1960; McPhail 2007; Tabor et al., 2007). The lacustrine Bear Lake Sculpin (*C. extensus*) use rocky, cobble or boulder substrate (Ruzycki et al., 1998). Both juvenile and adult Coastrange Sculpin (Cultus Population) have been captured in association with coarse benthic substrates during the breeding season from mid-May to late October (Woodruff, 2010).

No specific information exists on the oxygen requirements of *Cottid* species, but they are usually found in habitat with higher dissolved oxygen concentrations. Coastrange Sculpins (non Cultus populations) inhabit fast waters, especially riffles and glides (McPhail 2007), which tend to have higher oxygen content than stagnant pools. The British Columbia water quality guideline sets the minimum instantaneous oxygen level in the water column at 5 mg/L. This value takes consideration of the various natural aquatic ecosystems and their oxic states, as well as oxygen tolerance levels from species found in those systems (BC Ministry of Environment 1997. In the absence of specific data for the Coastrange Sculpin (Cultus Population), it is likely that 5 mg/L value is indicative to the minimum oxygen requirement for the species. More importantly, the optimum oxygen level for the species is likely to be higher.

CRITICAL HABITAT FEATURE – WATER COLUMN

The water column of Cultus Lake is recommended as a critical habitat feature for the Coastrange Sculpin (Cultus Population). It likely provides rearing, feeding and predator refuge functions for this species. The associated critical habitat attributes are identified as following:

- Lake water quality that maintains the structural and functional lake ecosystem characteristics necessary for the persistence of Coastrange Sculpin (Cultus Population)
- Maintenance of water clarity sufficient to retain the deep euphotic zone of Cultus Lake

Cultus Lake is a relatively productive lake system (oligo-mesotrophic) that has high *Daphnia* abundances (Shortreed 2007). The abundance of *Daphnia* prey items is also attributed as a possible factor for the behavioural difference of Coastrange Sculpin (Cultus Population).

In the context of prey supply, the water quality of the Cultus Lake ecosystem becomes integral in supporting a healthy population of Coastrange Sculpin (Cultus Population). Although the exact ranges of water chemistry parameters are not known, one can reasonably assume that the average levels, as reported by Shortreed (2007), provide a good present-day baseline. Examples include:

- dissolved oxygen (DO; 9.9 mg DO/L (surface avg.); 8.9 mg DO/L (hypolimnion)),
- secchi depth (9.2 – 10.6m),
- euphotic zone depth (average 15.8m),
- total dissolved solids (TDS; 101 - 106 mg/L), and
- nitrates (39-45 µg N/L May-October growing season average for euphotic zone).

These values should not be interpreted as critical thresholds and deviations from them would not necessarily indicate a threat to the Coastrange Sculpin (Cultus Population). However, deviations may indicate a deterioration of the lake environment as well as the critical habitat quality.

Shortreed (2007) compared lake water chemistry with historical data and presented convincing evidence that increases in lake nutrient levels from anthropogenic sources have likely contributed to the higher productivity levels. The anthropogenic sources of nutrient input into the lake include septic tank run-off and agricultural activities. As the history of Lake Washington has shown, however, increasing amounts of anthropogenic nutrients can result in eutrophication and a phytoplankton community dominated by inedible cyanobacteria (Edmondson 1994; Arhonditsis et al. 2003). This increase in productivity causes a decrease in water quality (Arhonditsis et al. 2003) and a decline in fish diversity (Lopez-Rojas and Bonilla-Rivero 2000). A similar process in Cultus Lake could very likely threaten the persistence of Coastrange Sculpin (Cultus Population). A meaningful exercise should be to establish lake water quality objectives, in consideration of historical and current lake water quality, surrounding land use practices and conservation needs of Coastrange Sculpin (Cultus Population).

Cultus Lake has relatively clear water, with average secchi depths ranging from 9.2-10.6 m and an average euphotic zone of 15.8m (Shortreed, 2007). If Coastrange Sculpin (Cultus Population) is indeed dependent on visual cues to forage, then water clarity is likely an important habitat attribute in that it allows the Coastrange Sculpin (Cultus Population) to visually find their preferred prey items *Daphnia* (E. Taylor, University of British Columbia, pers. comm., 2011). Furthermore, there is a strong positive association between water clarity and *Daphnia* abundance (Edmondson and Litt 1982). The depth of the euphotic zone is also important as it permits sunlight to provide energy for primary production at depth; the primary production in turn attracts zooplankton grazers, which are available to fish as prey in the deeper, cooler waters of the lake (Shortreed, 2007). This is especially important to Coastrange Sculpin (Cultus Population) as they tend to be distributed in deeper waters.

