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NICOLA LAKE EURASIAN WATERMILFOIL MANAGEMENT PLANNING

FISHERIES UTILIZATION ASSESSMENT

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Documents may undergo several Peer, Senior, Document, and/or Client Reviews before the final document is produced. A Document Review should be the final review in most cases where changes have been made to the text. Versions are numbered by v.1, v.2, etc. with the version number changing for each stage of the reporting process (e.g., Draft v.1, Client Review or Draft v.2, Final v.3)

Executive Summary

The Nicola Lake Working Group (NLWG) presented the draft Nicola Lake Action Plan (NLAP) to the public in June 2013. The Nicola Lake Steering Committee (NLSC) will be responsible for implementing the NLAP and guiding the Nicola Lake planning process. One of the key goals of the Plan is to control invasive species in Nicola Lake, and the corresponding objective is to develop and implement a Eurasian watermilfoil (EWM) management plan for Nicola Lake.

A EWM inventory of Nicola Lake completed in the summer of 2013 found that EWM was established in almost all areas suitable for macrophytes, and it was the dominant, or subdominant species in 77% of sites assessed. Given the prevalence and distribution of EWM in Nicola Lake, a management regime is required to control the spread of EWM, both within Nicola Lake and to other water bodies, and to limit potential negative effects of the EWM infestation to the ecological and recreational aspects of Nicola Lake.

To mitigate potential negative effects of EWM control on fish and fish habitat, an assessment of fish utilization in littoral areas identified as high use or value in the Nicola Lake Action Plan, and that have EWM as dominant macrophyte, was conducted in 2014. Results and recommendations from this assessment will be incorporated into the EWM management plan for Nicola Lake, and enable the NLSC to proceed with the implementation of a EWM control program.

Nicola Lake is located in the Thompson region of BC, approximately 10 km northeast of the City of Merritt. Nicola Lake is approximately 22 km long and has a surface area of approximately 2,500 ha. The lake supports a variety of resident and anadromous salmonids including Bull Trout, Cutthroat Trout, Kokanee and Rainbow Trout, Chinook, Coho, and Pink Salmon, and Steelhead Trout. Other sport fish known to occur in the lake include Burbot and Mountain Whitefish. These fish species contribute to valuable First Nations and recreational sport fisheries, and support the local economy. Nicola Lake is an important natural resource for ecological, social/cultural, aesthetic, and economic reasons.

Prior to selecting sites and undertaking field surveys, a thorough information review was completed that both summarized, and built on existing background reviews. Nine survey sites were selected from around the littoral zone of Nicola Lake. Survey sites were selected based on factors including areas of concern to the public, percentage of EWM cover, high use areas, known First Nations values and areas with potential to act as EWM source populations.

Not native to North America, EWM is a rooted, submersed aquatic plant characterized by rapid, dense growth. EWM may grow in water up to 6 m deep, although the optimal range is 0.5-3.0 m. The plant may grow up to 5 cm/day and upon reaching the water surface, often forms dense masses of vegetation. These EWM beds often dominate the macrophyte community to the detriment of native plant diversity, fish and wildlife habitat, water quality, flood control, recreation, and aesthetics. The plant primarily spreads through the production of numerous stem fragments, particularly in the early and late summer (autofragmentation). High water temperatures and nutrient levels in Nicola Lake create ideal conditions for EWM, and because EWM spreads by fragmentation, natural disturbances (wind events) or human activities like

boating, fishing and swimming will also fragment plants and facilitate the introduction/spread into other aquatic systems in the region.

Management (control) options for EWM generally depend on the scale of the infestation and the management objectives. Control methods vary widely (by hand using divers, mechanical harvesting and rototilling, biological and chemical) but can be placed into two main categories: 1. "Intensive" (i.e. selective and effective methods, which work best on smaller scale infestations); and 2. "Extensive" (i.e. non-selective (and often less effective) methods, which are more appropriate for large scale infestations).

In addition to fisheries and shellfish (freshwater bivalves) that this assessment focusses on, there are potential impacts from EWM control activities on other species and their habitats (including some at risk) to consider when development a EWM management plan. Aquatic vegetation removal is considered a very high risk activity and many of these species have timing windows and best management practices.

Although EWM and salmonids usually occupy distinctly separate habitats, salmonid species are known to utilize littoral areas. Fish may utilize the littoral zone of lakes in some or all life history stages for various activities, including foraging, reproduction, and refuge from predators. Potential use of the littoral zone varies by species and life history stage. Coho, Chinook and Steelhead juveniles have low to moderate potential; Rainbow and Kokanee juveniles, and Burbot (and potentially Kokanee) spawners have moderate potential; and Burbot larvae/juveniles have moderate to high potential for littoral use.

Field investigations were conducted in May and July 2014, and consisted of fish (electrofishing) and mussel (snorkel) surveys. Electrofishing and snorkel surveys of shoreline/littoral habitat were approximately 100 m long and 50 m long respectively. Temperature loggers were deployed at three sites to monitor change in water temperature near macrophyte beds through the growing season.

During the May electrofishing, a total of 63 fish comprising four species were captured from the nine survey sites. The majority of the fish captured were Large Scale Suckers (76% of the total catch) with Rainbow Trout (11%), Northern Pikeminnow (11%), and Redside Shiners (2%) making up the remaining catch. The average May catch-per-unit-effort (CPUE) was 0.025 fish/sec. During the July electrofishing, a total of 48 fish comprising six species Large Scale Suckers again made up the majority of the catch (48%) with Redside shiner (27%) Northern Pikeminnow (13%), Peamouth Chub (10%) and Mountain Whitefish (2%) making up the remaining catch. The average July CPUE was 0.017 fish/sec.

No live mussels were observed during either May or July snorkel surveys; however, three intact (i.e. both valves attached and relatively undamaged) floater (*Anodonta sp*.) shells were observed. *Anodonta sp.* are difficult to distinguish, but the shells were likely Oregon Floater (*A. oregonensis)*, or Western Floater (*A. kennerlyi).* A total of 24 shell fragments were also observed; an average of 2.7 shell fragments per site. Sculpins and Large scale suckers were commonly observed during May and July snorkel surveys. Redside Shiners were prevalent amongst the macrophyte beds during the July survey.

Fish species of "concern" for Nicola Lake, with potential (low to moderate) for temporal use of the littoral zone according the literature (CO, CH, KO, RB/ST and BB) were for the most part, not observed. The exception was a few Rainbow Trout juveniles captured at three sites during May sampling. High water temperatures impact fish populations (especially cold water species such as salmonids) in Nicola Lake. Average temperatures in Nicola Lake exceed preferred temperature ranges for rearing, migrating and spawning fish from July to September.

In general, fish habitat at the survey sites was considered poor to fair given the level of shoreline development (agricultural, transportation and urban land uses) and the limited amount of habitat complexity and cover observed. Substrate and depth characteristics at all sites were within the ranges of known preferred mussel habitat. Based on the results of this assessment (both the literature review and the field surveys), the use of salmonids during potential "high-risk" EWM control treatment periods (i.e. winter rototilling and/or summer harvesting) is unlikely, and the presence of mussels is also unlikely. The data from this assessment appears to indicate that fish species of concern and freshwater mussels are unlikely to be an issue in Nicola Lake and would not preclude EWM control options (provided the necessary mitigative measures are in place). These findings are in agreement with current EWM control programs on other lakes in BC with similar fish species assemblages.

Recommendations to assist with developing and implementing a EWM control program for Nicola Lake include:

- Implement diver control (hand pulling and/or cutting). It is a slow, but low risk, low impact and relatively low cost option.
- Pursue partnerships and/or coordinate with the Okanagan Basin Water Board, Columbia Shuswap Regional District and the Regional District of the Kootenay Boundary, to benefit from their EWM control knowledge and expertise.
- Identify Burbot (and Kokanee) spawning and rearing habitat, and time periods. Incorporate this information into the EWM management plan.

This report is rendered solely for the use of the NLSC in connection with Fisheries Utilization Assessment for Nicola Lake, and no person may rely on it for any other purpose without Triton Environmental Consultants Ltd.'s prior written approval. Should a third party use this report without Triton's approval, they may not rely upon it. Triton accepts no responsibility for loss or damages suffered by any third party as a result of decisions made or actions taken based on this report.

- The objective of this report is to address the following scope requirements: to assess fish utilization within the littoral areas identified as high use or value in the Nicola Lake Action Plan. The results and recommendations will be incorporated into the EWM management plan for Nicola Lake and enable the Nicola Lake Steering Committee to proceed with the implementation of a EWM control program.
- This report is based on facts and opinions contained within the referenced documents. We have attempted to identify and consider relevant facts and documents pertaining to the scope of work, as of the time period during which we conducted this analysis. However, our opinions may change if new information is available or if information we have relied on is altered.
- We applied accepted professional practices and standards in developing and interpreting data obtained by our field measurement, sampling and observation. While we used accepted professional practices in interpreting data provided third party sources we did not verify the accuracy of data provided third party sources.
- This report should be considered as a whole and selecting only portions of the report for reliance may create a misleading view of our opinions.

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1.0 Introduction

The Fraser Basin Council (FBC), on behalf of the Nicola Lake Steering Committee (NLSC), commissioned Triton Environmental Consultants Ltd. (Triton) in February of 2014 to conduct a fisheries utilization assessment in the littoral zone of Nicola lake, for use in Eurasian watermilfoil (EWM) (*Myriophyllum spicatum*) management planning.

1.1 Background and Scope

The Nicola Lake Working Group was established in November 2012. The NLWG is inclusive of all orders of government (federal, provincial, local and first nations), interests, rights, and property owners around the lake, and works by consensus. The purpose of the Group was to utilize public input to develop a draft Nicola Lake Action Plan (FBC, 2013). The NLWG met nine times between November 2012 and May 2013, and the draft Nicola Lake Action Plan was presented at a public meeting on June 8, 2013. During this meeting, the NLWG was dissolved, and a Terms of Reference for a new Nicola Lake Steering Committee (NLSC) was approved. The NLSC will be responsible for guiding the Nicola Lake planning process and implementing the action items in the Plan.

One of the Plan goals is to control invasive species in Nicola Lake, and the corresponding objective is to develop and implement a EWM management plan for Nicola Lake. High use areas and areas of public concern have been identified as a priority for EWM control; these areas include boat launches, residential developments, and recreational areas such as Monck Provincial Park and the Kamloops Sailing Association.

A EWM inventory of Nicola Lake was completed in the summer of 2013 by Golder Associates Ltd. (2013). Eurasian watermilfoil has established in almost all areas suitable for macrophyte establishment in Nicola Lake, and was categorized as the dominant or subdominant species in 77% of sites assessed (54 of 70 sites).

Given the prevalence and distribution of EWM in the lake, a management regime is required in order to control the spread of EWM, both within Nicola Lake and to other water bodies, and to limit potential negative effects of EWM invasion to the ecological and recreational aspects of Nicola Lake. In order to mitigate potential negative effects of EWM management on fish and fish habitat, an assessment of fish use within EWM dominant macrophyte beds is necessary.

1.1.1 Scope of Fisheries Utilization Assessment

This study will assess fish utilization within the littoral areas identified as high use or value in the Nicola Lake Action Plan and that have EWM at greater than 21% as identified in the report: Characterization of Macrophytes and Evaluation of the Prevalence of EWM (*Myriophyllum spicatum* L.; Golder, 2013).

This fisheries utilization assessment report (the results and recommendations) will be incorporated into the EWM management plan for Nicola Lake, and enable the NLSC to proceed with the implementation of a EWM control program.

1.2 Description of Project Area

Nicola Lake is located in the Thompson region of BC, approximately 10 km northeast of the City of Merritt. The majority of the lake shoreline occurs within the Very Dry Warm Bunchgrass biogeoclimatic zone (BGww2). The area is dominated by open grasslands with low shrubs, sagebrush, and ponderosa pine and interior Douglas-fir trees. Black cottonwood occur along floodplains and other wetted habitats with a narrow fringe of riparian shrubs (Patterson and Schleppe 2012). The climate is generally hot and dry in the summer and cold and dry in the winter and there is very little precipitation. The Nicola Valley is narrow and mountainous creating high winds (FBC, 2013).

Nicola Lake is approximately 22 km long, has a surface area of approximately 2,500 ha with a maximum depth of 55 m and an average depth of 24 m (FISS, 2014). Land use around the lakeshore consists of agricultural, transportation and urban development, and consists of ranching and logging in the higher elevations.

1.2.1 Nicola Lake Fisheries Resources

Nicola Lake supports a variety of resident sport fish species, including Kokanee, Rainbow Trout, Bull Trout, and Cutthroat Trout. Anadromous (i.e. sea-run) salmonids such as Coho, Chinook, Pink Salmon, and Steelhead Trout also occur in the lake. Other sport fish known to occur in the lake include Burbot and Mountain Whitefish (Fisheries Information Data Queries [FIDQ] 2014). The majority of sport fish caught by anglers in Nicola Lake are Rainbow Trout and Kokanee, and ice fishing for Burbot is common in the winter.

These fish species contribute to valuable First Nations and recreational sport fisheries, and support a considerable local ecotourism industry. Nicola Lake is an important natural resource for ecological, social/cultural, aesthetic, and economic reasons. A complete list of fish species observed in Nicola Lake is presented in Table 1.

Table 1. Fish species observed in Nicola Lake

English Name	*Scientific Name*	*Species Code*
Bull Trout	*Salvelinus confluentus*	BT
Burbot	*Lota lota*	BB
Carp	*Cyprinus carpio*	CP
Chinook Salmon	*Oncorhynchus tshawytscha*	CH
Coho Salmon	*Oncorhynchus kisutch*	CO
Cutthroat Trout	*Oncoryhnchus clarki*	CT
Dace (General)	*Rhinichthys sp.*	DC
Kokanee	*Oncorhynchus nerka*	KO
Lake Chub	*Couesius plumbus*	LKC
Longnose Sucker	*Catostomus catostomus*	LSU
Mountain Whitefish	*Prosopium williamsonii*	MW
Peamouth Chub	*Mylocheilus caurinus*	PCC
Pink Salmon	*Oncorhynchus gorbuscha*	PK
Rainbow Trout	*Oncorhynchus mykiss*	RB
Redside Shiner	*Richardsonius balteatus*	RSC
Sculpin (General)	*Cottus sp.*	CC
Steelhead	*Oncorhynchus mykiss*	ST
Sucker (General)	*Catostomus sp.*	SU

(Source: FIDQ 2014)

Of the above species, Bull Trout and Coho Salmon are considered "species at risk[1]". Bull Trout are listed as "Blue" provincially (MOE, 2014a), and "special concern" by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2014). Coho Salmon (Interior Fraser Population) are listed as "Yellow" provincially, and "Endangered" under COSEWIC.

