Lake Windermere
Aquatic Invasive Species Sampling
2016

Prepared for Lake Windermere Ambassadors

November 2016

Prepared by Rachel Darvill, BSc., MSc.
Goldeneye Ecological Services

Table of Contents

List of Tables

List of Figures

1. Introduction/Background

1.1. Invasive species

An invasive species is a plant, animal, or fungus species that is deliberately or unintentionally introduced into an area that is outside of their natural habitat (ISCBC, 2014). Invasive species can spread rapidly and cause severe environmental, economic and social harm (ISCBC, 2014). Invasive species are considered to be a major cause of extinctions worldwide, for instance, they are implicated to be the main cause of bird extinctions in recent years (Pimm et al., 2014).

Invaders have numerous pathways of invasion including transportation corridors (e.g. roads and railways) and the horticultural trade that spread terrestrial invasive plant species. Additionally, invasive mussel larvae (veligers) can be introduced into a new waterbody with retained ballast water in boat tanks; trailering boats for recreational pursuits continue to be an important vector for aquatic invasive species such as Eurasian Watermilfoil (*Myriophyllum spicatum*) and Zebra Mussel (*Dreissena polymorph)* (Rothlisberger, Chadderton, McNutty, & Lodge (2010).

Aquatic invasive species (AIS) are a major threat to our aquatic and riparian ecosystems, as well as to the species that rely on aquatic ecosystems and associated native aquatic plants for food, shelter and breeding. Aquatic invasive species can also be detrimental to humans in terms of the decreased availability of ecosystem services. An ecosystem service is a benefit that a human acquires from nature and is required in order that human well-being continues to persist (Daily, 1997). Examples of ecosystem services that are negatively affected by AIS include water filtration, water purification, flood control, fisheries values, recreational opportunities, water purification services and aesthetic values (Vila, Basnou, Pysek & Josefsson, 2010).

Additionally, AIS introductions can cause significant economic degradation as evidenced by the Zebra Mussel's (*Dreissena polymorph*) costly economic impacts on infrastructure such as hydroelectric dams and drinking water facilities; estimated at billions of dollars of direct damage in the Great Lakes region (O'Neill, 1997) alone. Zebra mussels (*Dreissena polymorph*) are the cause of great environmental and economic harm in Eastern Canada due to their rapid spread ever since their introduction to the Great Lakes in the mid-1980's (Ludyanskiy, McDonald, & MacNeil, 1993). Hundreds of millions of dollars are spent annually in the Great Lakes region in pursuit of their eradication and attempts to control their rapid spread (The Nature Conservancy, 2016).

1.2. Aquatic invasive species in the Columbia Basin

Several AIS have now made their way into waterbodies within the Columbia Basin and are spreading, for example, Eurasian Watermilfoil (*Myriophyllum spicatum*), Yellow Flag-Iris (*Iris pseudacorus*), and Yellow Perch (*Perca flavescens*) (Craig, 2015). However, to-date and according to the report by Craig (2015), only aquatic invasive fish species have been detected and reported in the Columbia Wetlands ecosystem, which includes Lake Windermere and

Columbia Lake. The invasive fish species reported in the Columbia Wetlands have been identified as Northern Pike located in the Parson area (Craig, 2015), as well as Largemouth Bass in Lake Windermere and Columbia Lake, with additional Pumpkinseed Sunfish reported in Columbia Lake.

At present, there is a major effort underway throughout the province of British Columbia (BC) working to prevent new aquatic invaders from entering the province. The 'Canadian Columbia Basin Regional Framework for an Aquatic Invasive Species Program: 2015 to 2020' (Craig, 2015) is assisting to guide the regional effort to prevent the spread of AIS in the Canadian portion of the Columbia Basin. This effort includes inventories for AIS, the utilization of the 'Clean-Drain-Dry' educational campaign, and the decontamination of infected boats at watercraft inspection stations located in BC (eight stations in 2016) operated by provincial government staff (Province of BC, n.d). In 2016, the eight stations spread across the province inspected 24,100 watercraft; 17 boats inspected were carrying adult invasive mussel species (Province of BC, n.d). Ten of the infested boats were found in Golden, BC (CSISS, 2016).

1.3. Aquatic invasive species sampling in Lake Windermere

Lake Windermere is a part of the Columbia Wetlands ecosystem located within the Canadian portion of the Columbia River Basin. In order to collect baseline data on invasive plants in the Columbia Wetlands region, Wildsight's Columbia Headwaters Invasive Plant Species Project (CHIPSP) was successfully implemented in 2008. Previous to the CHIPSP no baseline data existed for AIS in this region, although there was a two-part historic study completed on the aquatic macrophytes (plants rooted in shallow water with vegetative parts emerging above the water surface) of Lake Windermere (Hawthorn, 1973; Hawthorn & McCormick, 1972). To date, aquatic invasive plant species have not been detected in Lake Windermere or the Columbia Wetlands, although a need exists to be diligent in efforts of preventing and detecting any new invaders.

Increased population growth, the technical evolution of trailering motorized/non-motorized boats, and the growing popularity of boating on Lake Windermere, has resulted in the lake having an ever-increasing potential of introducing AIS into the Upper Columbia River. There could be significant environmental, societal and economic consequences with the introduction of additional AIS in Lake Windermere. Any invasive species introduced here could rapidly spread to other portions of the Columbia Wetlands and Columbia Basin with costly implications to the entire Upper Columbia River system; including negative effects on biodiversity values, impacted social activities including recreational pursuits, and negative economic burdens that could include costly damage to downstream dam infrastructure.