The water column of Cultus Lake may also serve as a predator refuge for the Coastrange Sculpin (Cultus Population). Similar to other populations of the Coastrange Sculpin (*Cottus aleuticus*), the Coastrange Sculpin (Cultus Population) is known to spend the first month of its life in the water column of the lake, feeding on plankton (McPhail 2007). Prickly Sculpin also inhabits the benthic habitat of the lake (Shortreed, 2007; Woodruff, 2010) and has been observed to prey upon Coastrange Sculpin (Cultus Population) individuals. Woodruff's (2010) behavioural study showed that Coastrange Sculpin (Cultus Population) individuals remained in the water column in the presence of Prickly Sculpin, in spite of their negative buoyancy (Scott and Crossman, 1973; McPhail, 2007). This interspecific interaction may have caused Coastrange Sculpin (Cultus Population) to use the water column as a predator refuge, but no specific data is available to indicate exact water column attributes that contribute to the predator refuge function.

In summary, the water column is a critical habitat feature of Coastrange Sculpin (Cultus Population) that supports feeding and rearing life functions. Excellent baseline lake water quality and productivity levels are needed to support a high abundance and year-round availability of prey items such as *Daphnia*. High water clarity should also exist to allow the deep penetration of light (euphotic zone), maintaining primary production in the cooler, deeper waters of the hypolimnion and allowing for efficient feeding of Coastrange Sculpin (Cultus Population). The overall lake productivity (largely dictated by nutrient levels), however, exists in a delicate balance and lake eutrophication remains a major concern (COSEWIC 2003). Furthermore, the water column may also support the function of predator refuge for Coastrange Sculpin (Cultus Population).

FUTURE STUDIES

Although a recommendation of critical habitat has been made to the extent possible based on best available information, further studies are suggested here to fill identified knowledge gaps.

Table 2. Future studies for Coastrange Sculpin (Cultus Population) to address identified knowledge gaps.

Research Activity	Rationale	Priority
Conduct studies on Coastrange Sculpin (Cultus Population) life history and its associated habitat use in Cultus Lake, as well as accurate abundance information.	Current knowledge of Coastrange Sculpin (Cultus Population) life history such as migrations, water column use for predator refuge and changes in habitat usage with age is limited. Refinement of life history of Coastrange Sculpin (Cultus Population) will help to refine the identification of critical habitat. As well, accurate abundance information is essential since existing data is unreliable.	High
Periodic monitoring of Cultus Lake limnology	Periodic monitoring of the Cultus Lake in terms of its limnology will provide essential information on the trend of critical habitat quality. Elements of the monitoring program should include water chemical and physical parameters and plankton abundance and distribution, in both pelagic and benthic environment.	Medium
Establish feeding behaviour and diet of Coastrange Sculpin (Cultus Population)	Feeding behaviour and diet of Coastrange Sculpin (Cultus Population) should be established to further explore possible utilization of the water column in the lake pelagic environment.	Low

EXAMPLES OF ACTIVITIES LIKELY TO RESULT IN THE DESTRUCTION OF CRITICAL HABITAT (ALTD CH)

Table 3. Examples of activities likely to result in the destruction of the critical habitat of the Coastrange Sculpin (Cultus Population).

Activity	Effect Pathway	Function Affected	Feature(s) Affected	Attribute Affected
Excessive nutrient inputs from septic seepage, agricultural run-off, golf courses, lawn fertilization, etc.	Eutrophication causing algal blooms in the lake lead to reduced light penetration, water clarity, oxygen depletion, change in water chemistry and increased sedimentation rates; altered food web structure for Coastrange Sculpin (Cultus Population), and possibly shallowing of the euphotic zone	Spawning Rearing Feeding	Water Column Benthic Substrate	Lake water quality Depth of euphotic zone and water clarity Coarseness of benthic substrate

Activity	Effect Pathway	Function Affected	Feature(s) Affected	Attribute Affected
Excessive application of fertilizers in agricultural and private lands	Eutrophication causing algal blooms in the lake lead to reduced light penetration, water clarity, oxygen depletion, change in water chemistry and increased sedimentation rates; altered food web structure for Coastrange Sculpin (Cultus Population), and possibly shallowing of the euphotic zone	Spawning Rearing Feeding	Water Column Benthic Substrate	Lake water quality Depth of euphotic zone and water clarity Coarseness of benthic substrate
Deliberate or accidental transport and release of invasive species into Cultus Lake	The deliberate or accidental transport and release of invasive species may lead to dramatic change in the lake nutrient regime that result in reduced light penetration, water clarity, oxygen depletion, and increased sedimentation rates.	Spawning Rearing Feeding	Water Column Benthic Substrate	Lake water quality Depth of euphotic zone and water clarity Coarseness of benthic substrate

ACKNOLWEDGEMENT

I would like to thank Sean MacConnachie (DFO, Pacific Biological Station) for the invaluable inputs and comments, as well as the support and inputs from Martin Nantel (DFO).