1.2.1.1 Shellfish (Freshwater Bivalves)

The freshwater bivalve (clam and mussel) species found in interior BC with the potential to occur in Nicola Lake include native clams (Family Sphaeriidae), and the following mussel species: Winged Floater (*Anodonta nuttalliana*), Oregon Floater (*Anodonta* oregonensis), Western Floater (*Anodonta kennerlyi*), Western Pearlshell (*Margaritifera falcata*), and Rocky Mountain Ridged Mussel (*Gonidea angulata*) (Lindsay, 2003; L. Nield, 2014. pers. comm. 11 June). Of the above mentioned species, only the RocRidged Mussel is considered at risk - Provincially designated as "Red", and Federally as "Special Concern" (Species at Risk Act [SARA]) and "Endangered" (COSEWIC) (COSEWIC, 2014) and MOE (2014). Ridged Mussels have only been found only in the Columbia River System (Okanagan and Kootenay Rivers) of BC, but may also be present in other similar areas in southern BC (DFO, 2014).

[1] Provincial – "Yellow": not at risk; "Blue": special concern (vulnerable); "Red": extirpated, endangered or threatened. COSEWIC/SARA – "Special Concern": may become a threatened or an endangered species because of a combination of biological characteristics and identified threats. "Threatened": likely to become endangered if limiting factors are not reversed. "Endangered": facing imminent extirpation or extinction (MOE, 2014a).

2.0 Methods

2.1 Information/Literature Review

Prior to selecting survey sites and undertaking field surveys, a thorough information review was completed that both summarized, and built on existing background reviews. The review focussed on the sources outlined in the Request for Proposals, as well as on scientific journal articles, papers and reports on milfoil ecology and management, littoral fish habitat and utilization by fish and freshwater bivalves. Examples of information sources reviewed include:

- The Nicola Lake Action Plan and mapped areas of concern for EWM control (Nicola Lake Working Group 2013);
- Investigations of EWM control programs elsewhere in BC (Okanagan, Shuswap, Christina Lake[2]), including literature review and interviews/discussions (e.g. Okanagan Basin Water Board, Ministry of Forests, Lands and Natural Resource Operations staff);
- Foreshore Inventory and Mapping for Nicola Lake (Patterson and Schleppe, 2012);
- Characterization of Macrophytes and Evaluation of the Prevalence of Eurasian Watermilfoil (*Myriophyllum spicatum* L.) (Golder, 2013);
- First Nations values and traditional ecological knowledge (Traditional Ecological Knowledge pertaining to Nicola Lake was obtained from the Nicola Tribal Association; T. Geraldine, 2014, pers. comm., 8 April);
- Other reports, including those listed in the Ecological Reports Catalogue (MOE, 2014b); and,
- Provincial and Federal websites (best management practices for aquatic vegetation management, standards for fish habitat inventory, potential listed (at risk) aquatic species).

As part of the pre-field preparations, a fish collection permit (under the *Wildlife Act*) was obtained from the Permit and Authorization Services Bureau of the Ministry of Forests, Lands and Natural Resource Operations (Permit No. KA/14-93659). A scientific license was obtained (under Section 52 of the Fishery [General] Regulations) from Fisheries and Oceans Canada (License No. XHAB 18 2014).

[2] Christina Lake has many characteristics in common with Nicola Lake. They are approximately the same size, length and average depth (2,500 ha, 20 km and 30 m); both have high summer water temperatures, high levels of nutrients and high amounts of recreation activity.

2.1.1 Site Selection Process

Selection of survey sites was on based on several considerations (in particular the results of the information/literature review). Nine survey sites were selected from around the littoral zone of Nicola Lake (Table 2, and Appendix 1). Areas selected for sampling were weighted based on the following factors:

- Identified as areas of concern to the public;
- >21% EWM cover (Golder, 2013);
- High use/traffic (e.g. well known boat launches, parks and residential areas);
- Known First Nations values; and,
- Potential to act as EWM source populations.

Additional considerations/goals included surveying a representative sample of EWM areas (distributed evenly around the lake) and maximizing value of the data (by optimizing the effectiveness and efficiency of sampling efforts) based on the available budget.

Survey site naming conventions in 2014 were ordered from F1 to F9, starting at the Kamloops Sailing Association, and moving in a clock-wise pattern around the perimeter of the lake.

Table 2. Name, location and description of survey sites

Survey Site		*UTM (Zone 10)*		*Location*	
2014 (Triton)	*2013 (Golder)*	*Easting*	*Northing*	*Name / Area Description*	*Features*
F1	1b	676729	5559131	Kamloops Sailing Association	Boat anchors, boat launch, breakwater, dock, high traffic area
F2	5e	670848	5558411	Highway 5a Boat Launch	Boat launch, high traffic area
F3	7c	672198	5559276	Harmon Estates	Boat anchors, small docks, residential area
F4	10a, b	676217	5561259	Monck Provincial Park	Boat launch, high traffic area
F5	15a, 16b	678044	5563139	Nicola Estates	Dock(s), residential area
F6	22a	679632	5567400	North end of N. Nicola Lake Road	Docks, residential area
F7	31a-c	679676	5565752	Nicola Bay RV Park	Docks, residential area (high density)
F8	32a	679649	5564738	N'Kwala Beach RV Park Upper Nicola River	Docks, residential area, historical use (fishing) area
F9	35a-c	679476	5562040	"Old Nicola Trail", Quilchena	Boat launch, docks, residential area

UTM – Universal Traverse Mercator, NAD 83

2.2 Field Surveys

Triton conducted two rounds of field surveys, such that potential temporal changes in species assemblage present at growing EWM sites could be detectable. The first survey, consisted of fish

(electrofishing) and mussel (snorkel) surveys at all nine sites, and was conducted May 29, 2014 (Round 1). At this time of year macrophyte growth was minimal, allowing for less obstructed examination of potential bivalves on/in the lake bed substrate. The lake level measured at the Environment Canada Hydrometric Station "Nicola Lake near Nicola, BC" (08LG046) was 625.44 m[3].

Round 2 of surveys was conducted July 29, 2014 (macrophytes were present, and growing at/near the surface) and consisted of electrofishing all nine sites and snorkel surveys at three sites. The original survey plan called for only a single round of snorkel surveys in May. However, to improve the potential for mussel detection (some native mussel species burrow into the lakebed during colder periods) snorkel surveys were repeated in July (when water temperatures were >16°C; Mackie et al., 2008). The lake level at Stn. 08LG046 was 625.79 m (Environment Canada, 2014).

All surveys were completed by the same trained and experienced crew members, using the same equipment during both rounds of sampling.

2.2.1 Fish Surveys

Electrofishing was conducted using a Smith-Root generator powered pulsator (5.0 GPP) electrofisher, with two arrays mounted off the bow of a 6.1 m Ali-Craft aluminium jet boat. The electrofisher was set at a frequency of 30 Hz direct current, with an amperage target of 3.0–3.5 A, obtained by using the high output setting (100–1,000 volts) at 50–60% output. A crew size of four was used for the surveys: two electrofishers (with long-handled dipnets) stationed at the railed platform at the bow of the boat, (one operating a foot pedal to control the current), a data recorder/look out, and the boat operator.

Once arriving at the predetermined/programmed GPS location for center of each site, sampling involved electrofishing 50 m on either side of the site center for a site length covering an approximately 100 m long section of shoreline/littoral habitat. Along each 100 m section, the boat was maneuvered in an "in and out pattern" perpendicular to the shore, ranging from approximately 5-20 m from shore.

Fish were captured and placed in a partially filled 150 L aerated cooler. Fish were identified, measured (fork length), assigned to a life history category and photographed before being released after electrofishing was completed. Seconds from each sampling effort were recorded to calculate the catch-per-unit-effort (CPUE; fish per second of electrofishing) for each site.

A general assessment of fish habitat features (e.g. macrophytes, cover, substrate, riparian condition) and basic water quality information (temperature, turbidity, dissolved oxygen, and pH, using a YSI Professional Plus meter), was also completed at each site.

[3] The mean water level for Nicola Lake (1933-2011) was approximately 625.4 m (based on an assumed datum). The mean low and high periods are approximately 625.0 m (December to April) and 626.1 m (June/July) respectively.

2.2.1.1 Temperature Data Loggers

Onset tidbit temperature sensors (loggers) were deployed (at approximately 2 m depth) at three sites around the lake during the first round of surveys in May), with the goal of monitoring the change in water temperature near macrophyte beds throughout the growing season. The loggers were retrieved during the second round of surveys (July).

2.2.2 Mussel Surveys

Two crew members snorkel surveyed 25 m on either side of each site center for a site length covering approximately 50 m of shoreline/littoral habitat. Along each 50 m section, three transects (at 5, 10 and 15m parallel from shore) were surveyed. The lakebed was examined for the presence of any mussels (or clams), and each observation (live, whole shell or shell fragment) was identified (to genus), noted and photographed with an underwater camera.

Similarly to the fish surveys, a general assessment of fish habitat features (macrophytes, cover, and substrate) as well as an assessment of visibility was completed during the snorkel surveys. Observations of fish were also noted, identified and assigned a life history stage.

3.0 Results

3.1 Information Review – Eurasian Watermilfoil

3.1.1 Eurasian Watermilfoil

Eurasian watermilfoil (EWM) is not native to North America, and was first observed in British Columbia in 1970 in Okanagan Lake. The plant has since spread to Shuswap and Mara Lakes, to Christina and Champion Lakes in the Kootenays, to all the main lakes in the Okanagan Valley and to numerous water bodies in the Lower Mainland and Vancouver Island. EWM was first discovered in Nicola Lake in 1991. Many uninfested water bodies in these areas and elsewhere in British Columbia remain susceptible to the introduction of this plant (MOE, 2011).

Eurasian watermilfoil is a rooted, submersed aquatic plant which is characterized by rapid, dense growth. The plant primarily spreads through the production of numerous stem fragments, particularly in the early and late summer (autofragmentation). Autofragmentation involves the breaking off of large mature stems and/or the abscission of the plant tips. Fragments caused by mechanical means (e.g. boat propellers) are also commonly viable, contributing to the rapid spread of this species in many systems (Aiken et al., 1979; Johnstone et al., 1985; Madsen et al., 1988). The fragments may float for several days, and can be transported to different parts of the lake by wind, water currents, even waterfowl until they sink to the bottom. Root shoots then develop from the base of the stem (Okanagan Basin Water Board [OBWB] 2013). Within an established macrophyte bed, EWM also spreads via stolons (Madsen et al., 1988). In the winter buds detach from the roots and establish new plants early in the growing season. EWM may also disperse sexually by pollination and production of seeds (Aiken et al., 1979). In colder environments EWM typically dies back in the fall and overwinters as a propagating root (Grace and Wetzel, 1978).

Eurasian watermilfoil may grow in water up to 6 m deep, limited by the penetration level of sunlight (although the optimal range is 0.5-3.0 m). The plant, which has the capability to grow in a wide range of habitats, typically begins growth early in the spring and, in summer, may grow up to 5 cm/day (OBWB, 2013). When stems reach the surface, they branch extensively, forming an expansive, dense horizontal canopy. EWM flourishes in eutrophic lake systems (i.e. Nicola Lake), and can competitively displace most other aquatic plants in a few years (Aiken et al., 1979). EWM success is highest during late summer in shallow water on rich organic sediments when light availability, temperature and sediment nutrient levels are high (Kimbel, 1982).

3.1.2 Problems caused by Eurasian watermilfoil

Problems caused by this aggressive invasive plant species are numerous. Eurasian watermilfoil often dominates the submersed plant community to the detriment of native plant diversity, fish and wildlife habitat, water quality, flood control, recreation, and aesthetics (Parsons J. et al., 2011). Eurasian watermilfoil, with its rapid growth and spread, can lead to continued invasion of areas presently devoid of plant growth, and reduction in potential habitat for native plants. There is also a reduction in biological diversity through displacement (invading and replacing) of native plant communities (MOE, 2011). Native watermilfoils (*M. sibiricum* and *M verticillatum*)

identified during previous surveys (MOE, 1992) appear to be almost or entirely displaced (Golder, 2013).There is also the increased risk of introduction into other aquatic systems in the region (MOE, 2011; Golder, 2013). There are many lakes in the Merritt – Kamloops area, along with Nicola, which are heavily utilized for fishing, and trailered boat traffic from Nicola Lake to other lakes in the region is extensive.

Aquatic plants provide critical habitat structure for invertebrates and fish as well as important substrates on which algae and microbes grow (Carpenter and Lodge 1986). Yet, not all macrophytes provide equal quality habitat and structure; EWM tends to support fewer individuals and species of macroinvertebrates (Cheruvelil et al. 2002). Eurasian watermilfoil exudes polyphenols in higher concentrations than other macrophytes. These chemicals appear to inhibit the growth of epiphytic algae (Gross et al. 1996) and may deter generalist herbivores from eating it (Marko et al. 2008). By altering the abundance and composition of their macroinvertebrate prey as well as habitat structure, EWM may negatively affect fish abundance, composition and diet (Keast 1984, Lyons 1989, Dibble and Harrel 1997). Dense beds of EWM may lead to the overpopulation and stunted growth of forage fish, (Engel 1995), as well as physically inhibit (obstruct swimming) and disrupt foraging behavior by pelagic/predatory game fish (Valley and Bremigan 2002).

By limiting sunlight penetration and water movement, EWM depletes dissolved oxygen inshore, which can be exacerbated when shoots decay in autumn (Engel, 1995). Dense canopies of invasive macrophytes like EWM have also been found to profoundly alter water quality, creating strong vertical gradients of pH and dissolved oxygen in the water column, which in turn affects the distribution of macroinvertebrates and fish (Carpenter and Lodge 1986, Frodge et al. 1990).

