Protecting Our Waters from Aquatic Invasive Species: Phase 3 (COL-F17-F-1204)

Prepared for:
Fish and Wildlife Compensation Program

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EXECUTIVE SUMMARY

Aquatic invasive species (AIS) pose a significant threat both ecologically and economically to waterbodies in the Central and West Kootenay regions of British Columbia. It is known that the aquatic invasive plants Eurasian Watermilfoil (*Myriophyllum spicatum*) and Curlyleaf Pondweed (*Potamogeton crispus)* are present throughout Kootenay Lake and the Columbia and Kootenay Rivers. Within close proximity to our region's borders there are confirmed populations of Flowering Rush (*Butomus umbellatus*), Virile Crayfish (*Orconectes virilis*), and Parrotsfeather (*Myriophyllum aquaticum*). Furthermore, highly invasive species such as Zebra and Quagga Mussels (*Dreissena polymorpha* and *D. rostriformis bugenis*) have been detected in western provinces and states as close as Manitoba and Montana.

The popularity of the Kootenays as a recreational boating destination increases the potential risk of an accidental introduction of a number of high priority AIS. Furthermore, invasive species already present within the region could easily be spread to other waterbodies currently free of AIS. The public play an important role in preventing the introduction and spread of AIS because human activities pose the greatest risk for AIS movement between inland waterways. Therefore, it is essential to continue providing education on how to change the behaviours that are responsible for spreading AIS. To address this, the CKISS engaged in various outreach activities and media directed at specific target audiences and the general public, raising awareness about aquatic invasive species through education and promoting the province-wide Clean Drain Dry, Don't Let it Loose, and PlantWise programs.

Priority waterbodies within the region were surveyed and monitored for the presence of invasive aquatic plants and dreissenid mussels. Substrate equipment used to detect the presence of juvenile and adult dreissenids was monitored monthly from July through September. A total of 62 plankton samples were collected from 17 waterbodies, and analyzed for any presence of dreissenid veligers (mussel larvae). Littoral surveys for invasive plants were conducted on Rosebud, Nancy Greene, Erie, Summit, Box, Fish, and Beaver Lakes. High risk areas such as boat launches, marinas, and recreation sites were surveyed on Slocan, Whatshan, and Upper and Lower Arrow Lakes.

Plankton samples were analysed using cross-polarized light microscopy in the laboratory by a certified analyst. All samples were negative for the presence of dreissenid veligers. Similarly, no juvenile or adult dreissenid mussels were detected on any of the substrate equipment.

No submerged aquatic invasive plants were discovered at any of the waterbodies surveyed in the course of this study and points sampled on Rosebud, Summit, Box, Fish, Beaver, Whatshan, Slocan and Arrow Lakes were free of invasive plants, both riparian and aquatic. At

Nancy Greene and Erie Lakes, Fragrant Water Lily (*Nymphaea odorata*) was present, and at Mel Deanna Pond a newly reported infestation of the emergent plant was confirmed. At Nancy Greene Lake, this species has been treated since 2014, and its' area has been greatly reduced. In Erie Lake, this species is expanding, with the discovery of two new patches. At Mel Deanna Pond, a large patch was discovered and the accessible portions were treated mechanically. Yellow Flag Iris (*Iris pseudacorus*) has been treated for several years at Nancy Greene Lake, and for the second year in a row, no plants have been found. In Erie Lake, the *I. pseudacorus* population is increasing, with a number of new clumps or individual plants detected. Watercress (*Nasturtium officinale*) was detected in the region for the first time. Near the Kootenay Lake community of Boswell, this plant was confirmed to be growing on both public and private land. Further surveys are required to determine the full extent of the colonization.

The existing populations of *Myriophyllum sp.* in the Kootenay-Columbia system may be hybridizing, which would make traditional methods of field identification more difficult. Furthermore, hybrid milfoils are more invasive than parental pure *M. spicatum* lineages. Currently, the geographical extent of invasive hybrid watermilfoils in North America is unknown and should be pursued by additional sampling and genetic testing.