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FIGURES

Figure 1. Coastrange Sculpin (Cultus Population). (Photo Credit: Sylvia Letay, BC Natural Resources Management and Operations)

Figure 2. Coastrange Sculpin (Cultus Population) in comparison with common Coastrange Sculpin (top). (Photo Credit: Patricia Woodruff, UBC)

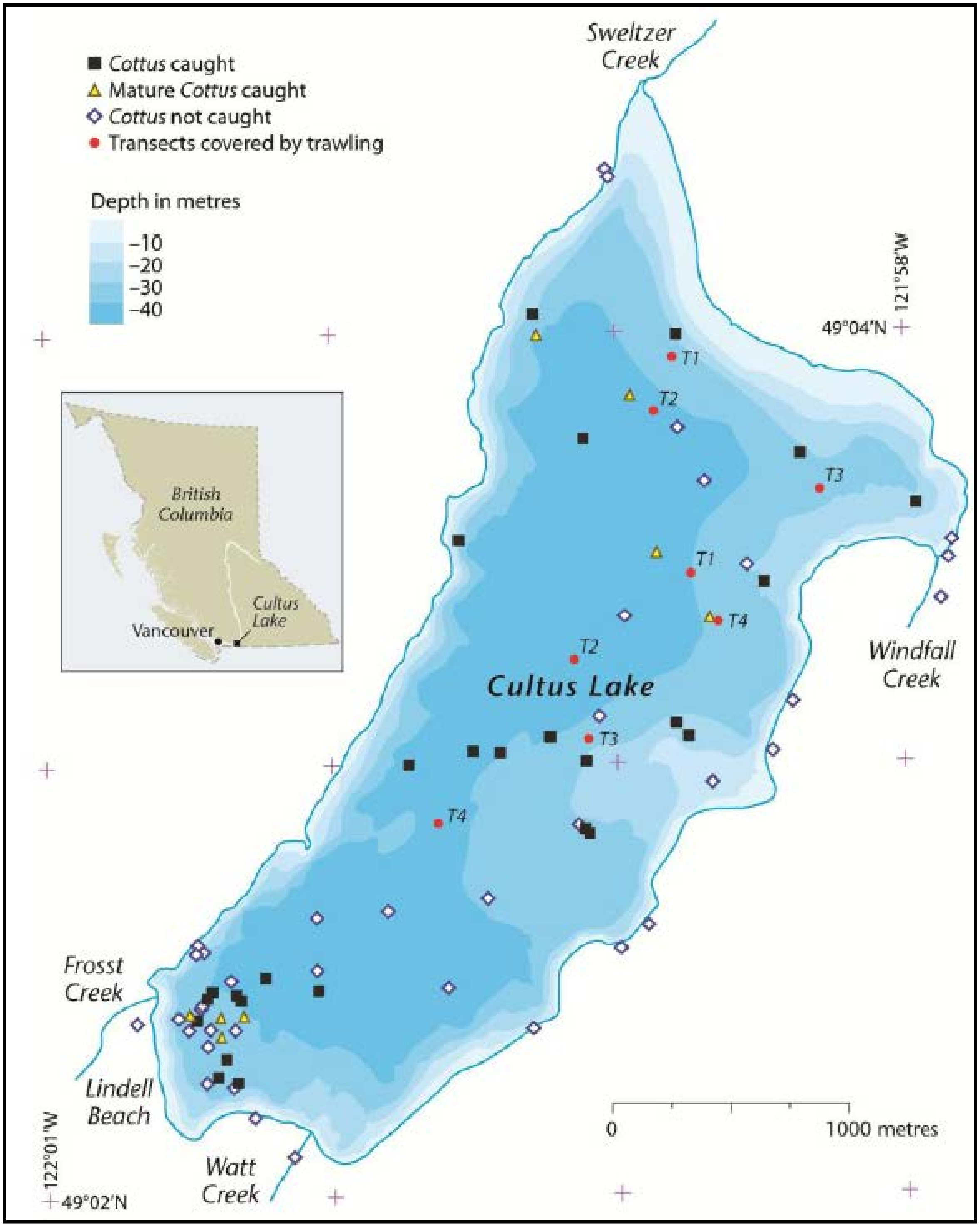

Figure 3. Capture locations of Cultus Pygmy Sculpin (from Woodruff 2010)