Eurasian watermilfoil can impede flood control, water conservation, drainage and irrigation works (MOE, 2011). For example, uncontrolled growth of EWM has the potential to restrict water flow through the outlet channel of Nicola Lake, which may impair management of lake water levels (storage water and the control structure are used for agricultural, fisheries and flood control purposes).

Growth of EWM in the outlet channel of the lake also has the potential to impact important salmonid spawning habitat downstream (EWM covering spawning gravels would reduce the area available for kokanee spawning; MOE, 1992; Golder, 2013).

The dense weed beds can be a nuisance and a hazard for recreational users of the lake; restricting navigability of the lake, and obstructing boaters, swimmers, anglers and waterfront property owners. There can be a decrease in the quality of shoreline/beach areas for recreational activities due to the accumulation of plant debris (Golder, 2013; OBWB, 2013; MOE, 2011). This in turn can reduce the economic benefits of tourism where dense growth limits recreation. Lastly as EWM infests a lake, adding to the total macrophyte growth, lakefront property values can be diminished (Zhang and Boyle, 2010).

3.1.3 Status of Eurasian Watermilfoil in Nicola Lake

Ministry of Environment Staff identified that there was a high potential for large, extensive beds of EWM to develop in Nicola Lake (MOE, 1992). This determination was based on considerations of the maximum depth of macrophyte growth measured, Nicola Lake bathymetry/reservoir plans, and the operating level of the lake to arrive at a theoretical maximum littoral area available for the growth of EWM.

Much of Nicola Lake's shoreline has a shallow shelf, usually 5-15 m off shore and 1-5 m in width. This shelf hosts a dense cover of macrophytes and is typically dominated by EWM. Inventory work completed in 2013 (Golder, 2013) determined that EWM was prevalent and pervasive throughout Nicola Lake. It is clear that the distribution of the species has increased considerably since it was surveyed in 1991 and that limited efforts to control the plant at that time were unsuccessful (Golder, 2013).

Of 70 sampled locations within 38 mapped macrophyte beds, 30 were categoirzed as having EWM as a dominant species and 24 as subdominant. EWM was generally mixed with native species, commonly at 0.5 to 3.0 m depth. The substrate in which it occurred was variable ranging from fines to cobbles (Golder, 2013).

3.1.3.1 Contributing Factors

Environmental conditions such as water clarity, temperature and nutrient levels directly affect the growing conditions for macrophytes. High water temperatures in Nicola Lake are partly the result of inherent regional and system factors, including warm summer climate. Riparian losses (through logging, agriculture and urban development), and water withdrawals have further aggravated a naturally elevated thermal regime (Walthers and Nener, 1997). High nutrient and sediment levels in Nicola create ideal conditions for EWM growth and determining and reducing the sources has been identified as objectives in the Nicola Lake Action Plan (FBC, 2013). Spring run-off periods also provide an extended period of nutrient inputs to the lake at the beginning of the growing season.

Eurasian watermilfoil spreads by fragmentation, so natural disturbances (wind events) or human activities like boating, fishing and swimming will fragment plants and allow them to spread. Surface flow, which is affected by wind and currents can carry EWM fragments for kilometers. Obstructions to the natural flow of surface water appears to affect EWM populations; obstructions like docks, buoys, boat lifts, and others appear to trap floating fragments, allowing for new infestations to take hold (Caswell, 2010). Results from the Foreshore Inventory Mapping for Nicola Lake completed in 2012 indicate that the foreshore areas of Nicola Lake have been moderately impacted by land use practices; 45% (24 kilometers) of shoreline has been disturbed by land use activities such as agricultural, transportation, residential and parks. Examples of residential development impacts include: riparian vegetation removal, lake bed substrate modification, and the construction of 154 groynes, 106 docks, 83 retaining walls and 15 boat launches (Patterson and Schleppe, 2012).

3.1.4 Eurasian Watermilfoil Management

There is abundant information available on EWM management. For this assessment efforts were made to focus on knowledge/experience gained from existing EWM control programs in the Southern Interior of BC (i.e. Okanagan Basin Water Board [OBWB], Columbia Shuwap Regional District [CSRD] and Regional District of Kootenay Boundary [RDKB]). It is anticipated that the Nicola Lake Steering Committee (NLSC) will be developing a management/control program that is similar to existing operating plans.

In most instances, eradication of EWM is unrealistic; therefore, a management plan should be developed that concentrates efforts where they will produce the greatest benefits. The first goal of the Nicola Lake Action Plan (FBC, 2013) is to control invasive species in Nicola Lake (EWM). Given the distribution and abundance of EWM in Nicola Lake, priority management options should focus (at least initially) on maintaining or improving areas of high importance to the public, and on minimizing risk of additional EWM introductions.

There are many management/control options depending on the scale of the EWM infestation, and management objectives. Control methods vary widely (by hand, mechanical, biological or chemical) but generally can be placed into two main categories: 1. "Intensive" (i.e. selective and effective methods, which work best on smaller scale infestations); and 2. "Extensive" (i.e. non-selective (and often less effective) methods, which are more appropriate for large scale infestations).

Intensive Control Methods:

- Divers (hand removal [pulling and/or cutting] EWM);
- Bottom barriers (placing material onto the lake bed that blocks sunlight);

Extensive Control Methods:

- Rototilling (mechanical de-rooting, shallow water tillage);
- Harvesting (mechanical cutting, lake mower);
- Lake draw down* (lowering the water level to expose macrophytes).
    - *Has not been used in BC – discussed in Appendix 3*

Intensive or Extensive Control Methods:

- Biological control* (aquatic weevil that consumes EWM);
    - *Currently not an operational level option in BC – discussed in Appendix 3*
- Chemical control* (applications of aquatic herbicide);
    - *Currently not an option in BC – discussed in Appendix 3*

Eurasian watermilfoil control options mentioned in the Nicola Lake Action Plan (NLAP) include:

- Hand pulling;

- Rototilling;
- Harvesting; and
- Weed razor.

3.1.4.1 Other Species Considerations

In addition to fisheries and shellfish (freshwater bivalves) that this assessment focusses on, there are potential impacts from EWM control activities on other species, (including some at risk) and their habitats to consider when development a EWM management plan. Aquatic vegetation removal is considered as a very high risk activity and many of these species have timing windows and best management practices. Great Basin Spadefoot Toad[4] (*Spea intermontana*) and Western Toad[5] (*Anaxyrus boreas*) may use shoreline areas for breeding and rearing (tadpoles/toadlets) in the spring and summer. Painted Turtle[6] (*Chrysemys picta pop. 2*) may use shoreline/littoral areas year round, and hibernate in the lakebed in the winter. In addition to EWM, there were native macrophytes and some at risk plant species identified (Perfoliate pondweed[7] [*Potamogeton perfoliatus*] and Sheathing Pondweed[5] [*Stuckenia vaginata*]). Given these considerations, a combination of management techniques will likely be necessary.

3.1.5 Eurasian Watermilfoil and Littoral Zone Fish Habitat

Although EWM and salmonids usually occupy distinctly separate habitats, three resident (non-anadromous) salmonid species are known to utilize the littoral (inshore) areas where conflicts might occur. Kokanee spawn along lakeshores (although kokanee spawning also occurs at different depths and on different substrate than that which supports milfoil), rainbow trout use the shallows seasonally before seeking deeper water (Morley and Reid, 1977) and Lake Trout spawn in water as shallow as 0.3m (Scott and Crossman, 1973). However, there is no known shore spawning Kokanee, nor is there known presence of Lake Trout in Nicola Lake (A. Morris, 2014. Pers. comm. September 15).

Fish abundance and diversity results varied among literature sources and even within individual studies (Weaver, 1997). Some investigators found the effect of EWM on fish species abundance to be low as long as native vegetation beds in the shallows (1.0-1.3 m) were preserved. Eurasian watermilfoil may act as a shelter from predators for juveniles or smaller species of fish. In Okanagan Lake, dense EWM (among other macrophyte species) at 1.0-3.0 m depth did not appear to have a detrimental effect on salmonid gamefish, as most of these species avoided the littoral area during the summer, occurring at depths beyond those presently occupied by EWM (Robinson, 1981).

[4] Great Basin Spadefoot Toad - Provincial: Blue; COSEWIC/SARA: Threatened; Known occurrence near Quilchena (MOE, 2014).
[5] Western Toad status - Provincial: Blue; COSEWIC/SARA: Special Concern
[6] Painted Turtle (Inter/Rocky Mountain Population) - Provincial: Blue; COSEWIC/SARA: Special Concern
[7] Perfoliate pondweed and Sheathing pondweed - Provincial: Blue; COSEWIC/SARA: None

Eurasian watermilfoil control techniques should include those that manage the nuisance to allow recreational access without significant losses of fish habitat. This recognizes that non-native plants do serve as habitat. In fact, there is little evidence to suggest introductions of Eurasian watermilfoil will lead to dramatic declines in fisheries (Valley et al., 2004).

Other researchers observed that some fish species may avoid EWM beds due to reduced prey (invertebrate) availability (Keast, 1984). Dense plant beds growing to the water surface are often associated with stunted fish com-munities (Engle, 1995; Dibble et al., 1997). The dense plants, especially dense stands of EWM, support fewer macroinvertebrates to feed the fish and are also more difficult for fish to forage through (Dibble et al., 1997; Sloey et al., 1997; Valley and Bremigan, 2002; Theel and Dibble, 2008). Fish and prey invertebrate abundance was several times greater in native *Potamogeton vallisneria* beds (1.0-1.3m) than in EWM beds (2.0-3.5 m), and these differences were greatest in the late summer. Numbers of potential prey invertebrates (isopods, chironomid and trichopteran larvae, ephemeropteran nymphs) were significantly reduced at 2.0-3.5 m after milfoil invasion (Keast, 1984).

Larger fish often associate with plant bed edges (Engel, 1987) where macroinvertebrate prey resources are mostly concentrated (Sloey et al., 1997). Thus a reduction in dense vegetation, rather than eradication, should increase predator-prey interactions, improve fish growth (Bettoli et al., 1992; Bettoli et al., 1993) and augment fish production (Smith, 1993).

Therefore, where fisheries are of concern to lake management, the selective removal or treatment of monospecific vegetation stands to create the optimum amount of edge habitat for fish should be considered (Unmuth et al., 1998).

3.2 Information Review - Fisheries Utilization of Littoral Zones

Fish may utilize the littoral zone of lakes in some or all life history stages for various activities, including foraging, reproduction, and refuge from predators (Weaver et al., 1997; Pratt and Smokorowski, 2003; Valley et al., 2004; Winfield, 2004). Distribution of salmon juveniles in the littoral zone is also related to the proximity of natal streams and suitable rearing habitat (Russel et al., 1990). Nearshore complexity has been identified as preferred habitat for fish species and aquatic macrophytes are often cited as the most important habitat structures of the littoral zone (Beauchamp et al., 1994; Pratt and Smokorowski, 2003). These areas are heavily used as shelter and feeding grounds for smaller fish.

Temporal use of littoral areas has been noted for cold water species, such as salmon and trout, with higher use during spring and early summer (abundant after freshet when juveniles emerge and begin migration) and reduced presence in shallower littoral areas as water temperatures elevate (Russell et al., 1980; Stewart et al., 1989). Few fish utilized shorelines before April 25 or after July 6. Most juvenile chinook and coho caught during sampling periods carried out between May 30 and June 15 coincided with high numbers of zooplankton. Juvenile Chinook and Coho may overwinter offshore but adjacent to "productive littoral areas" to benefit from both pelagic and littoral food sources (Russel et al., 1980).

Several coarse fish species (present in Nicola Lake), including young of the year Peamouth Chub, Redside Shiners, Largescale Suckers, Northern Squawfish, and Sculpin can be found close to shore (in the littoral zone; Ali, 1959). Brown and Winchell (2004) noted that of 14 total fish species caught and identified, within 3 m of the lake edge, Sculpins, Redside Shiner and Chinook (juveniles) dominated (93%) the catch. These coarse fish species prefer warmer water temperatures which occur coincidentally with maximum macrophyte biomass.

3.2.1 Select Fish Species (Life History Stages) and Their Use of the Littoral Zone

Life history stages potentially most at risk of impacts from EWM management activities are likely associated with limited mobility (eggs, larvae, fry) and/or juveniles in littoral/shore margins. Overview life histories for species that are either at risk and/or support regionally important fisheries, and their potential utilization of the Nicola Lake littoral zone are discussed below. A summary is presented in Table 3.

Adult Bull Trout are generally found in deep water, but may move to shallower littoral areas at night. Adults are very rarely encountered in temperature above 15°C. Bull Trout are fall spawners and there is no known lake spawning. Fry of adfluvial Bull Trout populations may migrate from stream to lake in their first summer, but most juveniles found in lakes are >200 mm, which indicates their preference to rear in streams (one to four years), before migrating to lake, and then they generally move to deep water.

Adult Coho Salmon are either in the ocean, or migrating back to their natal streams in the fall to spawn. Fry emerge in the spring and juveniles generally rear in streams (preferably in pools associated with cover) for one or two years. There are stream versus lake rearing coho, and the lake variety may spread out in the littoral zone, and/or form schools. Similarly to other salmonids, juvenile Coho will typically move away from warmer areas within the littoral zones (i.e. macrophyte beds) as the temperatures increase through the spring and summer (Stewart et al., 1989; James and Kelso, 1995).

Adult Chinook Salmon are in the ocean or migrating in the summer to spawn in streams in the early fall. Fry emerge in the spring and generally rear in streams or will utilize shallow littoral areas during the early rearing period from April through June. Chinook utilize most near shore habitat types, but tend to be found in highest densities near beach areas (Brown and Winchell, 2004). These species, also move out of the littoral zones (i.e. macrophyte beds) as the temperatures increase through the spring and summer.