The year of 2016 marked the seventh successive year (exception of 2013) of aquatic plant monitoring on Lake Windermere for the purpose of detecting aquatic invasive plant species. This was the second year that this study included offshore surveys utilizing boat travel, and the second year that the East Kootenay Invasive Species Council (EKISC) assisted with veliger sampling for invasive mussel species (zebra and quagga) detection. The Ministry of Forest Lands and Natural Resource Operations also initiated sampling for invasive mussels on Lake

Windermere in 2015 (Linda McVetty, personal communication, September 17, 2015). The author is unsure if this provincial effort continued on Lake Windermere in 2016. Both the Columbia Shuswap Invasive Species Society (CSISS) and East Kootenay Invasive Species Council (EKISC) have been monitoring for aquatic invasive plants on additional lakes located within in the Columbia Valley (in 2015 and 2016). Both EKISC and CSISS have not detected AIS in the Columbia Wetlands ecosystem to date.

The purpose of conducting AIS monitoring on Lake Windermere in 2016 is to sample both offshore and onshore locations for AIS such as Eurasian Watermilfoil (*Myriophyllum spicatum*), Curyleaf Pondweed (*Potamogeton crispu*), Zebra Mussel (*Dreissena polymorph*) and Quagga Mussel (*Dreissena bugensis*). Continuing to sample for AIS on an annual basis on Lake Windermere will facilitate a rapid response for any detected species within this high risk lake ecosystem.

2. Study Area

Lake Windermere (UTM: 0571182; 5590080) is located approximate 30 kilometers north (downstream) of the source of the Columbia River, located in Canal Flats. The Columbia River is approximately 2000 kilometers long and is the largest river in the Pacific Northwest with 14 large hydroelectric dams on the Columbia River along its course (Wikipedia, 2016a). Lake Windermere is approximately 14 kilometers long and 1-2 kilometers wide. The village of Windermere (pop: 1300) is located along the east side of the lake, and Invermere (pop: 4000 permanent residents) is the community situated at its north end. The community of Invermere's summer population expands to approximately 40,000 people on summer weekends (Wikipedia, 2016b).

Portions of Lake Windermere could be classified as a shallow open water wetland as there are the portions of the lake where water levels are within a range that is able to create habitats that sustain floating and aquatic vegetation (Zoltai & Vitt, 1995). The deepest section of Lake Windermere is located near the northwest end of lake and its maximum depth measures approximately 6.4 meters deep (Megan Peloso, personal communication, November 28, 2016).

Lake Windermere is also part of the Columbia Wetlands ecosystem. The Columbia Wetlands is a Ramsar site that has significant biodiversity values providing habitat for several at-risk species (e.g. Wolverine, Common Nighthawk, Grizzly Bear), and is an integral component of the Pacific Flyway for migrating birds. The Columbia Wetlands have been internationally recognized by the International Convention on Wetlands (also known as the Ramsar Convention) as one of three wetlands in British Columbia with international significance. The Columbia Wetlands is a continuous mosaic of diverse wetlands, aquatic and riparian habitats, including open water, river channels, sloughs and marshes. These extensive wetlands of the upper Columbia River are one of the longest continuous wetlands in North America, the only remaining natural portion of the Columbia River within Canada.

Approximately half of the Columbia Wetlands lie within with the Regional District of East Kootenay (Areas F and G) with the remaining half in the Columbia Shuswap Regional District (CSRD) Area A. The entire wetland complex, its ecosystem services and its habitat value to

wildlife is under cumulative stress from a variety of threats including urban/rural development, agriculture, increasing recreational activities, and invasive species. Climate change is expected to have additional broad and negative impacts with increasing fluctuating water levels, resulting from more severe weather events (Environment Canada, 2013).

3. Methods

3.1 Shoreline surveys

Previous years (2009-2014) of monitoring for AIS on Lake Windermere followed a monitoring protocol outlined by Darvill (2015). However, due to the recent and growing attention given to AIS by multiple agencies, specific protocols have now been developed for sampling specific species of AIS in BC. In order to maintain consistent sampling methodology throughout BC, survey methods as outlined in the guide entitled 'British Columbia Aquatic Invasive Species Survey Methods' (Inter-Ministry Invasive Species Working Group (IMISWG), 2015) were adopted in 2015 and 2016.

Shoreline sampling occurred at six monitoring locations located at Lake Windermere. In total, seven stations (2 rake pulls/station) were sampled at each of the six locations. Each location was considered to be a high risk for AIS introduction. High risk sites were those areas that have a high amount of trailered boat traffic (boats are coming in from other areas), public boat launches, boat marina's, or boat docks with multiple slips. GPS coordinates were recorded at each station.

In some cases it was not possible to sample at all seven stations per location, due to obstructions such as private property at the Fairmont side channel, or bushy riparian vegetation along the shoreline at Althalmer/Pete's Marina. The six shoreline locations sampled were: Baltac Beach, Fairmont Side Channel (in Fairmont), Rushmere Community Docks, end of Ruault Road, Calgary Beach and Althalmer/Pete's Marina. All shoreline sampling was conducted over a seven hour period on September 12, 2016. A volunteer was enlisted to assist with the vegetation surveys at all shoreline locations.

At each station, a thatched rake with a 9.7m long rope was use for sampling aquatic plants in the water. Rake pulls occurred at the "initial feature" (e.g. public boat launch) as well as at three places located both upstream and downstream of the "initial feature", and separated by 25 meters. The rake was thrown into the water as far as possible and pulled back to the shoreline, enabling the rake to gather plants located along the lake bottom (see Figure 1). All aquatic plants collected on the thatched rake were recorded to include the family level and where possible, the species level identified. Two rake throws were conducted at each monitoring station.