Management and control measures should continue, or be implemented where they do not currently exist, in order to stop and reverse the continued expansion of populations of AIS present in the region. At current levels of infestation, mechanical and cultural removal methods are recommended due to their selectiveness and low ecological impacts. No large monotypic stands of AIS were detected to warrant the use of mechanical harvesters; however, this could change rather rapidly if no action is taken.

Dreissenid mussel and aquatic plant monitoring should continue on priority waterbodies in order to detect new infestations early thus allowing for the implementation of a rapid response plan. Continued outreach and education on best management practices, coupled with collaborative activities with bordering jurisdictions, will greatly assist in preventing the introduction and establishment of aquatic invasive species throughout the region.

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SECTION I. INTRODUCTION

Aquatic invasive species (AIS) include non-native fish, animal and plant species that have been introduced into an aquatic ecosystem where they have not been found historically. Once introduced, AIS such as Fragrant Water Lily (*Nymphaea odorata*), Zebra Mussels (*Dreissena polymorpha*) and Quagga Mussels (*D. rostriformis bugensis*) can spread aggressively and rapidly, resulting in severe and often irreversible consequences for native species and ecosystems by radically altering habitat and rendering it inhospitable (GoC 2004). Aquatic invasive species have been implicated in vast reductions or the outright extinction of indigenous fish populations across Canada, devastating local fisheries (CCFAMAISTG 2004). Moreover, studies have shown that the establishment of non-native species can facilitate the survival of other non-native species, thereby amplifying invasions in what is referred to as the invasional meltdown hypothesis (Adams et al. 2003).

The risk of AIS introductions to British Columbian waters is escalating rapidly, as it is elsewhere in the country with approximately 15 non-native species becoming established in Canadian waters every decade (CCFAMAISTG 2004). Many anthropogenic factors contribute to the introductions and spread of these non-native species such as increased global trade, illegal dumping of horticultural and aquarium species, and water-based recreation. All waterbodies in the Columbia basin specifically, have been assigned a high-very high risk status for the survival and subsequent invasion of dreissenid mussels (Therriault et al. 2013). Furthermore, freshwater ecosystems in general are more vulnerable to aquatic invasive species invasions than terrestrial ecosystems (Vander Zanden and Olden 2008). This increased vulnerability, coupled with the inability to utilize chemicals for control or eradication, emphasizes the critical importance of preventative and early-detection activities.

The threat of AIS to waterways in the Central Kootenays is also increasing as species such as Virile Crayfish (*Orconectes virilis*), Parrotsfeather (*Myriophyllum aquaticum*) and Flowering Rush (*Butomus umbellatus*) have been confirmed in neighbouring jurisdictions (Stewart 2014; Washington 2016; USGS 2016). A number of AIS are currently present in the CKISS region including Eurasian Watermilfoil (*Myriophyllum spicatum*), *N. odorata* and American Bullfrog (*Lithobates catesbeianus*), which presents an ongoing risk that these species will be accidentally or intentionally introduced to uninfested bodies of water within the region. Should new introductions of AIS remain undetected for an extended period, they may cause significant damage to the ecosystem before they are treated. A delayed detection and response time can greatly increase costs and reduce effectiveness of control methods while potentially increasing the AIS in question's range of establishment. To address the risk of new introductions, the provincial government has developed an Early Detection Rapid

Response (EDRR) plan in order to find, identify and systematically eradicate, contain or control new invasive species before they can reproduce and disperse beyond their point of entry (IMISWG 2014), thereby substantially reducing control efforts and costs. This same concept can be applied to smaller geographic units including individual waterbodies ensuring that small, localized infestations are discovered promptly and treated where feasible.

As a result of previous surveys, it was determined that aquatic invasive plants were present in a limited number of waterbodies throughout the Central Kootenays. *M. spicatum* and Curlyleaf Pondweed (*Potamogeton crispus*) are present throughout the Kootenay-Columbia system and have expanded their range and abundance since 2010. Golder Associates Ltd. and Poisson Consulting Ltd. (2015) have observed a gradual increase in aquatic vegetation (dominantly *M. spicatum*) in low water velocity areas throughout the Lower Columbia River.