Adult Steelhead Trout are in the ocean, or migrating to streams in the late summer (summer-run steelhead) or winter (winter-run steelhead) to spawn in the spring. Fry emerge in the summer and rear in streams or lakes typically for one to four years. While juveniles have been found to utilize littoral areas for rearing (Wurtsbaugh et al., 1975), they have been found to have a closer association with boulders and rocky habitat within the littoral zone rather than with aquatic macrophytes (Tabor and Wurtsbaugh, 1991; Beauchamp et al., 1994). These species, also move out of the littoral zones (i.e. macrophyte beds) as the temperatures increase through the spring and summer.

Sub-adult and adult sized/aged rainbow trout in lake environments are often pelagic in their distributions; however, sampling in littoral areas indicate that shoreline habitats can also be a key aspect of their lives. Adults may be found there during the periods before and after spawning (in streams; Kelso and Kwain, 1984; Wenger et al., 1985). Juvenile and young-of-year rear in streams and in littoral areas of lakes. Juveniles have been found to have a closer association with boulders and rocky habitat within the littoral zone rather than aquatic macrophytes. These species, also move out of the littoral zones (i.e. macrophyte beds) as the temperatures increase through the spring and summer.

Adult Kokanee prefer offshore habitats and are crepuscular (dawn and dusk) migrations/foragers (move up to feed, then back down into cool hypolimnion at night and during the day). There is no known lake spawning in Nicola Lake. Spawning (fall) is reported to occur primarily in two major tributaries to the lake: the Nicola River and Moore Creek (Lorz and Northcote, 1965; Kosakoski and Hamilton, 1982). While there is no confirmed foreshore spawning for kokanee to date, there is likely some foreshore (or nearshore) use, based on the fact that so few stream spawners are seen for a lake the size of Nicola (A. Morris, 2014. pers. comm. September 15. Shore spawning in Okanagan Lake begins in early October with peak of activity occurring in the third week and completion by the first week of November. Lake spawners differ in that they are not nest builders. They broadcast their eggs in nearshore areas in substrate that provides spaces for eggs to settle into. Typically angular substrate often associated with steep slopes is selected (A. Wilson pers comm.). Incubation follows the same pattern as stream type kokanee, with emergence in March or April. Kokanee fry are not typically found in the littoral zone. As fry, they usually move directly to the pelagic environment from the spawning area, but they may reside in the littoral zone near the spawning area for a short time before moving offshore as juveniles (Ford et al., 1995). Young-of-year fish from some populations remain near shore littoral and forage for variable amounts of time, before transitioning to the limnetic zone. Like the other salmonids mentioned above, Kokanee also move out of the littoral zones (i.e. macrophyte beds) as the temperatures increase through the spring and summer.

Adult Burbot are generally a benthic species, preferring the deeper/cooler waters during the day, is (Ali, 1959). Burbot spawn in the winter, when water temperatures are 0.6-1.7 ºC (Scott and Crossman, 1973; Roberge et al., 2002). They spawn over fine to gravel substrates in shallow bays, or shoals, in 0.3-3.0 m of water (Scott and Crossman, 1973). Eggs are released into the water column, and sink to the substrate below (Scott and Crossman, 1973; Roberge et al., 2002). After emergence, Burbot start as limnetic larvae (at moderate depths), and drift passively with flow until their swimming performance increases and then form loosely aggregated schools (McPhail, 1997), young-of year can be common in littoral areas, associated with cover (boulder). There are a few observations of juvenile burbot rearing in vegetated foreshore areas along the northwest side of the lake in the vicinity of the outlet (A. Morris, 2014. Pers. comm. September 15). Once larvae are about 15 mm in length, they move to benthic areas and live a nocturnal, solitary life (McPhail, 1997). Although juvenile Burbot may be found in rocky or vegetated areas within the littoral zone of lakes (Ford et al., 1995) 2+ fish generally stay below the thermocline.

Table 3. Select species (life history stage) and their potential use of the littoral zone

Species	*Life History Stage*	*Potential use of Littoral Zone*
Bull Trout	Adult	Low
	Spawner	None/Low
	Juvenile	Low
Coho Salmon	Adult	None
	Spawner	None
	Juvenile	Low/Moderate
Chinook Salmon	Adult	None
	Spawner	None
	Juvenile	Low/Moderate
Steelhead Trout	Adult	None
	Spawner	None/Low[1]
	Juvenile	Low/Moderate
Rainbow Trout	Adult	Low
	Spawner	Low
	Juvenile	Moderate
Kokanee	Adult	Low
	Spawner	Low/Moderate[2]
	Juvenile	Moderate
Burbot	Adult	Low
	Spawner	Moderate/High[3]
	Larvae/Juvenile	Moderate

[1] Summer run steelhead enter streams in the summer of the year prior to spawning, and reach full maturity while holding in fresh water.
[2] Kokanee shore spawning is not known to occur in Nicola Lake, although it is suspected.
[3] Information on Burbot life history in Nicola Lake is limited.

Other lakes with EWM (particularly those in the Shuswap and Okanagan drainages) have similar fish species assemblages, and have developed effective mitigative measures for their long-standing EWM control/management programs.

3.3 Information Review - Mussels

As mentioned in Section 1, the freshwater bivalve (clam and mussel) species found in interior BC with the potential to occur in Nicola Lake include native clams (Family Sphaeriidae), and five freshwater mussel species: Winged Floater, Oregon Floater, Western Floater, Western Pearlshell, and Rocky Mountain Ridged Mussel. Floater (*Anodonta sp*.) taxonomy remains under investigation, and *A. kennererlyi* and *A. oregonensis* may be a single clade. Differentiation based on morhphology is difficult, and in many instances investigators have identified one or the other as *Anodonta sp*.

Little is known about the biology of freshwater clams and their distribution in B.C., and presently, it is not possible to assess which species may be at risk (MOE, 2014c). Western Pearlshell habitat is generally limited to streams, and therefore is not discussed in this document.

Oregon Floaters are found across southern BC, and Western Floaters are found throughout BC, north to 56°N lat. Rocky Mountain Ridged Mussels (RMRM) are known in BC to be in the Okanagan Basin. The preferred habitats of *Anodonta sp*. includes shallow silty, muddy or sandy/gravelly substrates in slow rivers and lakes although they have been observed in soft substrates between large cobble/boulders. The preferred habitat of the RMRM ranges from soft muddy or sandy substrates to large cobble/boulder along lakeshores and within the Okanagan River. They are most commonly observed in waters less than 1.5 m deep; however, has been seen in water to 8 m deep (MOE, 2014d).

Larvae of mussels (glochidia), are released into water and must encounter and attach to a host fish where they remain for several weeks (the host fish species are unknown in BC). Juvenile mussels release from their host fish, sink to the bottom, burrow into sediment and remain buried until mature (several years). Mussels can live from 10 to 100 years.

3.4 Electrofishing Surveys

During May sampling, the average water temperature was 11.0°C (14.5°C measured at the temperature loggers) and the average conductivity was 112 µS/cm. The average depth of the survey sites was 2.2 m, with the dominant substrate being gravel and cobble, and fines the subdominant substrate. Average values for other water quality parameters (turbidity, dissolved oxygen and pH were 2.51 NTU, 9.27 mg/L, and 8.48 respectively. Electrofishing sampling conditions for each survey site are presented in Table 4.

Table 4. Electrofishing sampling conditions (Spring)

Date	Site	Water Temp (°C)		Turbidity	Dissolved Oxygen	pH	Conduct	Depth	Substrate	
		Surface	Logger	(NTU)	(mg/L)		(µS/cm)	(m)	Dom	Sub
May 29, 2014	F1	11.8	15.9	1.76	9.01	8.69	118	1.8	G	F, C, B
	F2	8.6	14.0	1.53	9.43	8.28	112	2.3	G	F, B
	F3	9.1	14.0	1.55	9.38	8.23	113	2.0	G	F
	F4	11.0	15.9	1.10	8.59	8.55	115	1.8	C	B
	F5	11.7	15.9	2.12	9.23	8.61	116	2.6	C	B
	F6	12.6	13.0	1.23	8.69	8.70	117	2.0	C	F, B
	F7	12.0	13.0	1.32	10.13	8.45	114	2.6	F	G
	F8	9.8	13.0	6.49	9.81	8.14	85	2.3	F	G
	F9	12.0	15.9	5.45	9.13	8.71	121	2.3	G	F
Spring Average		**11.0**	**14.5**	**2.51**	**9.27**	**8.48**	**112**	**2.2**		

NTU: Nephelometric Turbidity Units; Conduct: Conductivity; Dom: Dominant; Sub: Subdominant. Depth and substrate were estimated from surface observations; Substrate, F: Fines; G: Gravel; C: Cobble; B: Boulder

During July sampling, the average water temperature was 19.7 °C (19.8 °C measured at the temperature loggers). Average values for other water quality parameters (turbidity, dissolved oxygen and pH were 1.52 NTU, 8.18 mg/L, and 8.72 respectively. Average macrophyte cover estimated from the surface was 45%. Electrofishing sampling conditions for each survey site are presented in Table 5.

Table 5. Electrofishing sampling conditions (Summer)

Date	Site	Water Temp (°C)		Turbidity	Dissolved Oxygen	pH	Macrophyte
		Surface	Logger	(NTU)	(mg/L)		Cover (%)
July 29, 2014	F1	18.2	18.7	1.18	8.52	8.69	40
	F2	20.1	19.7	0.40	7.90	8.58	50
	F3	19.3	19.7	1.06	8.26	8.66	50
	F4	18.2	18.7	2.32	8.74	8.68	40
	F5	19.2	18.7	2.08	8.16	8.75	25
	F6	19.2	21.2	0.70	7.61	8.82	55
	F7	20.6	21.2	1.66	8.51	8.78	75
	F8	20.7	21.2	1.65	8.17	8.79	40
	F9	22.0	18.7	2.59	7.75	8.76	30
Summer Average		**19.7**	**19.8**	**1.52**	**8.18**	**8.72**	**45**

NTU: Nephelometric Turbidity Units

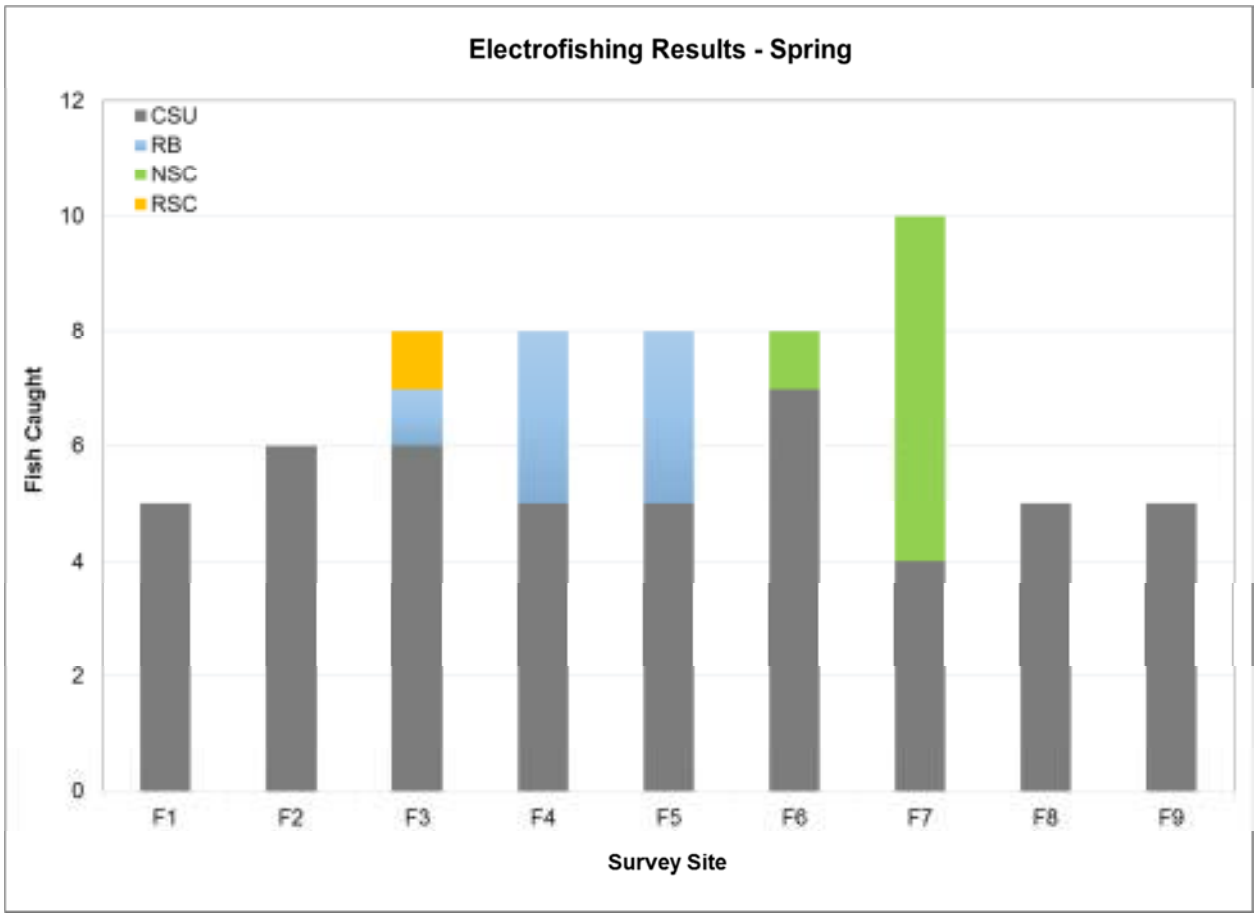
During the spring electrofishing, a total of 63 fish comprising four species were captured from the nine survey sites. The majority of the fish captured were Large Scale Suckers[8] (76% of the total catch) with Rainbow Trout (11%), Northern Pikeminnow[7] (11%), and Redside Shiners (2%) making up the remaining catch. The average effort was 284 seconds (SD 55), the average catch was seven fish (SD 1.8) and the average Catch-per-unit-effort (CPUE) was 0.025 fish/sec (SD 0.006). Electrofishing results for each survey site are presented in Table 6 and Figure 1.