Figure 1. Native aquatic plants collected with a rake toss.

3.2 Offshore sampling

An aluminum boat utilized for AIS sampling on Lake Windermere was piloted by the Program Coordinator of the Lake Windermere Ambassadors (LWA) (Megan Peloso). Offshore sampling for aquatic invasive plants occurred over a two-day period, September 14th and September 15th. On September 14, 2016, aquatic invasive plant offshore surveys were conducted at seven high-risk locations. As with shoreline surveys, high risk locations for offshore AIS sampling were considered as those areas with an increased incidence of trailered boat traffic (boats coming in from places other than Lake Windermere), public boat launches, boat marina's or boat docks with multiple slips. Sites sampled for AIS on September 14th were: Rushmere, Lakeshore Resort, Ruault Road, Indian Beach, Tretheway Docks and Akiskinook Resort Docks. On September 15th, four sites were monitored for aquatic invasive plants: End of Coy Road, Baltac Beach, Lakeview Meadows, Althalmer/Pete's Marina.

To ensure consistency of surveys repeatable over time, we followed IMISWG (2015) methods for lake boat sampling when possible. However, given the large geographic scale of Lake Windermere and limited human/financial resources, a modification was adapted to the IMISWG protocol (as was also done with the previous study in 2015), omitting the recommendation to conduct contiguous surveys every 100 meters, as recommended in the IMISWG (2015) protocol. Rather survey efforts were focused at high risk locations as described

above, where AIS introductions are most likely. Two rake pulls per high risk location were conducted, alternating throws off each side (right and left) of the boat.

Additionally, another necessary modification to the protocol was adopted as we did not have access to an underwater viewer, snorkelling or scuba gear. Rather, surface visual observations into shallow water were conducted to optimize the potential for detecting small isolated infestations (IMISWG, 2015). These observations were made by recording all plants visually located along a transect at the high risk sites, starting at the initial survey points (where rake tosses occurred) and moving 100 meters parallel to the shoreline. GPS coordinates were collected at the initial survey (rake toss) locations, as well as at the end of the 100 meter transect.

In 2015, an unknown microfilamentous algae species was detected at two locations on Lake Windemere; at the rock weir near Althalmer and attached to rock substrates on the lake bottom, located in front of Pete's Marina. These sites were revisited in 2016 to sample for the presence or absence of this previously documented species.

3.3 Mussel veliger sampling

An EKISC staff member conducted veliger sampling for both Zebra Mussel (*Dreissena polymorph*) and Quagga Mussel (*Dreissena bugensis*). This was done from the boat at two locations on Lake Windermere on September 14th, 2016. Methods followed the protocol as outlined by IMISWG, 2015. Using a plankton tow net, vertical plankton tows were conducted at two station locations: 1) four samples were collected at the centre of Lake Windermere (UTM: 0571044; 5590679, 3m of water column collected) and placed into a jar (see Figure 2). Four samples were collected 80m offshore Calgary Beach (UTM: 0569448; 5595038, 12.2m collection of water column). Additionally, on September 15th, 2016, the EKISC staff member conducted a plankton tow from the boat bock located at Pete's Marina (UTM: 0569511; 5596463). All samples were put into glass jars and shipped by the EKIPC to a lab for analysis.

Figure 2. Water sample collected for detecting invasive mussel larvae.

4. Results

4.1 Shoreline sampling

No aquatic invasive plants were detected during the monitoring effort that took place along the shoreline of Lake Windermere in 2016. While AIS detection is the primary focus on this study, all native plant species that were collected through rake pulls are listed on Tables 1 and 2. The *Najas sp.* (water nymph) detected were likely *Najas flexilis*, since previous reports document this species (Hawthorn, 1973). Also detected were aquatic moss, unknown fish species and native mussel species. All Watermilfoil species (*Myriophyllum sp.)* detected had nine or less leaflet pairs per leaf. Native Watermilfoil species has 5-10 leaflet pairs, whereas Eurasian Watermilfoil (*Myriophyllum spicatum*) has leaves with 12-21 leaflet pairs (Minnesota Sea Grant, 2016). Therefore, all Watermilfoil species (*Myriphyllum sp.)* found were assumed to be native species. A high amount of native aquatic plant biomass was detected at Pete's Marina, as has been detected in previous years of survey effort (see Figure 3). During shoreline sampling, some AIS signs were detected at some of the survey sites (see Figure 4a and 4b) such as Calgary Beach, Fairmont Side Channel and Althalmer/Pete's Marina.

Figure 3. Native aquatic plant bed found off boat docks at Pete's Marina.

4.a.

4.b.

Figure 4.a. Aquatic invasive species signage located at Calgary Beach in Invermere.
Figure 4.b. Aquatic invasive species signage located at the public boat launch at Althalmer.

4.2 Offshore sampling

All offshore sampling resulted in the detection of no aquatic invasive plant species. There were however multiple beds of dense native aquatic plants, as evidenced at Ruault Road densely populated with native *Myriophyllum sp.* (see Figure 5). While AIS detection is the primary focus of this study, all native aquatic plants were identified to the species level where possible and are listed in Tables 3 and 4. Further sampling this year for the unknown microfilamentous algae detected in the 2015 study did not reveal the presence of this species at the same sites as documented in 2015.

Figure 5. Native aquatic plant bed located offshore from Ruault Road, Lake Windermere.