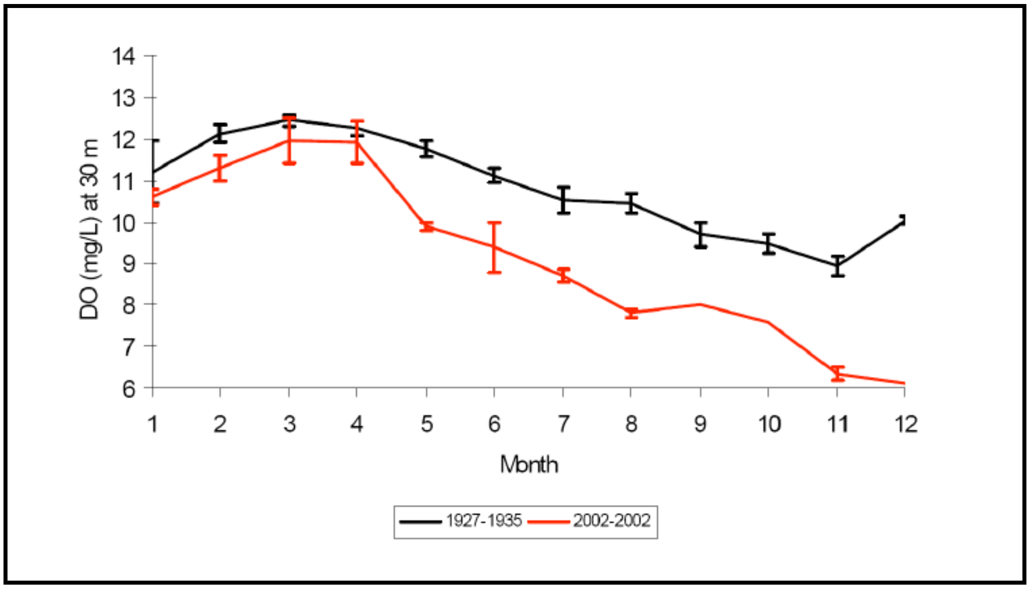

Figure 4. Comparison of monthly mean deepwater (hypolimnetic, 20m) dissolved oxygen (DO) concentration in Cultus Lake, BC between 1927-1935 and 2002. Modified from Shortreed (2007).

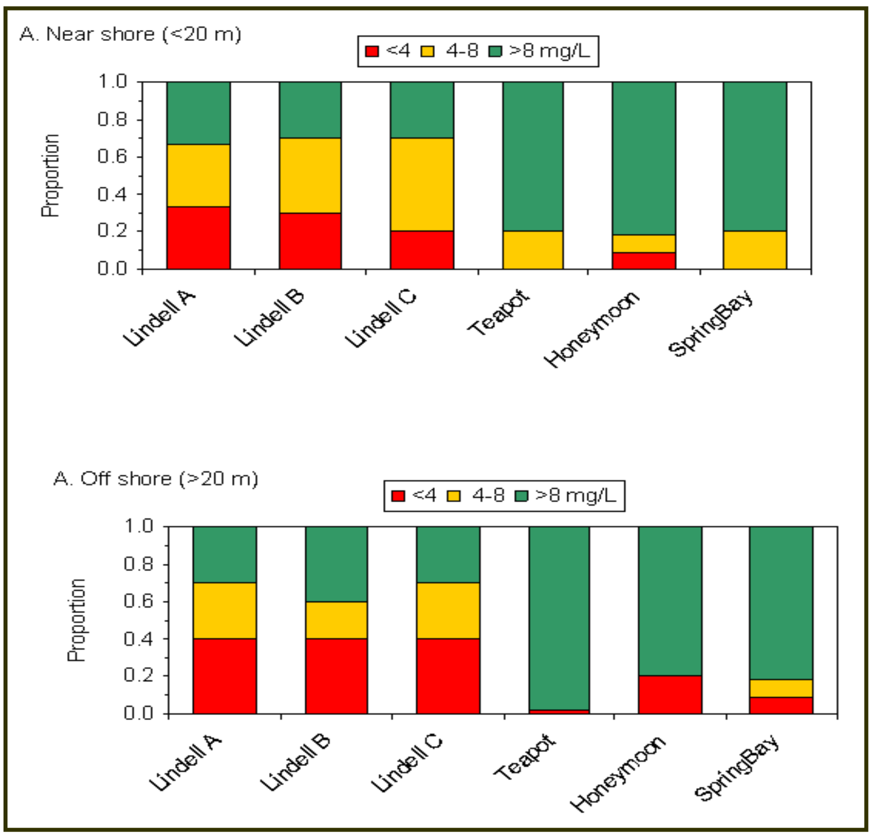

Figure 5. Dissolved oxygen level at various sites in Cultus Lake. Sites in Lindell Beach area consistently have higher incidents of anoxic conditions (<4 mg/L) (Hume, J. 2005. unpubl data.)