Table 6. Electrofishing results (Spring)

Date	Site	Effort (sec)	Catch (total)	CPUE (fish/ sec)	Catch (species)	Life Stage	Comments: Fish Observations	Comments: Habitat Features
May 29, 2014	F1	295	5	0.017	CSU (5)	Adult	CSU (12)	NE of breakwater Sparse riparian, SW – willow riparian, rock bluff
	F2	249	6	0.024	CSU (6)	Adult	CSU (3)	Boulders along shore, Mostly willow riparian, some cottonwood
	F3	209	8	0.038	CSU (6) RSC (1) RB (1)	Adult Juven Adult	CSU (2)	Sparse riparian (retaining walls)
	F4	325	8	0.025	CSU (5) RB (3)	Adult Juven	CSU (6), RB (2), CC (2),	LWD along bank, sparse riparian
	F5	294	8	0.027	CSU (5) RB (3)	Adult Juven	CSU (4), RB (2). RB closer to shore, CSU deeper (>2m)	Willow, cottonwood riparian
	F6	332	8	0.024	CSU (7) NSC (1)	Adult Adult	CSU (2), NSC (2), most near cover (docks)	Sparse riparian, rock bluff SW of site
	F7	376	10	0.027	CSU (4) NSC (6)	Adult Adult	CSU (6) most near cover (docks)	Sparse riparian
	F8	215	5	0.023	CSU (5)	Adult	NCS (1)	Sparse riparian, some willow and angular boulder near shore
	F9	262	5	0.019	CSU (5)	Adult	CSU (4)	Willow riparian, some cottonwood
Spring Total		**2557**	**63**					
Spring Average		**284**	**7**	**0.025**				

CSU: Large Scale Sucker; NSC: Northern Pikeminnow; RB: Rainbow Trout; RSC: Redside Shiner; Juven: Juvenile; LWD: large woody debris

[8] Large Scale Sucker (*Catostomus macrocheilus*) and Northern Pikeminnow (*Ptychocheilus oregonensis*) were not previously identified as being observed in Nicola Lake on the Fisheries Information Data Queries site (MOE, 2014e).



CSU: Large Scale Sucker; RB: Rainbow Trout; NSC: Northern Pikeminnow; RSC: Redside Shiner

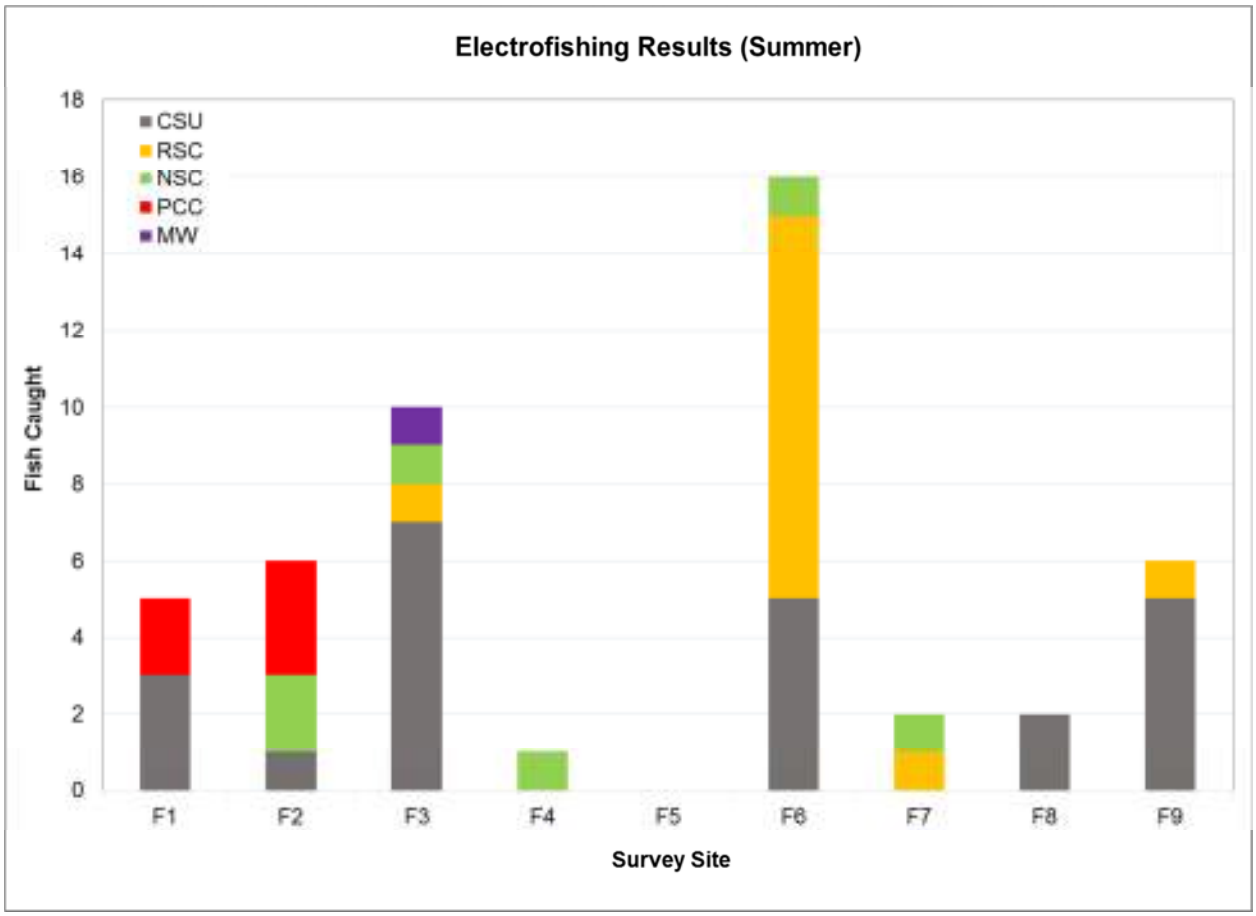
Figure 1. Electrofishing results (Spring)

During the summer electrofishing, a total of 48 fish comprising six species were captured from the nine survey sites. The majority of the fish captured were Large Scale Suckers (48% of the total catch) with Redside Shiner (27%) Northern Pikeminnow (13%), Peamouth Chub (10%) and Mountain Whitefish (2%) making up the remaining catch. The average effort was 301 seconds (SD 78), the average catch was five fish (SD 5.6) and the average CPUE was 0.017 fish/sec (SD 0.015). Electrofishing results for each survey site are presented in Table 7 and Figure 2.

Table 7. Electrofishing results (Summer)

Date	Site	Effort (sec)	Catch (total)	CPUE (fish/ sec)	Catch (species)	Life Stage	Comments: Fish Observations	Comments: Wildlife Observations
July 29, 2014	F1	249	3	0.012	CSU (3)	Adult	CSU (3)	30 Canada Geese (shore)
	F2	268	5	0.019	NSC (2) PCC (2) CSU (1)	Adult, Juven Adult Adult	NSC (2), CSU (2)	-
	F3	277	13	0.047	CSU (7) PCC (3) NSC (1) RSC (1) MW (1)	Adult Adult Adult Adult Adult	CSU (5), NSC (4),	Osprey
	F4	273	1	0.004	NSC (1)	Adult	NSC (2), CSU (2)	Beaver lodge
	F5	313	0	0.000	-	-	NSC (1)	-
	F6	495	16	0.032	RSC (10) CSU (5) NSC (1)	Adult, Juven Adult Juven	RSC (10), CSU (5), NSC (2)	-
	F7	300	2	0.007	NSC (1) RSC (1)	Adult Adult	CSU (1)	-
	F8	226	2	0.009	CSU (2)	Adult	CSU (4),	10 Canada Geese (lake)
	F9	309	6	0.019	CSU (5) RSC (1)	Adult Juven	CSU (3)	-
Summer Total		**2,710**	**48**					
Summer Average		**301**	**5**	**0.017**				

CSU: Large Scale Sucker; RSC: Redside Shiner; NSC: Northern Pikeminnow; PCC: Peamouth Chub; MW: Mountain Whitefish; Juven: Juvenile



CSU: Large Scale Sucker; RSC: Redside Shiner; NSC: Northern Pikeminnow; PCC: Peamouth Chub; MW: Mountain Whitefish

Figure 2. Electrofishing results (Summer)

3.4.1 Temperature Data Loggers

Over the two month period for which the three temperature loggers were deployed (May 29 to July 29, 2014) the daily average water temperature of the Nicola Lake littoral zone was 16.6°C. Temperature values for each temperature logger site are presented in Table 8 and Figure 3.

Table 8. Water temperatures (May 29 - July 29, 2014)

Logger		*Daily Average*	*Max Daily Average*	*Min Daily Average*
Name	*Location (site)*	*(°C, May 29-July 29)*	*(°C, date)*	*(°C, date)*
Nicola 1	F6	17.6	22.6 (July 16)	12.7 (May 29)
Nicola 2	F3	15.6	22.2 (July 11)	10.0 (May 29)
Nicola 3	F9	16.7	21.9 (July 16)	12.1 (May 29)
Average		**16.6**	**22.2**	**11.6**

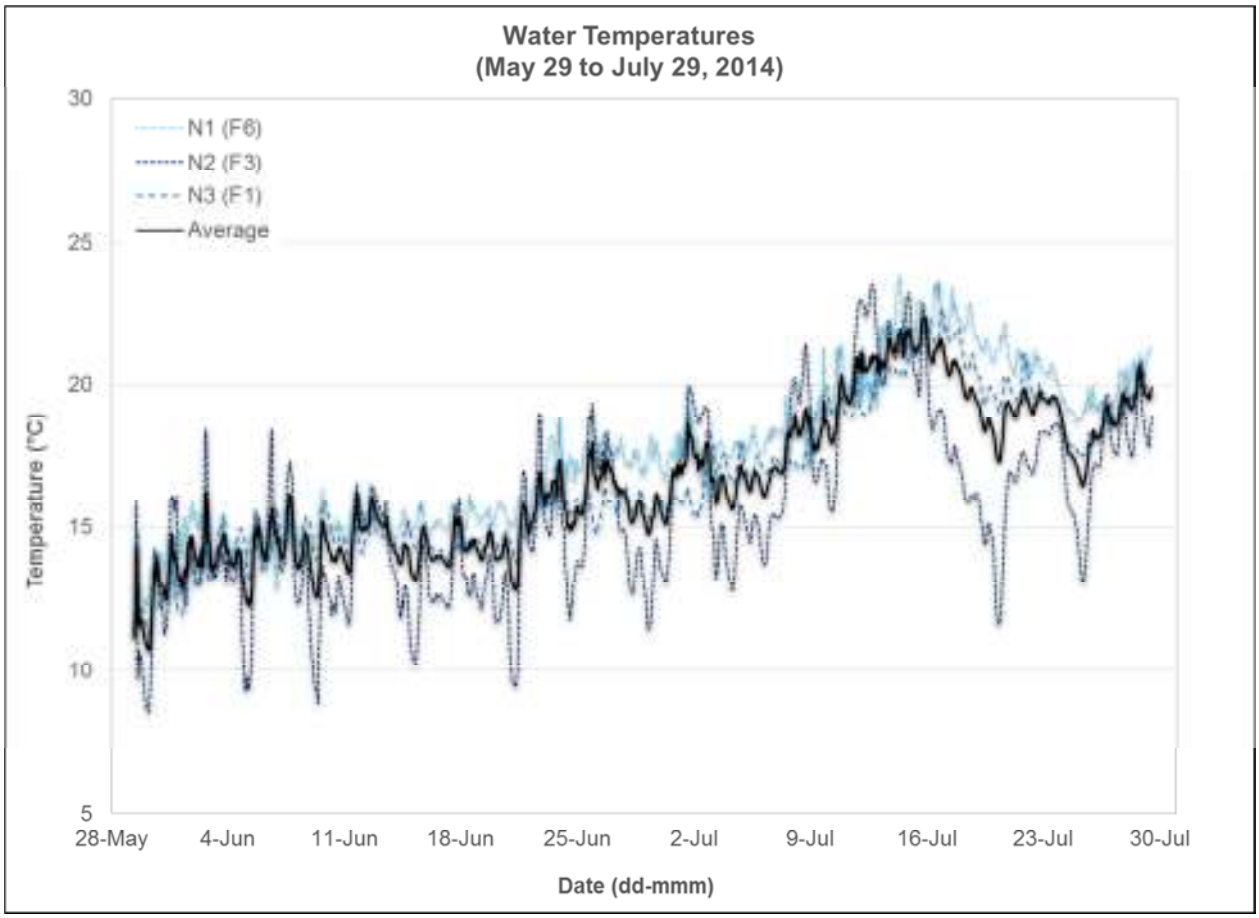


Figure 3. Water temperatures (May 29 - July 29, 2014)

3.5 Snorkel Surveys

During May surveys, the average water visibility was considered "fair" at only 1.3 m, likely due to spring run-off and possibly lingering effects from spring turn-over. The average depth at the survey sites was 1.7 m, which meant the lakebed along the 15 m transect line (farthest from shore) was intermittently visible. As expected, substrate composition was similar to the results during electrofishing; however, during snorkel surveys, gravel, cobble and fines were observed in approximately equal proportions (averaged over the nine sites). The dominant macrophyte observed was Eurasian watermilfoil, and the subdominant species were Richardson's pondweed (*Potamogeton richardsonii*) and fennel-leaved pondweed (*Stuckenia pectinata*). Canadian waterweed (*Elodea canadensis*) was the subdominant macrophyte species at site F7. A thick layer (up to 3 cm) of periphyton was commonly observed (as was a layer of fine sediment), with the periphyton being most pronounced on larger substrate (where present).

During July surveys, water clarity was modestly improved (relative to spring surveys) although a summer bloom of blue-green algae still influenced visibility (estimated at 2.3 m). Thick beds of macrophytes (most often sporadic distributions of EWM) also hampered observations during the July surveys. Snorkel survey conditions for each survey site are presented in Table 9.