4.3 Mussel veliger sampling

All veliger samples submitted to the lab were reported as negative indicative that no invasive mussel (Zebra Mussel (*Dreissena polymorph*)/Quagga Mussel (*Dreissena bugensis*) veligers were identified by the laboratory that analyzed the samples.

Table 1. Results from Lake Windermere shoreline sampling for aquatic invasive plants – Part 1.

Site	AIS sampling location	Aquitic Plants Identified (ranked in order of % in the pull)	Observations/Notes
1. Baltac Beach	Launch (Public Boat Launch) UTM: 0570748; 5593608	**Pull 1**: No plants **Pull 2**: No plants	Could see *Myriophyllum sp* . from shoreline
	South 1 (25m) UTM: 0570750; 5593584	**Pull 1:** No plants **Pull 2:** *Chara sp.*	*Myriophyllum* sp. washed up on shore; *Potomogeton richardsonii* seen in water from shoreline.
	South 2 (50m) UTM: 0570760;	**Pull 1**: No plants. **Pull 2**: No plants.	Directly beside small private dock. Mass of knotted aquatic plants uprooted and floating against the docks; native *Myriophyllum sp.*
	South 3 (75m) UTM: 0570779; 5593544	**Pull 1:** No plants. **Pull 2**: No plants	Rocky substrate.
	North 1 (25m) UTM: 0570739; 5593631	**Pull 1**: *Chara sp.* **Pull 2:** *Chara sp* .	Numerous plants stem fragments of *Myriophyllum sp* . Washed up on shore. Also *Najas sp* ., *Elodea canadensis* fragments washed up.
	North 2 (50m) UTM: 0570728; 5593656	**Pull 1:** *Chara sp.* **Pull 2**: *Chara sp, Myriophyllum sp.*	N/A. Saw a fragment of Baby's Breath (terrestial invasive plant) on shoreline
	North 3 (75m) UTM: 0570714; 5593672	**Pull 1:** *Chara sp..* **Pull 2:** Chara sp.	Seen from shoreline: Najas sp., Myriophyllum sp.
2. Rushmere Community Docks	Launch (centre of private docks) UTM: 0574650; 5585352	**Pull 1:** No plants. **Pull 2**: No plants	Free-floating aquatic plant fragments prevalent along the shoreline, especially native *Myriophylllum sp* ., and *Megaladonta beckii*
	South 1 (25m) UTM: 0574659; 5585334	**Pull 1**: *Chara sp.., aquatic moss, Utricularia sp.* **Pull 2**: *Chara sp., aquatic moss, sago sp., Potamogeton sp.* (likely *P.gramineus), Elodea canadensis*	Rake pulls conducted from a small dock.
	South 2 (50m) UTM: 0574666; 5585311	**Pull 1:** *Chara sp., Utricularia sp.* **Pull 2:** *Chara sp., Utricularia sp., Potamogeton pectinatus, Ranunculus aquatilis, Najas sp.*	Several aquatic plant fragments washed up on shoreline.
	South 3 (75m) UTM: 0574674; 5585287	**Pull 1:** *Myriophyllum sp., Megalodonta beckii, Potamogeton praelongus, Potamogeton natans* **Pull 2:** *Utricularia sp., Potamogeton praelongus*	N/A
	North 1 (25m) UTM: 0574637; 5585375	**Pull 1**: *Potamogeton pectinatus* **Pull 2**: *Myriophyllum sp.*	Many aquatic plants washed up on shore, mostly *Myriophyllum sp.* , but also *Potamogeton amplifolius, Potamogeton natans, Potamogeton praelongus, Megalodonta beckii.*
	North 2 (50m) UTM: 0574623; 5585394	**Pull 1:** *Myriophyllum sp.* **Pull 2:** *Utricularia sp., Chara sp., Najas sp., Potamogeton gramineus*	N/A
	North 3 (75m) UTM: 0574611; 5585417	**Pull 1:** *Myriophyllum sp., Megalodonta beckii, Chara sp., Sagittaria cuneata, Elodea canadensis, Potamogeton sp. (*likley *P.praelongus),* aquatic moss, *Potamogeton pectinatus* **Pull 2:** *Myriophyllum sp., Sagittaria cuneata, Chara sp.*	N/A
3. Fairmont Side Channel	Boat launch UTM: 0580441; 5577289	**Pull 1:** *Chara sp., Potamogeton sp.* (thin-leaved species; likley P. vaginatus) **Pull 2:** *Chara sp.*	New outhouse, picnic tables, garbage cans, and comment cards for public comment; supplied by the Columbia Wetlands Stewardship Partners.
	South 1 (25m) UTM: 0580421; 5577269	**Pull 1:** *Chara sp., Potamogeton sp.* (likley *P. vaginatus*). **Pull 2**: *Chara sp., Potamogeton sp.* (likley *P. vaginatus*)	Could not go further south due to private property. Did not sample here in 2015.
	North 1 (25m) UTM: 0580450; 5577309	**Pull 1:** *Potamogeton sp. (likley P. vaginatus), Potamogeton richardsonii.* **Pull 2:** *Potamogeton sp. (likley P. vaginatus), Potamogeton*	Some garbgage was in the water; this was removed and disposed of properly.
	North 2 (50m) UTM: 0580451; 5577332	**Pull 1:** *Potamogeton sp.* (likley *P. vaginatus*), *Chara sp* . **Pull 2**: Chara sp., Potamogeton sp. (likley P. vaginatus), Potamogeton praelongus	Private property at 75m north. Looked like more of same species as found at other Fairmont locations, although looked to be more biomass accumulation of *P. praelonngus* compared to other species.
	Additional Notes: It was not possible to sample at more than three locations at Fairmont Side Channel due to steep riparian banks and private		