In 2010, the CKISS Board and members identified the need for a collaborative approach to address AIS and this led to the establishment of a multi-agency Aquatic Working Group (AWG) in 2011. The goal of this group is to provide a forum for discussion, coordination and action with respect to AIS including prevention, early detection, monitoring, and outreach in the CKISS region.

In 2012 and 2013, representatives from FortisBC Inc., Teck Metals Ltd., BC Ministry of Environment, and Slocan Lake Stewardship Society (all members of the CKISS AWG) carried out the Upper Columbia Basin Zebra and Quagga Veliger Monitoring Project. This program surveyed for the presence of the highly invasive dreissenid mussels in Slocan, Kootenay, and Upper and Lower Arrow Lakes, and Pend D'Oreille and Lower Columbia Rivers.

In 2014, a partnership was struck between the Columbia Basin Trust and the four regional invasive species organizations (RISO's) that operate in the Columbia Basin Trust portion of the Canadian Columbia Basin to address the ecological, economic, and social impacts of AIS in a proactive and collaborative way. Through this partnership, and with input from key stakeholders and various government and non-government agencies, a framework document was developed for use by these RISO's and their partners to create or expand current AIS programs to achieve common goals in a coordinated manner.

In 2014 and 2015, with support from the Fish and Wildlife Compensation Program (FWCP), Phase I and II activities of the Protecting Our Waters from Aquatic Invasive Species Project were implemented throughout the CKISS region, resulting in the coordination and delivery of an extensive aquatic invasive species surveying and monitoring program.

This project aligns with the Small and Large Lake Action Plans through the actions of minimizing invasive species introductions and potential incursions.

Section II. Goals and Objectives

The objective of this project was to ensure productive and biologically diverse aquatic ecosystems within the Central and West Kootenay region. The goals of this project were as follows:

- Survey for over 40 high priority provincial and regional aquatic invasive species
    - Survey and monitor for new incursions of highly-invasive AIS
    - Monitor changes in composition, density, and distribution of existing infestations of invasive aquatic plants
    - Survey high priority waterbodies for the presence of Zebra and Quagga Mussels by means of plankton tows and substrate samplers
- Undertake invasive species management activities where feasible
- Support regional, provincial, and cross-border initiatives to allow for coordinated delivery of key messaging and the promotion of best practices
- Increase education and awareness of AIS across a broad spectrum of audiences
- Collaborate with partners to implement Early Detection Rapid Response plans should certain high priority species be detected
- Accomplish Phase II recommendations

Section III. Study Area

The study area for this project was the Central Kootenay Invasive Species Society's (CKISS) working region, which is approximately 30,500 km^2 (Fig. 1). It encompasses all of the area within the boundaries of the Regional District of Central Kootenay, as well as Areas A and B of the Regional District of Kootenay Boundary. This region is located in the southwestern portion of the Canadian Columbia River basin, which is located in southeastern BC. The CKISS is one of four regional invasive species organizations that operate within the portion of Canadian Columbia Basin where waterbodies drain into the Columbia River north of the border with the United States.