Table 9. Snorkel survey conditions summary

Date	Site	Visibility	Depth	Substrate		Macrophytes		Periphyton
		(m)	(m)	Dom	Sub	Dom	Sub	(cm)
May 29, 2014	F1	0.8	1.3	G	C, F	MS	SP, PR	3
	F2	1.7	2.0	F	C	MS	PR, SP	2
	F3	Fair	1.5	G	F, C	MS	PR	1
	F4	Fair	1.3	G	C, F	MS	PR, SP	<1
	F5	Fair	2.0	C	G, F, B	MS	SP	<1
	F6	Fair	1.5	C	G, F	MS	SP	1
	F7	1.3	2.0	F	G	MS	EC, PR	1
	F8	1.4	1.8	F	G	PR	MS, SP	2
	F9	Fair	1.8	C	F	MS	PR, SP	2
Spring Average		**1.3**	**1.7**					**1.5**
July 29, 2014	F3	2.0	1.5	G	F, C	MS	PR	-
	F6	2.5	1.5	C	G, F	MS	SP	-
	F9	2.5	1.8	C	F	MS	PR, SP	-
Summer Average		**2.3**	**1.6**					

Visibility, Fair: 1-2 m est.; Substrate, F: Fines; G: Gravel; C: Cobble; B: Boulder) Macrophytes, MS: *Myriophlyllum spicatum* (Eurasian watermilfoil); SP: *Stuckenia pectinata*; PR: *Potamogeton richardsonii*; EC: *Elodea Canadensis*

No live mussels were observed during either May or July snorkel surveys; however, three intact (i.e. both valves attached and relatively undamaged) floater (*Anodonta sp*.) shells were observed. As mentioned in Section 3.3, *Anodonta sp.* are difficult to distinguish, but the shells were likely Oregon Floater (*A. oregonensis)*, or Western Floater (*A. kennerlyi).* A total of 24 shell fragments were also observed, averaging 2.7 shell fragments per site[9]. Sculpins and Large Scale Suckers were commonly observed during May and July snorkel surveys. Redside Shiners were prevalent amongst the macrophyte beds at site F6 during the July survey. Unidentified snails were observed at three sites (F5, F7 and F9). Snorkel survey results for each survey site are presented in Table 10.

Table 10. Snorkel survey results

Date	Site	Mussels (Anodonta sp.)			Fish	Life	Comments
		Live	Shell (intact)	Shell (fragment)	(species)	Stage	
May 29, 2014	F1	0	0	0	CC (2)	Adult	Poor visibility
	F2	0	0	2	CC (2) CSU (5)	Adult, Juven Adult	Green filamentous algae
	F3	0	1	6	CC (2) CSU (1)	Adult, Juven Adult	
	F4	0	0	1	0	n/a	
	F5	0	0	2	0	n/a	Snail shell
	F6	0	2	3	0	n/a	
	F7	0	0	5	CC (1)	Juven	Snail shells
	F8	0	0	0	CC (2)	Adult, Juven	
	F9	0	0	5	CC (8)	Adult, Juven	Snail shells
Spring Total		0	3	24			
Spring Average			**0.3**	**2.7**			
July 29, 2014	F3	0	0	7	0	n/a	
	F6	0	0	3	RSC (>100) CSU (2) CC (2)	Adult, Juven Adult Adult	
	F9	0	0	2	0	n/a	

3.5.1 Fish Habitat Observations

In general, fish habitat at the survey sites was considered poor to fair given the level of shoreline development (agricultural, transportation and urban land uses) and the limited amount of cover observed (both in-lake and riparian). Most of Nicola Lake's shoreline has a low slope and the resulting lakebed/substrate composition at most sites is often homogenous, lacking habitat complexity and cover elements (i.e. boulders, LWD, drop offs). Areas of potentially suitable

[9] Totals/averages do not include data from replicate sampling of three sites in July.

shore spawning habitat do exist (although no shore spawning by salmonids is known to occur, and the spawning habitat does not typically overlapping with priority EWM areas), but the few that were identified were generally intermixed with fines and coated in a layer of fines and/or periphyton of varying thickness.

4.0 Discusssion

4.1 Eurasian Watermilfoil Management/Control Options

As mentioned in Section 3.1, the main sources of information for EWM control/management options were from three existing operational programs (OBWB, CSRD, RDKB). In the case of both Okanagan and Shuswap Lakes, EWM programs have evolved over the past 30 to 40 years due to expanding milfoil populations and funding constraints. Intensive control techniques (i.e. divers and bottom barriers) have been replaced with less expensive and less effective control techniques. The two main control options being used for these systems are rototilling and harvesting. For Christina Lake, the 20-year program has always been primarily diver removal, and diver cutting. In recent years, all three lakes have implemented small scale controlled mechanical cutting using a lake mower (often loaned out to volunteers for cosmetic control). The above programs are expensive to operate (OKWB, CSRD and RDKB have operating budgets of approximately $500,000, $200,000-300,000 and $150,000 annually); (OKWB, 2013; CSRD, 2010; Caswell, 2010).

4.1.1 Divers

Eurasian watermilfoil control using divers is an effective and sensitive approach for smaller scale sites, but there may be areas where it's not possible to treat everything; it's an environmental balance. Divers must be trained in plant identification, and be to be effective, it is recommended that maximum available resources be applied early in the control program at the lowest level of the infestation.

A diver control program typically would consist of two crews of divers working through the summer season. Only an intensive program will begin to reverse the trend in expanding Eurasian watermilfoil populations. The technique has proven successful, for example: the Christina Lake Milfoil Control Program has been able to successfully control the spread of EWM using the intensive and environmentally responsible method of diver hand removal for the past 20 years. In the case of 3rd Champion Lake (a much smaller lake), the RDKB has controlled EWM for almost 30 years, with only a few EWM plants found in the lake in 2010 (Caswell, 2010). In more recent years, diver hand removal and hand cutting has been used with a floating net system, which has proved invaluable/essential to capturing all the EWM fragments.

The EWM control program in 3rd Champion Lake shows that in the case of smaller lakes, diver hand removal and survey can reduce milfoil populations to near eradication (see details of the White Lake program in Section 4.1.2). Although diver control of EWM is time consuming and must be repeated each year, there is evidence that with a significant presence of divers, upward trends in milfoil populations can be stopped, even reversed.

Eurasian watermilfoil areas are fully monitored annually to ensure that the infestation is being kept at the desired low level. Eurasian watermilfoil is a prolific species capable of rapid and aggressive expansion. As EWM populations increase in size and density, it may challenge the capacity of diver control crews to manage the volume of plant being removed. Should expansion

occur to the extent that the problem no longer can be managed by divers working during the summer, then this method should be abandoned.

4.1.2 Bottom Barriers

Bottom barriers are solid barriers placed on the lakebed that limit plant emergence indiscriminately, and result in plant decay within 30 days (Mayer 1978) and root mass decomposition within 60 days. Generally, given the non-selectivity of the treatment, benthic barriers are deployed where EWM dominates the aquatic plant community (Eichler et al. 1995). Bottom barriers are generally implemented in combination with diver hand removal/cutting efforts. For example, an intensive control treatment technique was implemented at White Lake in 1994 when EWM was first identified. From 1995 to 1997, continued bottom barrier and diver handpicking treatments were successful in eradicating the milfoil sites. Subsequent diver and surface surveys from 1998 through 2008 have been unable to find any EWM plants in White Lake (CSRD, 2010).

The bottom barrier technique does have potentially adverse long term effects on EWM populations in certain areas. The geotextile fabric deteriorates over time, and is covered in silt. The silt covered geotextile acts as a nursery for EWM fragments, allowing them to easily take root and produce new adult plants. In some circumstances, a monoculture of EWM grows directly atop the existing bottom barrier (Caswell, 2010). In other instances bottom barriers have lifted up off the lake bed and/or torn due to gas pockets forming when plant material decays (J. Littley, 2014. pers. comm. July 25). For these reasons bottom barriers should be intended for short-term (one or two growing seasons) suppression of EWM growth.

4.1.3 Rototilling

Rototilling is undertaken by a floating, powered barge carrying a modified agricultural-type rototiller. The rototiller head, supported by long arms, is pulled along the lake bottom where the rotating blades non-selectively shear and up lift macrophyte plant roots as it passes over them. Rototilling is conducted primarily in the late fall and winter months when plant biomass is reduced, fragments are less numerous, less buoyant and less viable, and when water levels are lower and the lake is ice free. This schedule is also determined by the time of least impact on aquatic species and habitat as outlined by provincial regulation. The rototiller head is attached to hydraulic arms on a floating barge and can effectively treat in depths from 0.3-3 m. Macrophytes are anchored to the lake bottom by a tangle of root fibres. Once the fibres are sheared, the rest of the plant including the upper portion of the root, floats to the water surface. Once on the surface, the plants drift onto shore where most become unviable (MOE, 1992).

Although this method is more time intensive than harvesting, it is less socially intrusive and more effective; the removal of the root system allows treatment to be done less frequently, and because roots are removed, this method provides a better degree of control and for a longer period of time than harvesting and treatments in the same location may allow the re-establishment of native plant populations, due in part because their root systems are longer (Wallis and Maxnuk, 1983).

However, because this method uses a series of rotating metal blades to disrupt the lake bottom, the potential exists for adverse impacts on the environment. Any species and/or habitats in the upper 15 cm of the lake bed (e.g. mussels, turtles, fish eggs, benthic invertebrates) will be disrupted.

There is also the potential for the re-suspension of nutrients and other materials present in lake sediments which had become otherwise separated from the water column. A de-rooting operation typically causes silt to become suspended in the water column, resulting in localized, short-term turbidity (MOE, 1992).

Some sections of heavily developed shoreline of Nicola Lake could be untreatable/inaccessible due to the number of obstacles (docks, water lines, anchors, and other obstructions). A similar albeit smaller scale method of rototilling is known as shallow water tillage. This method is a de-rooting process which uses a tractor modified to operate in water depths up to 1.25 metres, to tow an agricultural cultivator. While this method is more restricted than rototilling in terms of operating depths, it can be less expensive per hectare of area treated and can access shallow, and/or confined areas not accessible to a rototiller (OBWB, 2013).

Rototilling (like harvesting, discussed below) is not selective, and it generates and spreads EWM fragments; therefore, it should be considered only after large, dense EWM beds have developed.

4.1.4 Harvesting

Harvesting mechanically cuts the top few metres of summer plant growth, effectively creating a shallow weed-free zone for up to a month. This method is limited to late spring and summer when plants are near the surface in large dense mats that can be seen by an operator, and when potential for conflicts with other water users is greatest. Harvesting is accomplished with floating, powered barges which cut and remove aquatic vegetation from the water. Harvesting removes only the stem and leaf portions of watermilfoil plants. The roots are left intact, and regeneration of new shoots begins immediately. Harvesters cut the growing shoots of EWM that are rooted in deeper water, which only provides a temporary measure since regrowth is rapid (Strange et al., 1975; Perkins and Sytsma; 1987, Wilson and Carpenter, 1997). Cutting EWM at the sediment surface (with divers) is more successful for controlling regrowth than clipping plants higher along their shoots (Livermore and Koegel, 1979; Cooke et al., 1986). The physical removal of the plants also creates the need to dispose of the material, as decomposition is unsightly and has an unpleasant odor.

Harvesting (like rototilling) is not selective. Harvesters cut and clear all vegetation in their path (including nan-target native species). However, harvesting is much less disruptive to the lake bed than rototilling, and would have fewer adverse impacts on other aspects of the environment. As EWM grows back at a much faster rate than native aquatic plants, the use of harvesters can speed up the process of invasion. Harvesting is a short-term cosmetic approach and because of rapid plant growth (up to 5 cm per day), multiple harvests in the same area may be needed each year.

Mechanical harvesting could be used selectively in areas where removal of the bulk of the plant mass from an infestation area would limit the potential for spread by fragmentation. For this method to be effective, a control team should be present to contain and control EWM fragments.

A sub category of harvesting includes the use of small-scale, specialised cutting methods/equipment, such as the Weed Razer[10] or Jensen Lake Mower[11]. These can be used to manage small EWM beds adjacent to waterfront homes and/or docks, and help address areas that the large floating harvesters are unable to access/treat. Like the large harvesters, these cutting methods are not selective, only remove the stem and leaves and create fragments. However, unlike harvestors, these methods cut the weeds close to the lake bed surface (generally more successful for controlling regrowth).

In summary, with almost any EWM control program, once started, the approach should be continued for the foreseeable future. One cannot expect to put resources in for one or two seasons and then be able to discontinue control work. In a large lake it will likely never be possible to locate and remove every EWM plant in the lake; there will always be plants left behind to maintain the population. The best condition that one can hope for is to put in a few years of maximum effort followed by several years of reduced effort to maintain the EWM biomass and percent cover at a low level.

4.1.5 Other Eurasian Watermilfoil Control Options

Details on lake drawdown, biological, and chemical control options are provided in Appendix 3.

4.1.6 Prevention

Prevention is the best EWM control option. Preventing the establishment and spread of EWM is more effective and economical than managing the impacts once it has established. Once established in a water body, EWM is very hard or impossible to eradicate. The same is true of individual EWM infestations, where prevention is certainly the most effective and affordable option. The RDKB milfoil control program includes regular surveys of other lakes in the district to prevent EWM infestations before they take place.

Evans et al. (2011) found that in a laboratory setting, even 100% dry (fully desiccated for 48 hours) fragments have a 0.02 probability of new growth, and that the new growth will likely form rootlets. Drying conditions in the environment, where fragments are clinging to watercraft may be very different than in this study. Fragments transported along with watercraft in wells, on bunks of trailers, and other locations are likely kept somewhat moist during transport. This emphasizes the need for continued vigilance on the part of educators and boaters because fragments that look, feel, and are dry may still be viable. Results of this study support the idea that efforts to prevent initial invasion are likely the best option for uninfected lakes.

Public education, signage, mandatory cleaning of watercraft, inspections, and focussing on boat launches for EWM control are all examples of sound preventative measures. Few studies have

[10] http://www.weedrazers.com/
[11] http://www.lakemower.com/

evaluated the efficacy of specific management interventions (e.g. boat launch stewards, boat washing). Implementation of these measures has the added benefit of reducing risk of other potentially invasive species (i.e. quagga or zebra mussel) to the region.

4.2 Electrofishing Surveys

According to the literature, the timing of the surveys was ideal, particularly for the May 29 survey, which corresponded to the key period for fish species of concern to be utilizing littoral areas. The literature review also highlighted fisheries information data gaps, most importantly the lack of knowledge of burbot life history and distribution (especially spawning and rearing habitat and timing). There was also minimal validation that could be found for the absence of kokanee shore spawning and little/none for the absence of Lake Trout[12] (shore spawners) in Nicola Lake.