Table 2. Results of the Lake Windermere shoreline sampling for aquatic invasive plants – Part 2

4. End of Ruault Road	Boat Launch UTM: 0572641; 5587665	**Pull 1:** *Chara sp.* **Pull 2**: *Chara sp, Potamogeton sp.(likely P.gramineus)*	Lots of dried up, uprooted plants (mainly *Myriophyllum sp.)* along shoreline.
	North 1 (25m) UTM: 0572619; 5587674	**Pull 1**: *Chara sp .*, *Myriophyllum sp* . **Pull 2:** *Chara sp., Myriophyllum sp., Elodea canadensis*	Lot of washed up dried plants on shoreline. Mainly *Myriophyllum sp. and Chara sp.*
	South 1 (25m) UTM: 0572664; 5587657	**Pull 1**: *Chara sp.* , **Pull 2:** *Chara sp., Myriophyllum sp.*	N/A
	South 2 (50m) UTM: 0572687; 5587647	**Pull 1:** *Chara sp .*, *Potamogeton sp.(likely P.gramineus)* **Pull 2:** *Chara sp., Potamogeton sp.* (likely *P.gramineus*)	Abundance of plants dried up on shoreline, mainly *Myriophhyllum sp.*
	South 3 (75m) UTM: 0572711; 5587639	**Pull 1**: *Chara sp.* **Pull 2**: *Chara sp.*	Very little Chara coming up with rake pulls.
	Additional Notes: Could not go further north beyond the 25m north because of extensive shoreline plants, i.e. did not peform rake pulls 50m north (North 2), or 75m north (North 3) at 'end of Ruault Road' site.		
5. Calgary Beach	Launch UTM: 0569369; 5595023	**Pull 1:** *Chara sp., Myriophyllum sp.* **Pull 2**: No plants	N/A
	North 1 (25m) UTM: 0569385; 5595046	**Pull 1**: *Chara sp., Myriophyllum sp, Potamogeton sp* . (likely P.gramineus). **Pull 2:** *Chara sp., Myriophyllum sp .*, *Potamogeton sp.* (likely *P.gramineus*).	N/A
	North 2 (50m) UTM: 0569372; 5595067	**Pull 1:** *Chara sp. Potamogeton sp.* (likely *P.gramineus), Elodea canadensis* **Pull 2:** *Chara sp. Potamogeton sp. (likely P.gramineus), Elodea canadensi, Potamogeton robbinsii*	N/A
	North 3 (75m) UTM: 0569356; 5595087	**Pull 1:** *Chara sp., Najas sp., Myriophyllum sp.* **Pull 2:** *Chara sp., Potamogeton sp.*	N/A
	South 1 (25m) UTM: 0569389; 5594995	**Pull 1:** No plants **Pull 2:** No plants	N/A
	South 2 (50m) UTM: 0569389; 5594972	**Pull 1**: *Chara sp.* **Pull 2**: *Chara sp., Najas sp, Myriophyllum sp.*	Several truck tire tracks on the shoreline. People launched their boat here while sampling.
	Left 3 (75m) UTM: 0569397; 5594948	**Pull 1:** *Chara sp., Myriophyllum sp., Potamogeton sp. (possibly P.Gramineus)* **Pull 2:** *Chara sp, Najas sp.*	In 2017 there was an abundance of washed up dried aquatic plants on shoreline, mainly *Myriophyllum sp* . In 2016, few washed up plants on shoreline were found.
6. Althalmer/ Pete's Marina	Boat Launch UTM: 0569529; 5596340	**Pull 1:** *Elodea canadensis, Najas sp., Myriophyllum sp.* **Pull 2**: *Chara sp., Elodea canadensis, Hippuris vulgaris, Najas sp.*	Busiest public boat launch access point on Lake Windermere.
	South 1 (25m) UTM: 0569535; 5596313	**Pull 1:** Chara sp., *Elodea canadensis, Najas sp., Myriophyllum sp.* **Pull 2:** *Chara sp., Myriophyllum sp., Elodea canadensis, Najas sp., Potomogeton vaginatus*	N/A
	South 2 (50m) UTM: 0569540; 5596290	**Pull 1:** *Chara sp., Myriophyllum sp., Elodea canadensis, Najas sp., Potamogeton pectinatus* **Pull 2:** *Chara sp., Myriophyllum sp., Elodea canadensis, Potamogeton (sp. richardsonii or praelongus)*	High abundance of submerged aquatic plants present at this site.
	South 3 (75m)	N/A	Could not conduct this pull due to extensive riparian shrubs obstructing sampling location. Did not sample here in 2015 either.
	North 1 (25m) UTM: 0569522; 5596362	**Pull 1**: *Elodea canadensis, Potamogeton richardsonii, Najas sp., Myriophyllum sp* . **Pull 2:** *Elodea canadensi, Chara sp., Myriophyllum sp.,Potamogeton richardsonii, Najas sp.*	N/A
	North 2 (50m) UTM: 0569516; 5596388	**Pull 1:** *Elodea canadensis, Myriophyllum sp., Potamogeton praelongus* **Pull 2:** *Elodea canadensis, Potamogeton praelongus, Potamogeton pectinatus, Myriophyllum sp., Najas sp.*	N/A
	North 3 (75m) UTM: 0569505; 5596416	**Pull 1:** *Chara sp., Elodea canadensis, Myriophyllum sp., Najas sp., Ranunculus aquatilis, Potamogeton pectinatus* **Pull 2:** *Elodea canadensis, Myriophyllum sp., Chara sp., Ranunculus aquatilis*	Althalmer Slough/Pete's Marina has the highest located biomass of aquatic plants seen during aquatic invasive plant surveys.