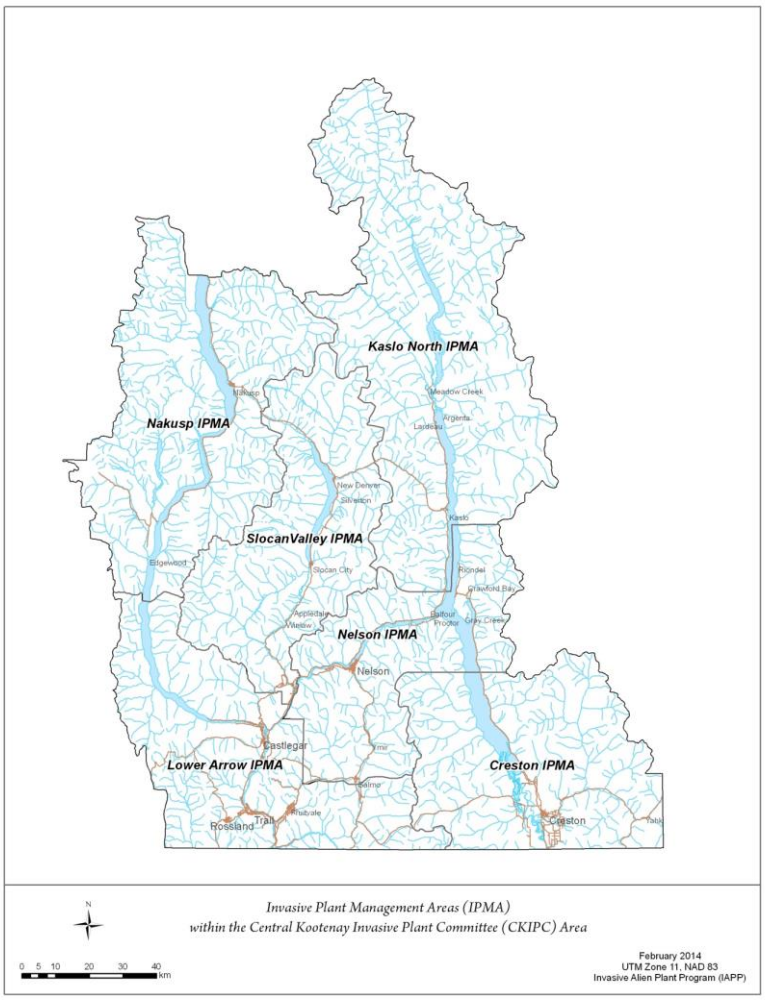

Figure 1. Map of the Central Kootenay Invasive Species Society Region.

A total of 11 waterbodies were surveyed for priority invasive aquatic plants and 17 waterbodies surveyed for dreissenid mussels in the CKISS region. Surveys for invasive aquatic plants were conducted in Summit, Box, Rosebud, Slocan, Whatshan, Upper and Lower Arrow, Erie, Nancy Greene, Fish, and Beaver Lakes. Surveys for dreissenid mussels occurred in Slocan, Kootenay, Upper and Lower Arrow, Summit, Box, Rosebud, Whatshan, Duncan, Fish, Nancy Greene, Erie, Cottonwood, Champion, and Upper Little Slocan Lakes and Columbia and Pend D'Oreille Rivers.

SECTION IV. METHODS

ZEBRA AND QUAGGA MUSSEL VELIGER MONITORING

Monitoring for Zebra and Quagga Mussel (*D. polymorpha* and *D. rostriformis bugensis*) veligers occurred during the months of July, August, and September. All surveying techniques were in accordance with the *British Columbia Aquatic Invasive Species Survey Methods*

developed by the BC Ministry of Environment (https://www.for.gov.bc.ca/hra/invasive-species/Publications/BC_Aquatic_Sampling_March2015.pdf).

In total, thirty-one sites were monitored in 2016 (Table 1). At all monitoring sites, a 64-micron plankton net was deployed into the water to a maximum depth of six metres, and not less than one metre for vertical tows, or to a distance of six metres for horizontal tows. Multiple plankton tows were collected at each site to increase the likelihood of collecting veligers. Plankton tows were also collected in different areas of the site to further increase the likelihood of collecting veligers. Samples were condensed into collection bottles and preserved for shipment to a certified analyst to detect any presence of dreissenid veligers.

All dreissenid mussel monitoring data was submitted to the Ministry of Environment, who is responsible for entering the data into the Pacific States Marine Fisheries Commission online database (formerly the Columbia River Basin Aquatic Invasive Species Database).

Table 1. Locations where Zebra and Quagga Mussel veliger sampling occurred around the CKISS region, 2012 - 2016.