Surface water temperatures during the summer sampling surveys were much warmer, (by 9°C, which put them well above the preferred temperature range for salmonids), and had corresponding lower dissolved oxygen levels.

Juveniles of fish species of "concern" for Nicola Lake, with potential (low to moderate) for temporal use of the littoral zone according the literature (CO, CH, KO, RB/ST and BB) were for the most part, not observed. The exception was a few Rainbow Trout juveniles captured at three sites during May sampling. As indicated in the literature, littoral areas are generally preferred habitat for coarse fish. Several coarse fish species within Nicola Lake, including young of the year Peamouth Chub, Redside Shiners, Largescale Suckers, Northern Squawfish, and Sculpin can be found close to shore (in the littoral zone). These species prefer warmer water temperatures which occur coincidentally with maximum macrophyte biomass. This was reflected in our catch results.

Large Scale Suckers were the dominant species during both spring and summer survey periods. There was a higher level of species diversity (albeit of "coarse fish") and more variation in catch results among sites during the summer surveys. The catch per site ranged from 0-16 fish/site during the summer survey, and from 5-10 fish/site during the spring survey. Although effort was consistent between sampling periods (slightly higher during the summer surveys), fewer fish were caught during the summer surveys. The average CPUE in the summer was 0.017 fish/sec (SD 0.015) compared to 0.025 fish/sec (SD 0.006) in the spring. Removing the two "outlier" sites (F3 and F6) where 54% of the fish were caught during summer surveys, results in an average summer CPUE of only 0.010 fish/sec (SD 0.007).

There could be some preferred aquatic habitat characteristic(s) at sites F3 and F6, since these two sites also had two of the three highest observations of mussel shell fragments, and were the only two sites where intact mussel shells were found. No unique/special habitat features were readily apparent at F3 or F6 during the surveys, although both sites are on the north shoreline and close to the SW end (near the lake outlet) and NE end (near the Moore and Stump Lake Creek confluences) of Nicola Lake respectively).

[12] Lake Trout have been observed in nearby Guichon Creek and in Farr and Alleyne Lakes (MOE, 2014f)

4.2.1 Temperature

Water temperatures during May surveys were within the preferred range (approximately 9 to 16°C depending on the species), so temperatures alone do not explain the general lack of salmonids caught in the spring. Temperatures during July surveys were well outside the preferred range of temperatures and would be one of the contributing factors to the lack of salmonids caught in the summer.

High water temperatures impact fish populations (especially cold water species such as salmonids) in Nicola Lake (Walthers and Nener, 1997). In July it was common for the water temperature to be above the preferred range of temperatures and there were even periods where the maximum guideline temperatures (19°C) were exceeded (MOE, 2006). Average temperatures at Nicola Dam exceeded preferred temperature ranges for rearing and migrating and spawning fish from early July to early September. Temperatures exceeded lethal tolerance range 21°C continuously for from July 20 to July 30 (Walthers and Nener, 1997).

4.3 Snorkel Surveys

No live mussels were observed at any of the survey sites during either spring or summer sampling period, despite all survey sites having substrate and depth characteristics known to be preferred mussel habitat. Although visibility conditions were less than ideal (particularly during spring surveys), observations of the lake bed up to 10 m from shore were acceptable during the spring surveys, and the lake bed through the entire 15 m width of the sites could be seen during the summer surveys (those areas not obscured by dense macrophyte beds).

There were intact mussel shells observed at two sites (F3 and F6) and fragments observed at seven of the nine sites. No discernable pattern in terms of substrate, depth or macrophyte distribution was observed. It is possible that river otters could be bringing mussels into the lake (R. McLean, 2014, pers. comm., May 29). This is a plausible explanation because otters are present in the lake (frequently seen by members of the Nicola Naturalist Society during their bird counts). Although fish, particularly slow moving species (e.g. suckers, shiners, northern pikeminnows) are their primary prey, mussels can also make up a portion of their diet. Interestingly, three of the four sites where the greatest number of fragments were observed, and the only two sites where intact shells were found, correspond to sites adjacent to the Nicola Lake outlet (F3), the confluences of Stump Lake and Moore Creeks (F6) and the confluence of the Upper Nicola River (F9).

Sculpins and Large scale suckers were observed during both May and July snorkel surveys. Redside Shiners were abundant and generally associated with macrophyte beds (at site F6) during the July survey.

4.3.1 Habitat

Salmonids and EWM generally occupy separate habitats, so it is not entirely unexpected that more juvenile salmonids were not observed during the surveys. In addition, most sites had a combination of one or more of the following habitat characteristics generally considered

unfavourable/ unsuitable for juvenile salmonids: lack of habitat complexity, lack of riparian and/or lakebed cover elements, and high disturbance/human activity.

5.0 Summary and Recommendations

5.1 Summary

The 2014 fish utilization assessment was successfully completed. The assessment describes the fish assemblage utilizing the littoral zone in areas with >21% EWM, and discusses management options that will have the least effect on fisheries resources.

The assessment sampled a very small percentage of the Nicola Lake's shoreline (1.7% by length), during a short period (i.e. a snapshot in time); therefore, site survey/catch data alone at this point is insufficient to categorize areas as "high", "medium" or "low" for shore spawning or juvenile rearing zones with any certainty. The habitat observations during the surveys and the available literature on species life history do provide some baseline information towards these habitat ratings.

Based on the results of this assessment (both the literature review and the field surveys), the use of salmonids during potential "high-risk" EWM control treatment periods (i.e. winter rototilling or summer harvesting) is unlikely, and the presence of mussels is also unlikely.

The data from this assessment appears to indicate that fish species of concern and freshwater mussels in Nicola Lake are unlikely to be in conflict with (i.e. would not preclude) EWM control options provided the necessary mitigative measures are in place. These findings are in agreement with current EWM control programs on other lakes in BC with similar fish species assemblages. A caveat to the above interpretation is that little is known about Kokanee and Burbot population life histories in Nicola Lake. Once this information on critical/high value habitats (e.g. spawning) is obtained, no rototilling/derooting activities should occur in known spawning habitat, or at stream mouths during known times of staging or holding.

5.2 Recommendations

Based on the results of the fisheries utilization assessment, Triton has identified the following recommendations to assist with developing and implementing a EWM control program for Nicola Lake.

5.2.1 Eurasian Watermilfoil Control Program Objectives

Goal #1 of the NLAP is to "Control Invasive Species in Nicola Lake", with the objective being "Begin a management regime for EWM in high use areas"

- Consider providing some background context with the above objective (e.g. "limit or stop the expansion of EWM populations into new littoral areas" and "minimize negative impacts of EWM on the environment, recreation and the economy".
- Keep the management objective current and involve stakeholder groups to ensure the objective remains the consensus of the community.

5.2.2 Control methods

- Implement diver control[13] (hand pulling and cutting where necessary). It is a slow, but low risk, low impact and relatively low cost option. Utilize floating (segment collection nets) while conducting control activities.
- If after a few years of diver control, the program is deemed ineffective/not meeting the desired objectives, consider a combination of diver hand removal, controlled cutting and community plant removal projects, and possibly a focussed amount of mechanical control or biological control (if available) in certain areas.
- Create a comprehensive set of maps of EWM areas from existing survey and GPS track data. These maps should include numbered polygons of all milfoil control areas, treatment prescriptions and work zones for species of concern.
- Conduct annual surveys (building on Golder's 2013 inventory data) and provide annual reports on the treatment provided each year.
- Closely monitor research developments into potential bio-control methods (milfoil weevils and the reintroduction of native plants).
- Whichever control method(s) is/are selected, it is important that they be implemented considering scientific method/study design criteria so that any treatments can be effectively monitored and evaluated.
- Conduct regular (annual or biannual) EWM diver and/or surface surveys in surrounding lakes in the District, to monitor for new potential EWM introductions/infestations. This could be part of a larger Thompson Nicola Regional District EWM control program/ initiative.

5.2.3 Permitting and Work Windows

The following is sourced largely from the *Okanagan Basin Water Board Eurasian Watermilfoil Control Program, Operational Plan and Policy Manual - 2013* (OBWB, 2013) and is intended as a guide for what could be included in a similar document for Nicola Lake.

- Obtain approval from the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) under the *Water Act*, Section 9 for EWM control works.
- Develop an Environmental Management Plan for EWM Control in Nicola Lake. The plan should include risks to fish and species at risk and their habitats based on specific development activities. The plan should also designate areas of the foreshore according to the value of the habitat and presence of species at risk.
- Regularly monitor the Conservation Data Centre (http://www.env.gov.bc.ca/cdc/access.html) and Species Inventory Databases (http://www.env.gov.bc.ca/wildlife/wsi/siwe.htm) for updates on species sightings.

[13] At the time this document was being prepared, diver control treatment(s) were already being implemented by the NLSC. The Monck Park boat launch and the Kamloops Sailing Association were both slated for diver control treatments in the summer of 2014.

- MFLNRO requires that work in the lake follows the timing windows of least risk. The work windows are general timing guidelines based on the fish species present in the lake. The timing windows can be downloaded from the province's website.

5.2.3.1 Fish

- All activities that have a risk of depositing sediment into fish streams, must be undertaken within a window of least risk to fish and fish habitat. Windows of least risk are designed to protect all fish species known to occur in a stream. For Nicola Lake, the fisheries work window (based on the general species work windows) would be July 22 to August 15. Additional information on fisheries work windows can be found at: http://www.env.gov.bc.ca/wsd/regions/thr/wateract/

5.2.3.2 Mussels

- Harvesting is allowed in known areas of mussel habitat if works are done when the water temperatures are greater than 16°C.
- No rototilling/de-rooting is allowed to occur in known mussel habitat.

5.2.3.3 Turtles

- There are no work window restrictions for harvesting in known turtle habitat.
- Rototilling/de-rooting must occur during the work window of April 1-October 15. This is to avoid de-rooting practices during hibernation.

5.2.3.4 Other Species (Including birds)

- Confirm annually where there is any concern with practices and other species by using the Wildlife observation records through the Conservation Data Centre for species at risk, and the Habitat Wizard (http://www.env.gov.bc.ca/habwiz/) provides observation records for other species. Most species of wildlife are at their highest risk for disturbance during the period where they raise their young. Some may be at risk during their dormant or hibernating period.
- work within designated work windows as indicted at: http://www.env.gov.bc.ca/wsd/regions/thr/wateract/

5.2.3.5 General for all species

- If works are proposed outside the listed windows the proponent must engage a qualified professional to assess species and habitats present and determine if a site specific plan can be developed to ensure compliance with all legislation.

5.2.4 Partnerships

- Pursue partnerships with OBWB, CSRD and RDKB to benefit from their knowledge and experience. There may be opportunities to borrow equipment and/or cost share operating and maintenance costs for equipment (if in the future this becomes necessary).

- Pursue research partnerships (e.g. universities). There could be opportunities for EWM-related studies. For example: a study comparing the specific environmental conditions a selection of EWM sites to their plant populations over a period of time, could help determine why infestations favor certain locations, which in turn would assist in developing a more informed EWM control program.
- Pursue volunteers and community support. There could be opportunities to have volunteers or community groups harvest discrete areas (avoid areas where macrophyte growth is predominately native species) using a small "Lake Mower" (http://www.lakemower.com/) type unit, with support/oversight from the NLSC diver program and employing a floating net system.

5.2.5 Eurasian Watermilfoil Awareness and Spread Prevention

There are public awareness initiatives already underway, but there may be a need for a more comprehensive and coordinated effort across the Region. It is important to connect and engage with the public for transparency, productive dialogue, and potential cooperation.

- Operate a boat wash/inspection station[14] or stations. Considering that Nicola Lake is an infested lake, effort should go into prevention of the spread of EWM.
- Install signage, on Highway 5A and on all boat launches.
- Consider the deactivation of some boat launches. Patterson and Schleppe (2012) identified 15 boat launches on Nicola Lake.
- Conduct EWM Control Workshops, and develop cooperative control projects.
- Consider using both mail and in-person surveys to poll registered boaters in the area/district about boat launching and cleaning practices.
- Distribute EWM control "calling cards". For example: if divers are unable to speak with residents during the course of their control activities, they can leave a card that informs the home owner about the EWM program and provides them with the appropriate contact for more information.
- Address dock structures that are not in compliance, those that do not have tenure and those structures that do not meet the standards as laid out in the private moorage permission document. (www.for.gov.bc.ca/land_tenures/tenure_programs/programs/privatemoorage/private_moorage_general_permission.pdf)

5.2.6 Information gaps

The following information gaps were identified during the course of the Fisheries Utilization Assessment (including the literature review and interviews). Once these gaps have been addressed, the information/findings should be incorporated into the EWM management plan.

[14] A boat wash station program (operated by the NLSC and employing summer students) is already into its second year of operation. The well received program also serves as a means to educate the public about Nicola Lake (Merritt Herald, 2014).

- Identify Burbot spawning and rearing habitat, and time periods. No burbot studies have been completed to date for Nicola Lake (A. Morris, 2014. Pers. comm. September 15).
- Determine Kokanee spawner distribution, enumeration and confirm the absence of shore spawning. As mentioned in Section 3.2, there is no confirmed foreshore spawning for kokanee to date; however there is likely some foreshore (or nearshore) use based on the fact that so few stream spawners are seen for a lake the size of Nicola (A. Morris, 2014. Pers. comm. September 15). If shore spawning Kokanee are found to be present, identify/map areas and time periods.
- Confirm presence/absence of Lake Trout in Nicola Lake (if found to be present, identify/map spawning habitat and time periods).
- Improve understanding of life histories for other species at risk with the potential to utilize the littoral/shoreline of Nicola Lake (e.g. Painted Turtles, Great Basin Spadefoot Toad, Western Toad).
- Conduct periodic surveys (biannually) for mussels. This can be done in coordination with diver EWM control activities. If possible surveys should focus on the window when temperatures are > 16°C, but before macrophyte growth is too developed. Survey site F1 (Kamloops Sailing Association) should be a priority, as visibility was poor during the spring 2014 survey.
- Determine the sources of the nutrient inputs into Nicola Lake and its tributaries. This is an objective under Goal #2 of the NLAP (Improve/maintain Water Quality in Nicola Lake”).