Table 3. Aquatic plant data from Lake Windermere boat surveys on September 14, 2016

Site Name	Distance from shoreline (m)	GPS coordinates	Time	Water Depth (m)	Sediment type	Rake Pull #	Aquatic Plant Species	Notes/Observations
Rushmere	347	Start: 0574907; 5585577. End of 100 m transect=057482 5; 5585661	1130	2.02	mud/sand	1	*Potamogeton natans, Chara sp., Potamogeton amplifolius*	Offshore from private community docks. 100m transect completed with naked eye due to calm water. Dense beds of submerged plants along transect.
						2	*Potamogeton natans, Chara sp., Elodea candensis, Myriophyllum sp.*	
						100m transect	*Potamogeton natans, Chara sp., Potamogeton amplifolius, Myriophyllum sp., Elodea canadensis, Potamogeton praelongus, Megalodonta beckii*	
Lakeshore Resort	110	Start: 0574771; 5586584. End of 100 m transect=057468 9; 5586649	1153	1.62	fine sand/silt, black in color	1	*Chara sp., Utricularia sp.*	Offshore from small private docks with moorage. Little vegatation present. 100 m transect was completed in front of moored boats.
						2	*Chara sp.*	
						100m transect	*Chara sp., Potamogeton natan,Myriophyllum sp., Elodea canadensis, Potamogeton praelongus, Megalodonta beckii*	
Ruault Rd. (also known as Larch Point)	161	0573120; 5587274. End of 100m transect=057307 7; 5587324	1226	2	N/A	1	*Myriophyllum sp., Potamogeton praelongus, Potamogeton richardsonii, Chara sp., Nitella sp., Hippuris vulgaris*	Very dense bed of submerged vegetation along transect; 100m transect completed with naked eye due to calm water. Saw fish within the transect, but unknown species.
						2	*Myriophyllum sp., Nitella sp., Potamogeton praelongus*	
						100m transect	*Myriophyllum sp., Potamogeton praelongus, Elodea canadensis, Potamogeton natans, Potamogeton richardsonii*	
Indian Beach	80	0572406; 5589096. End of 100m transect= 0572320; 5589160	1326	1	sand/silt	1	*Chara sp.*	Little aquatic plant life on lake bottom; mainly *Chara sp.* 100m transect completed with naked eye due to calm water.
						2	*Chara sp.*	
						100m transect	*Chara sp., Myriophyllum sp., Potamogeton pectinatus, Potamogeton sp. (* likely *P.gramineus), Potamogeton praelongus*	
Tretheway Docks	101	0571753; 5589727. End of 100m transect=057167 58; 5589763	1340	0.5	sand/silt	1	*Chara sp.*	Very little aquatic plant life in front of multiple private boat slips. Several empty mussle shells located on lake bottom.
						2	*Chara sp.*	
						100m transect	*Chara sp., Potamogeton pectinatus, Megalodonta beckii, Potamogeton richardsonii, Myriophyllum sp.*	
Akiskinook Resort Docks	82	0571278; 5591440. End of 100m transect=057124 9; 5591540	1430	3.4	N/A	1	*Myriophyllum sp., Elodea canadensis*	100m transect conducted along private boat docks. Relatively deep water at this location. Majority of the plants on rake pulls were *Myriophyllum sp.*
						2	*Myriophyllum sp.*	
						100m transect	*Myriophyllum sp., Potamogeton praelongus, Potamogeton richardsonii, Chara sp., Elodea canadensis*	
Calgary Beach	59	0569446; 5595057	1604	4.4	N/A	1	*Chara sp.*	100m transect not possible, as the bottom of the lake was too deep to see any plants.
						2	*Chara sp.*	
						100m transect	N/A	

Table 4. Aquatic plant data from Lake Windermere boat surveys on September 15, 2016

Site Name	Distance from shoreline (m)	GPS coordinates	Time	Water Depth (m)	Sediment type	Rake Pull #	Aquatic Plant Species	Notes/Observations
End of Coy Road	57	Start: 0570114; 5590974. End of 100m transect=0570164; 5590871	1006	1.96	sand	1	*Chara sp., Potamogeton natans*	Significant amount of *Chara sp* . and *P.zosteriformis* on the lake bottom. Beaver activity on lake bottom; channels in sand with empty mussle shells scattered on lake bed.
						2	*Chara sp., Potamogeton natans*	
						100m transect	*Chara sp., Myriophyllum sp., Potamogeton natans, Potamogeton sp. (thin-leaved). Potamogeton pectinatus, Potamogeton zosteriformis*	
Baltac Beach	69	Start: 0571103; 5593418 End of 100m transect= 0571011; 5593446	1036	1.07	sand (black in color)	1	*Chara sp.*	Very little aquatic plant biomass here.
						2	No plants	
						100m transect	*Chara sp., Potamogeton pectinatus*	
Lakeview Meadows (also known as Timber Ridge)	32	Start: 0570181; 5594078 End of 100m transect= 0570188; 5594180	1050	1.2	unknown	1	*Chara sp., Elodea canadensis, Myriphyllum sp.*	100m transect not possible due to wave action and suspended sediments in the water column.
						2	*Myriophyllum sp., Elodea canadensis, Megalodonta beckii*	
						100m transect	*Potamogeton praelongus, Elodea canadensis, Potamogeton natans, Myriophyllum sp., Chara sp.*	
Althalmer / Pete's Marina	18	Start: 0569534; 5596398 End of 100m transect= 0569562; 5596299	1130	1.05	sand/gravel	1	*Myriophyllum sp., Chara sp.,*	Saw kokanee salmon.
						2	*Chara sp., Potamogeton sp. (likley P. vaginatus)*	
						100m transect	*Potamogeton sp. (likley P. vaginatus), Myriophyllum sp.*	

5. Discussion/Recommendations

No aquatic invasive species of vegetation or mussel species have previously been detected in Lake Windermere and to the best of our knowledge; all aquatic plants found in Lake Windermere remain native species.