Waterbody	Common site name	UTM	Sampled in 2012	Sampled in 2014	Sampled in 2015	Sampled in 2016
Columbia River	Gyro Park, boat launch	11 U 448332 E 5439045 N	x	x	x	x
Columbia River	Old Bridge, Trail	11 U 449030 E 5437859 N	x	x	-	-
Columbia River	Robson, boat launch	11 U 449159 E 5464857 N	-	-	x	x
Slocan Lake	New Denver, boat launch	11 U 472925 E 5536943 N	x	x	x	x
Slocan Lake	Silverton, boat launch	11 U 473994 E 5533621 N	x	x	x	x
Slocan Lake	Slocan, boat launch	11 U 465959 E 5513126 N	x	x	x	x
Kootenay Lake	Balfour, boat launch	11 U 502978 E 5496721 N	x	x	x	-
Kootenay Lake	Kokanee Creek Provincial Park, boat launch	11 U 491741 E 5495260 N	-	x	x	x
Kootenay Lake	Lakeside Park, boat launch	11 U 479610 E 5484065 N	-	x	x	x
Kootenay Lake	Kaslo Marina	11 U 506611 E 5529018 N	-	-	-	x
Kootenay Lake	Kaslo Bay, boat launch	11 U 506829 E 5529205 N	x	-	x	-
Kootenay Lake	Riondel Marina	11 U 510285 E 5513027 N	-	x	x	x

Kootenay Lake	Kuskanook Marina	11 U 524508 E 5460867 N	-	x	x	x
Kootenay Lake	Boswell Marina	11 U 516895 E 5478782 N	-	-	x	-
Kootenay Lake	Tye Marina	11 U 515246 E 5464080 N	-	-	-	x
Kootenay Lake	Kootenay Lake Provincial Park, Lost Ledge Site, boat launch	11 U 504379 E 5549941 N	-	-	-	x
Upper Arrow Lake	Nakusp, boat launch	11 U 443096 E 5565192 N	x	x	x	x
Upper Arrow Lake	McDonald Creek Provincial Park, boat launch	11 U 442048 E 5553611 N	-	-	-	x
Lower Arrow Lake	Syringa Creek Provincial Park, boat launch	11 U 436701 E 5465721 N	x	x	x	x
Lower Arrow Lake	Scottie's Marina	11 U 439768 E 5465856 N	-	-	x	x
Pend D'Oreille River	Buckley campground, boat launch	11 U 464006 E 5431944 N	x	x	x	x
Pend D'Oreille River	Boat launch	11 U 459550 E 5428779 N	x	-	-	-
Pend D'Oreille River	Boat launch	11 U 472683 E 5429718 N	-	-	x	-
Upper Little Slocan Lake	Boat launch	11 U 452522 E 5503237 N	-	x	x	x
Summit Lake	Three Island Lodge, boat launch	11 U 452951 E 5556340 N	-	x	-	-
Summit Lake	Summit Lake Provincial Park, boat launch	11 U 453147 E 5556255 N	-	-	-	x
Box Lake	Boat launch	11 U 449195 E 5561760 N	-	x	x	x
Nancy Greene Lake	Boat put-in	11 U 431491 E 5456489 N	-	x	x	x
Nancy Greene Lake	Outflow near beach	11 U 431621 E 5456605 N	-	-	-	x
Rosebud Lake	Boat launch	11 U 480291 E 5432470 N	-	x	x	x
Trout Lake	Boat launch	11 U 462126 E 5610471 N	-	x	-	-
Trout Lake	Boat put-in	11 U 480303 E 5595508 N	-	x	-	-
Staubert Lake	Boat put-in	11 U 454841 E 5614426 N	-	x	x	-
Fish Lake	Boat put-in	11 U 487081 E 5543753 N	-	x	x	x

Wilson Lake	Boat launch	11 U 456954 E 5564743 N	-	x	x	-
Mosquito Lake	Boat launch	11 U 424222 E 5576051 N	-	-	x	-
Erie Lake	Boat launch	11 U 474320 E 5448793 N	-	-	x	x
Whatshan Lake	Boat launch, south end	11 U 419801 E 5530251 N	-	-	x	-
Whatshan Lake	Stevens Creek Rec. Site, boat launch	11 U 422021 E 5548621 N	-	-	-	x
Whatshan Lake	Richy Rec. Site, boat put-in	11 U 422330 E 5546808 N	-	-	-	x
Cottonwood Lake	Boat launch	11 U 481482 E 5475302 N	-	-	x	x
Duncan Lake	Howser Creek Rec. Site, boat launch	11 U 503977 E 5572259 N	-	-	-	x
Duncan Lake	Glacier Creek Regional Park, boat launch	11 U 505405 E 5569673 N	-	-	-	x
Champion Lake	Third lake, boat launch	11 U 455434 E 5448363 N	-	-	-	x