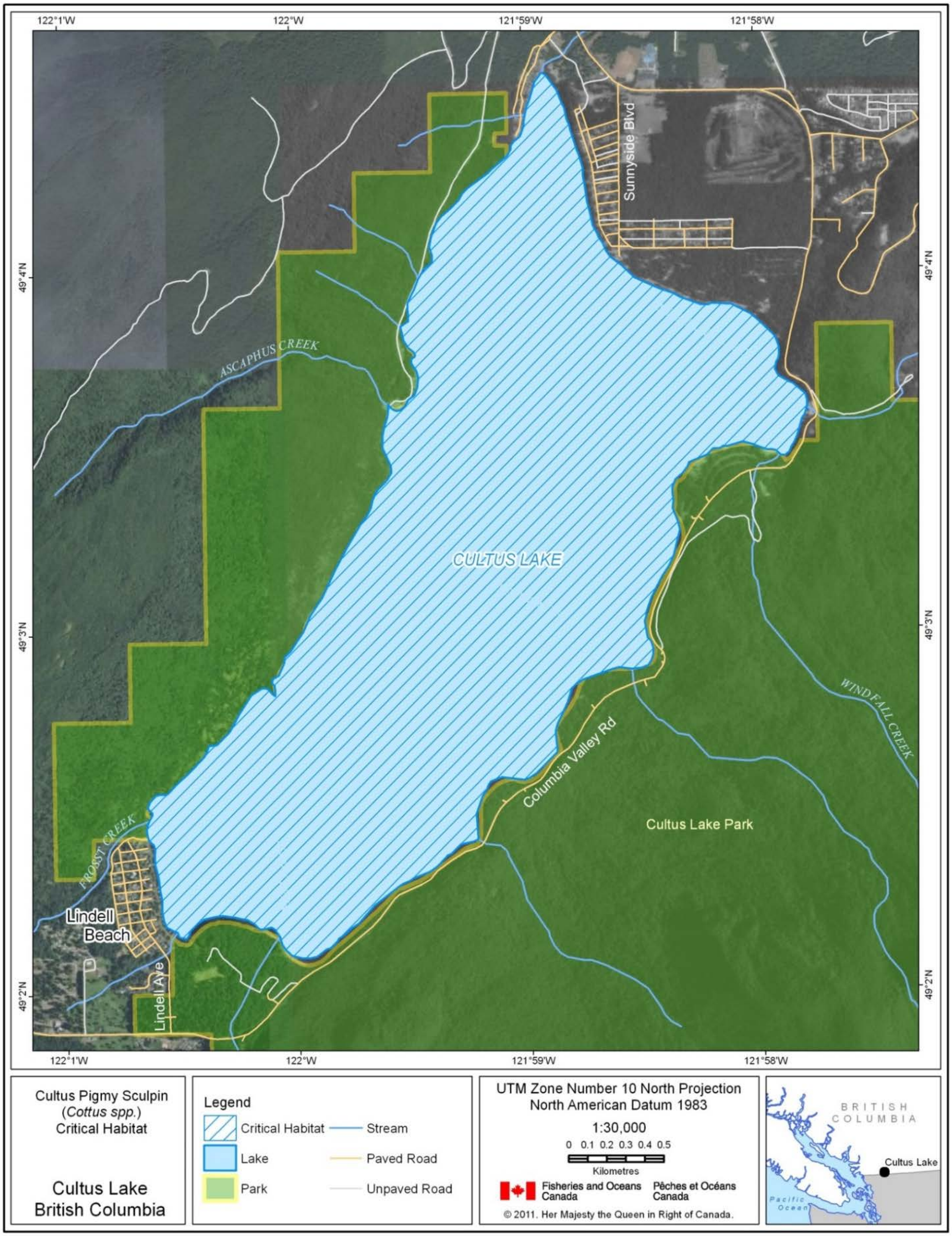

Figure 6. Geospatial extent of recommended for Coastrange Sculpin (Cultus Population) critical habitat.