Native plants may however be considered an annoyance to some individuals; as evidenced by the difficulties of motorized boat travel in lakes inhabited with high biomass of native plants, resulting in plant fragments getting caught up in propellers. However, it is important to recognize that native aquatic plants play a vital role in maintaining healthy ecosystem services and functions of the lake, for instance, structural stability, water purification, herbage and breeding material for waterfowl, refuge for fish and invertebrates, removal of excess phosphorus and nitrogen (Engelhardt & Ritchie, 2001; Medina, 1996; Meerhoff, Mazzeo, Moss & Rodrigeuz-Gallego, 2003).

It is important that any management practices maintain the physical and biological integrity of habitats that have high amounts of aquatic plant biomass (Medina, 1996; Meerhoff, Mazzeo, Moss & Rodrigeuz-Gallego, 2003), including lakes such as Lake Windermere, so that the important ecosystem services and functions will be maintained. Additionally, maintenance of a healthy composition of native aquatic plants results in a resilient ecosystem more resistant to new and opportunistic invasive species (Department of Ecology, State of Washington, n.d.). Wetland habitats (i.e. Lake Windermere) provide an abundant and diverse composition of native aquatic species (Medina, 1996); ensuring a productive and ongoing valuable natural resource for associated communities in the Columbia Valley. This implies that vigilant custodial care should be undertaken to ensure the ecological integrity of Lake Windermere so that essential ecosystem services and wildlife habitat can be maintained.

5.1 Continued monitoring for AIS

Maintaining the native biodiversity identified in Lake Windermere and the Columbia Wetlands is critically important for numerous economic, societal and environmental reasons, as noted in this report. Therefore, it is recommended that the annual monitoring of invasive aquatic plants and invasive mussel species be continued. It is also recommended that permission be sought from the private land owners of Tretheway Docks, to facilitate shoreline sampling from the available boat docks for future monitoring efforts. This year as well as previous years of study identified aggressive beds of aquatic plants growing amongst the Tretheway Docks, which cannot not be adequately assessed or surveyed with boat only access. Approaching these docks for further identification and survey of the aquatic plants from land was not pursued as the private lands were posted with “no trespassing” signs and secured gate at the dock entrance.

In 2015, there was a photograph and report of an invasive American Bullfrog sighting at nearby Upper Halgrave Lake (higher elevation lake in the Columbia Valley). As noted previously, there have also been invasive fish species detected and reported in past monitoring efforts by an

unconfirmed agency. Consideration of a joint effort by the LWA collaborating with the EKISC (or similar group/consultant) conducting surveys for invasive frog and invasive fish species within Lake Windermere is recommended; with the possible enlistment of citizen-scientists resulting in encouragement of community stakeholder involvement.

5.2 Outreach and education

The Clean-Drain-Dry message is being promoted widely across the province by a variety of agencies. In a local context, the LWA have been working to educate people including recreational boaters on Lake Windermere about the dangers of introducing invasive plants. In pursuit of this goal the LWA have been promoting the 'Don't Move a Mussel' campaign aiming to raise awareness of the invasive mussel species. These efforts should continue to be encouraged and pursued at a local scale, working in concert with the CSISS, EKISC and provincial government programs. An additional provision for these efforts could include a LWA volunteer or employee distributing AIS informational pamphlets on busy summer weekends at Althalmer/Pete's Marina on Lake Windermere. A new pamphlet could be drafted by the LWA (specific to AIS and Lake Windermere) addressing the importance of maintaining native aquatic plants in the lake. The brochure could also explain that the plants in Lake Windermere are not invasive species, but are native and are important for a multitude of significant ecosystem services, (e.g. water purification, flood protection, sediment control, biodiversity), critical to maintain in order for human well-being maintenance (Daily, 1997).

Furthermore, while some AIS signs are located at different access points of Lake Windermere, it is advised that all posted signage be consistent in their messaging. It would be additionally advantageous to install signage at all locations (including privately owned docks) where high levels of trailered boating activity has been identified.

It is also recommended that the LWA purchase an underwater viewer. This would serve as an educational tool for the citizen-scientists that currently attend weekly water quality sampling sessions with the LWA in the summer. Using the underwater viewer would increase community knowledge about native aquatic plants in Lake Windermere; incorporating the underwater viewer in the LWA weekly water monitoring regime will also contribute to additional monitoring capabilities, such as assessing any changes in populations of aquatic plants of Lake Windermere on an ongoing basis. As a final request, the purchase and use of a plankton net by the LWA, as well as shipping samples to a lab for invasive mussel veliger analysis on a monthly basis, would enable for more frequent monitoring of Lake Windermere for both Zebra Mussel (*Dreissena polymorph*) and Quagga Mussel (*Dreissena bugensis*). Monthly monitoring would also allow for a larger spatial area to be monitored for the presence of invasive mussel species.