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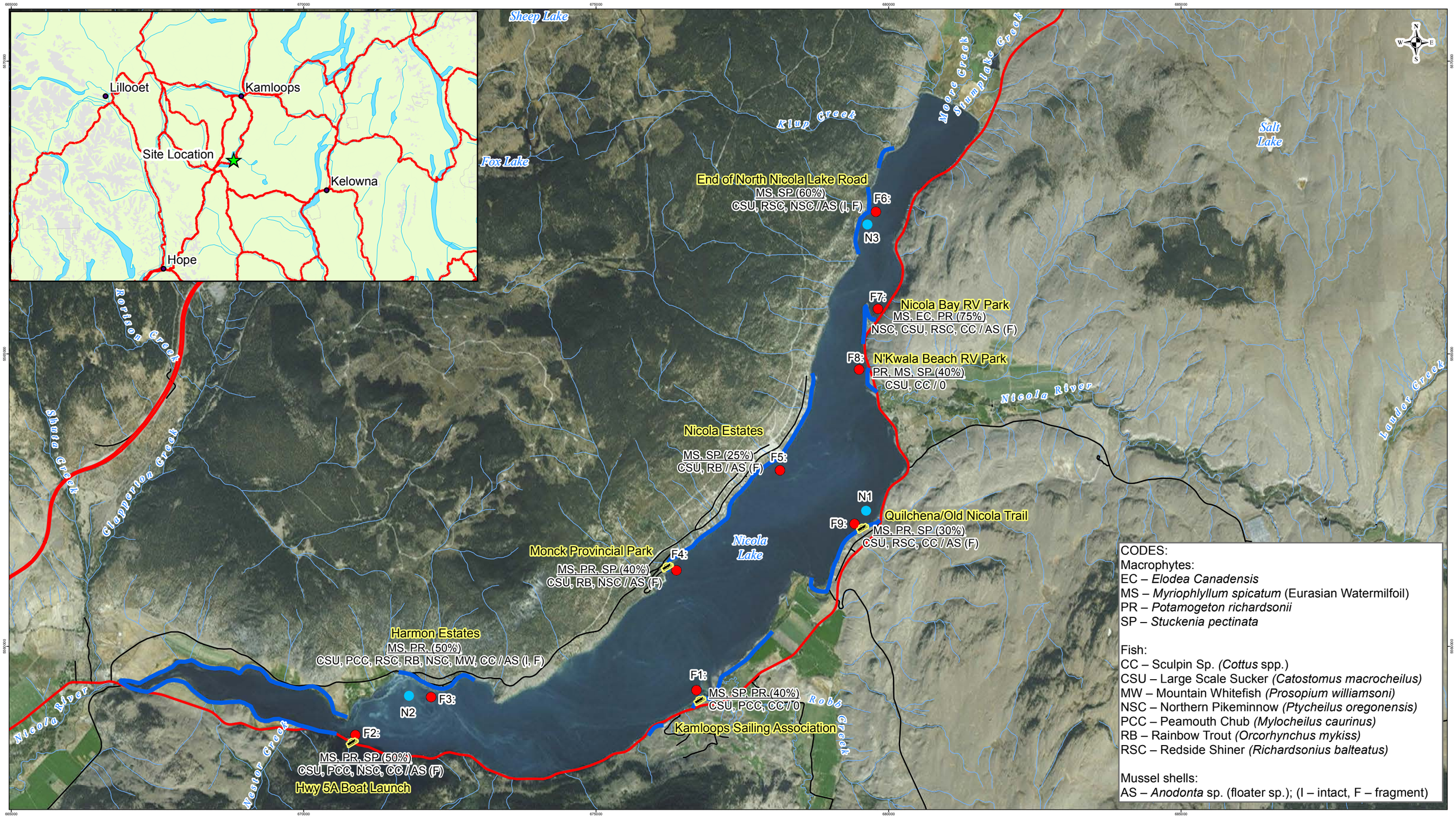
APPENDIX 1

NICOLA LAKE SURVEY LOCATIONS



Legend

- Fisheries Survey Locations
- Temperature Loggers
- Areas of Concern (high use/value) as indicated by the Public
- Boat Launches
- Highways
- Paved Roads
- Macrophytes (% coverage)
- Fish and Mussels (shell condition)

Fraser Basin Council

TRITON ENVIRONMENTAL CONSULTANTS LTD.

NO.	DATE (mm/dd/yyyy)	REVISION	BY
1	08/14/2014	Rev 1	DM
2	10/06/2014	Rev 2	DM

Nicola Lake Fisheries Utilization Assessment

Nicola Lake Survey Locations

File No: N:\ACTIVE\4970_FraserBasinNicolaLake\MXD\NicolaLakeSurveyLocationsInset.mxd

Basemap Source: ESRI World Imagery **Map Datum:** NAD 1983 UTM Zone 10N

Project No: 4970 **Date:** Oct 06, 2014

1 0.5 0 1 2 3 4 Kilometers

Scale: 1:60,000

APPENDIX 2

PHOTOGRAPHS

Photo A: Site F1 (Sailing Association) – looking east at site (29-May-14)

Photo B: Site F2 (Hwy 5A Boat Launch) – looking south at site (29-May-14)

Photo C: Site F3 (Harmon Estates) – looking east at site (29-May-14)

Photo D: Site F4 (Monck Park) – looking north/west at site (29-May-14)

Photo E: Site F5 (Nicola Estates) – looking east at site (29-May-14)

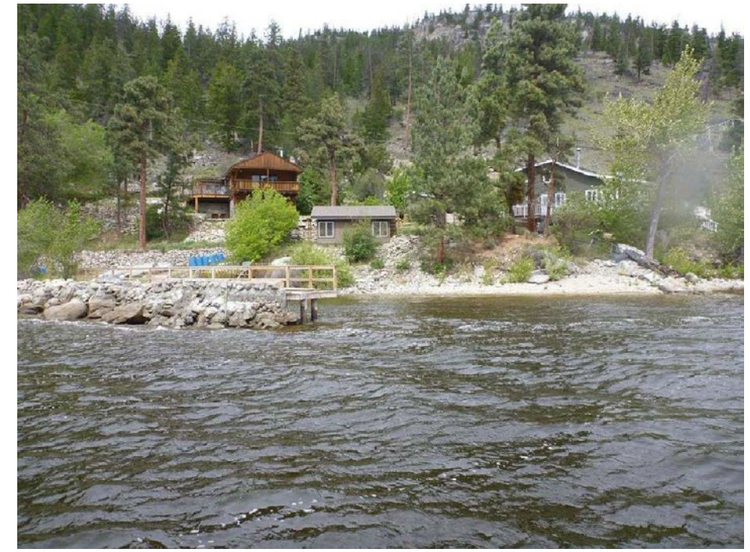


Photo F: Site F6 (end of N. Nicola Lake Rd.) looking north at site (29-May-14)

	Project Number: 4970	Date: August 2014	PROJECT: **Nicola Lake Eurasian Watermilfoil Management Planning - Fisheries Utilization Assessment**
	Fraser Basin Council	Drawn By: AH Field Photos May/July 2014	TRITON ENVIRONMENTAL CONSULTANTS LTD. — **Figure 1: Sites F1 – F6**

Photo A: Site F7 (Nicola Bay [N]) – looking southwest at site (29-May-14)

Photo B: Site F8 (Nicola Bay [S]) – looking southwest at site (29-May-14)

Photo C: Site F9 (Quilchena/Old Road) – looking southwest at site (29-May-14)

Photo D: Electrofishing boat set-up – (29-May-14)

Photo E: Snorkel surveyor - (29-May-14)

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	Fraser Basin Council	Drawn By: AH Field Photos May/July 2014	TRITON ENVIRONMENTAL CONSULTANTS LTD. — **Figure 2: Sites F7 – F9, EF and Snorkel**

Photo A: Large Scale Sucker at site F6 (29-May-14)

Photo B: Rainbow Trout at site F3 (29-May-14)

Photo C: Northern Pikeminnow at site F6 (29-May-14)

Photo D: Redside Shiner at site F3 – (29-May-14)

Photo E: Peamouth Chub at site F3 - (29-Jul -14)

Source USGS http://pubs.usgs.gov/sir/2006/5111/figure5.html

Photo F: Mountain Whitefish like observed at site F3 - (29-July-14)

	Project Number: 4970	Date: August 2014	PROJECT: **Nicola Lake Eurasian Watermilfoil Management Planning - Fisheries Utilization Assessment**
	Fraser Basin Council	Drawn By: AH Field Photos May/July 2014	TRITON ENVIRONMENTAL CONSULTANTS LTD. — **Figure 3: Fish examples**

Photo A: Intact Floater (*Anodonta sp.*) shell at site F3 (29-May-14)

Photo B: Intact Floater (*Anodonta sp.*) shell (#1) at site F6 (29-May-14)

Photo C: Intact Floater (*Anodonta sp.*) shell (#2) at site F6 (29-May-14)

Photo D: Sculpin sp. at site F9 – (29-May-14)

Photo E: Large Scale Sucker at site F6 - (29-Jul -14)

Photo F: Redside Shiners at site F6 - (29-Jul -14)

	Project Number: 4970	Date: August 2014	PROJECT: **Nicola Lake Eurasian Watermilfoil Management Planning - Fisheries Utilization Assessment**
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APPENDIX 3

ADDITIONAL EWM CONTROL METHODS

Lake Level Drawdown

At the request of the FBC, the idea of using the control structure at the outflow of Nicola Lake to drawdown the water level and expose shallow macrophyte communities was investigated.

Examples from BC of where this method has been tried could not be found, although in Osoyoos Lake, which generally has a largely variable operating lake level range, there are several areas that are either exposed to the air, or covered in ice over the winter; and each year the milfoil grows back. These are anecdotal observations, but seems to point to milfoil being resilient. The idea has been studied for Shuswap lake, but the drawdown would have to be below the level of the deepest milfoil (likely 10 m) and it would have to stay that low for an extended period (possibly years; J. Littley, 2014. pers. comm. July 25).

There are multiple issues that would make the lake level drawdown method difficult, and likely unsuccessful in Nicola Lake. Given the depth of Nicola Lake and the level of the outflow outlet of the dam, the lake could only be lowered to expose less than half of the EWM in most areas (Golder, 2013). Drawing the lake down below normal seasonal levels would also create the possibility of a drought. EWM's maximum growth occurs when the need to conserve water and maintain reservoir levels is highest. There is already insufficient water for both irrigation and fish (instream flow needs) during summer and early fall low flows. Multiple issues and concerns related to water use within the Nicola watershed have been identified and described within the Nicola WUMP (2010). Some of the key aquatic environmental issues identified for Nicola Lake include:

- Low summer reservoir levels restricting tributary access for spawning salmonids (i.e., kokanee, chinook, coho, pink salmon, and trout),
- Condition of burbot spawning and rearing habitats along the shoreline;
- Low reservoir levels impact on forage fish species populations (i.e., chub, shiner, northern pikeminnow), which may affect food availability for predator species (i.e., burbot, bull trout, rainbow trout);
- Low reservoir levels may restrict fish passage at the dam; and,
- Potential changes to littoral productivity.

The drawdown would likely be more detrimental to many other species in the substrate (native macrophytes, turtles, mussels, fish eggs) and habitats along the shoreline. Low reservoir levels in spring have the potential to affect staging habitat for waterfowl and fluctuating reservoir levels may affect nesting habitat.

In any event, the EWM roots would likely stay dormant (as a small percentage of stem fragments can remain viable after desiccation; [Evans et al., 2011]), or would re-establish quickly, and the roots would grow deeper in the remaining water, as the plant is dependent on light penetration.

Biological Control

Biological control agents for EWM control are not for the most part an operational option for a control program in BC. There are biological control agents that show promise in the laboratory, but have yet to reach an operational status in BC. Research into the milfoil weevil

(Euhrychiopsis lecontei) has made great progress, to the point where stocking of milfoil weevils is now seen as a viable method of EWM control, and has been used successfully in several lakes in the United States (Caswell, 2010). For example, a milfoil weevil augmentation project (Parsons et al., 2000) took place in Mattoon Lake in central Washington. During the project, EWM levels decreased significantly, and other aquatic plant species did not change or increased. The milfoil weevil took five years to establish, during which time a midge population controlled EWM growth. The fish community changed from domination by small sunfish to a balanced community of predator and prey fish. Fish diet analysis indicated that fish predation impacted herbivorous invertebrate populations. Their study supported the theory that fish and herbivorous invertebrates influence lake food web interactions.

Studies indicate that for effective control, a density of about 1 weevil per two stems of milfoil (as many as 100 weevils/m^2 is necessary (Jester et al., 2000). There are also mixed reports that fish can reduce weevil populations, as research has only been conducted in very limited settings. *Euhrychiopsis lecontei* was positively identified as a species native to Christina Lake, and there is ongoing research (RDKB/UBC) to pursue the integration of a biological control component in their EWM control program. Future research goals include implementation of a weevil rearing program and investigations into aquatic re-vegetation using native plants (Caswell, 2010).

Ongoing research into biological control options and native aquatic plant re-vegetation show great promise, and progress on the development of these bio-control methods should be closely monitored.

Chemical Control

Similarly to biological control, chemical control of EWM is also not currently an operational option for a control program in BC.

Aquatic herbicide application studies (treating EWM beds with 2,4-D) were conducted in the 1980s and 1990s in Okanagan Lake. The research proved the technique to be largely ineffective, in that the plants died off, but came back thicker the following year (J. Littley, 2014. pers. comm. July 25).

While there are a number of effective aquatic herbicides on the market, the majority of these products are not registered for use in Canada, and no permitting process currently exists for the large scale use of aquatic herbicides in Canada. Although they may be cost effective, aquatic herbicide use is currently not permitted in Canada and would generally be an unpopular option in most communities, with concerns about drinking water safety and potential environmental impacts.

There is a new chemical being developed in the United States (Washington), that apparently has a short half-life (18 hrs) and is quite selective (J. Littley, 2014. pers. comm. July 25), but as mentioned above, there are still many issues surrounding the use of aquatic herbicides in Canada. As with the research into bio-control options, it would be prudent to monitor research developments into potential chemical treatments as well.