6. Acknowledgements

The author would like to thank the funder of the study, the Kootenay Conservation Program's Columbia Valley Local Conservation Fund. This study would not be possible without their financial contributions to the AIS monitoring efforts. The Lake Windermere Ambassadors are to be congratulated on their ongoing efforts of ensuring that the AIS monitoring program continue on Lake Windermere, and in their work to highlight the importance of maintaining native plants in Lake Windermere. The author would also like to thank the LWA Program Coordinator Megan Peloso for the time she contributed to the AIS surveys in the field and the East Kootenay Invasive Species Council and their Field Operations Supervisor Pat Wray for contributing her time and efforts during the offshore veliger sampling.

7. References

BC Hydro. (2014). Fish and Wildlife Compensation Program. Columbia Basin Riparian and Wetlands Action Plan: Draft. Retrieved from http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/about/our_commitment/fwcp/fwcp-columbia-riparian-wetland-action-plan.pdf

Columbia Shuswap Invasive Species Council (CSISS) (2016). BC watercraft inspection stations; stopping the spread of invasive mussels! Retrieved from: http://ckiss.ca/2016/08/bc-watercraft-inspection-stations-stopping-spread-invasive-mussels/

Craig, J. 2015. Canadian Columbia Basin Regional Framework for an Aquatic Invasive Species Program: 2015 to 2020. Retrieved from: http://www.friendsofkootenaylake.ca/wp-content/uploads/2016/02/Final-CBAIS_Regional_Program_Framework_1June2015.pdf

Daily, G.C. (1997). Nature's services: Societal dependence on natural ecosystems. Washington, DC: Island Press.

Darvill, 2015. Lake Windermere aquatic invasive plant sampling.

Department of Ecology, State of Washington. (n.d.). Native freshwater plants. The uses and benefits of aquatic plants. Retrieved from: http://www.ecy.wa.gov/programs/wq/plants/native/uses.html

Engelhardt, K. A., & Ritchie, M. E. (2001). Effects of macrophyte species richness on wetland ecosystem functioning and services. *Nature*, 411(6838), 687-689.

Environment Canada (2013). Bird conservation strategy for bird conservation region 10 Pacific and Yukon Region: Northern Rockies. Retrieved from: https://www.ec.gc.ca/mbc-com/B0E2C86B-57E6-419A-B3E9-E1CD1808ADFE/BCR-10-PYR-FINAL-Abridged-Feb2013.pdf

Hawthorn, R.S. (1973). Studies on aquatic macrophytes. Part II: Aquatic plants of Lake Windermere. Water Investigations Branch. British Columbia Water Resources Service. Department of Lands, Forests, and Water Resources. Parliament Buildings, Victoria, BC.

Hawthorn, R.S., & W.A. McCormick. (1972). Water investigations branch studies on aquatic macrophytes Part I: A literature review of aquatic macrophytes with particular reference to those present in Windermere Lake, British Columbia. Department of Lands, Forests, and Water Resources. Parliament Buildings, Victoria, BC.

Inter-Ministry Invasive Species Working Group (IMISWG). (2015). British Columbia aquatic invasive species survey methods. Retrieved from https://www.for.gov.bc.ca/hra/invasive-species/Publications/BC_Aquatic_Sampling_March2015.pdf

Invasive Species Council of British Columbia (ISCBC). (2014). Aquatics. Retrieved from: http://bcinvasives.ca/resources/programs/aquatics/

Ludyanskiy, M. L., McDonald, D., & MacNeill, D. (1993). Impact of the zebra mussel, a bivalve invader. *BioScience*, 533-544.

Medina, A. L. (1996). Native aquatic plants and ecological condition of southwestern wetlands and riparian areas.

Meerhoff, M., Mazzeo, N., Moss, B., & Rodríguez-Gallego, L. (2003). The structuring role of free-floating versus submerged plants in a subtropical shallow lake. *Aquatic Ecology*, 37(4), 377-391.

Minnesota Sea Grant. (2016). Eusasian Watermilfoil. Retrieved from: http://www.seagrant.umn.edu/ais/watermilfoil

O'Neill Jr, C. R. (1997). Economic impact of zebra mussels- results of the 1995 National Zebra Mussel Information Clearinghouse Study. *Great Lakes Research Review*, *3*(1), 35-44.

Pimm, S. L., Jenkins, C. N., Abell, R., Brooks, T. M., Gittleman, J. L., Joppa, L. N., P.H Raven, & Sexton, J. O. (2014). The biodiversity of species and their rates of extinction, distribution, and protection. *Science*, 344(6187), 1246752.

Province of BC. (n.d.) BC Inter-Ministry Invasive Species Working Group. Retrieved from: https://www.for.gov.bc.ca/hra/invasive-species/inspectionprogram.htm

Rothlisberger, J. D., Chadderton, W. L., McNulty, J., & Lodge, D. M. (2010). Aquatic invasive species transport via trailered boats: what is being moved, who is moving it, and what can be done. *Fisheries*, *35*(3), 121-132.

The Nature Conservancy. 2016. Aquatic invasive species cost businesses hundreds of millions annually. Retrieved from: http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/minnesota/newsroom/aeg-report-on-economic-impact-of-ais-in-great-lakes.xml

Vilà, M., Basnou, C., Pysek, P., & M. Josefsson. (2010). "How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment." *Frontiers in Ecology and the Environment* 8.3 (2010): 135-144.

Wikipedia. (2016a). Columbia River. Retrieved from: https://en.wikipedia.org/wiki/Columbia_River

Wikipedia. (2016b). Invermere. Retrieved from: https://en.wikipedia.org/wiki/Invermere

Zoltai, S. C., & Vitt, D. H. (1995). Canadian wetlands: environmental gradients and classification. In Classification and inventory of the world's wetlands (pp. 131-137). Springer Netherlands.