Zebra and Quagga Mussel Juvenile and Adult Monitoring

Monitoring for dreissenids at the juvenile and adult life stages was done by use of substrate samplers. The installation of substrate samplers was dependent on approval from the appropriate authority, public safety, and depth requirements. In 2016, four substrate samplers were in place at various locations around the CKISS region (Table 2). Two of the substrates were the responsibility of the CKISS, and were installed and monitored in accordance with the *British Columbia Aquatic Invasive Species Survey Methods* during the months of July, August, and September. The monitoring status of the other two substrates is unknown as those were donated to partner organizations and therefore the responsibility of those organizations.

High boat traffic areas were chosen for substrate installation. Substrate samplers were deployed in covered areas (e.g. undersides of docks) with some water flow, and as deep as possible (up to 8 m). Samples were collected from substrates only if suspect organisms were seen or felt. When monitoring the installed substrates, which are a small surface area, the opportunity was taken to check additional nearby substrates (e.g. docks, pilings, boat hulls, etc.), as well as the shoreline, for any presence of dreissenids.

Table 2. Locations of substrate sampling equipment for Zebra and Quagga Mussel monitoring around the CKISS region, 2016.

Waterbody	Common site name	Nearest town	UTM	Monitoring Organization
Kootenay Lake	Kuskanook Marina	Creston	11 U 524508 E 5460867 N	CKISS
Slocan Lake	Slocan boat launch	Slocan	11 U 465959 E 5513126 N	CKISS
Kootenay Lake	Riondel Marina	Riondel	11 U 510285 E 5513027 N	Eastshore Freshwater Habitat Society
Kootenay Lake	Tye beach Marina	Ymir	11 U 515246 E 5464080 N	Nature Conservancy of Canada

AQUATIC INVASIVE PLANTS

All aquatic invasive plant surveys were carried out in accordance with the *British Columbia Aquatic Invasive Species Survey Methods* protocols for littoral or shoreline surveys. A list of target aquatic and riparian plant species for the province was provided by the Provincial Early Detection Rapid Response Coordinator from within the Ministry of Forests, Lands and Natural Resource Operations prior to commencing surveying (Appendix A). Waterbodies identified as high risk by the CKISS Aquatics Working Group were ranked in priority based on a variety of factors including, but not limited to, ease of access for illegal dumping (lakes on major routes with rest stops), gaps in past survey data, and those listed as high priority on the FWCP's Small Lakes Action Plan. Occurrences of invasive plants were recorded following provincial protocols and data was entered into the IAPP (Invasive Alien Plant Program) database.

The entire littoral zones of Rosebud, Nancy Greene, Erie, Summit, Box, Fish and Beaver Lakes were surveyed, and sections of the littoral zones of Whatshan and Slocan Lakes near high risk areas (e.g. boat launches, marinas, recreation sites) were also surveyed. For littoral surveys, a hard rake was deployed at 100 m intervals from a watercraft, (motorized when possible) retrieving plants from the substrate. At each sampling point, UTM's, depth, substrate, plants found (native and non-native) and other relevant data, (riparian usage, flow, inflow creeks, etc.) was recorded. The riparian zone was also scanned for the presence of target invasive plants. The shoreline method was utilized at Syringa Creek and McDonald Creek Provincial

Parks on Arrow Lake Reservoir. For this method, the rake was tossed from shore at 25 m intervals, and UTM's, substrate, and plants present were recorded. The shoreline was also scanned for the presence of invasive plant fragments.

Modified surveys were conducted at three sites where invasive plant sightings were reported by concerned citizens. In Boswell (eastside of Kootenay Lake), where Watercress (*Nasturtium officinale)* was reported to be present in a small creek, the accessible sections of the creek were walked in order to confirm the sighting and determine the extent of the colonization. In Mel Deanna Pond, where *N. odorata* was reported to be present, the pond was surveyed from shore where accessible, and with the aid of binoculars from vantage points along the path that encircles the wetland. Particular attention was paid to the outflow and around the main entrance and major access points. At the Arrow Lakes restoration site, near the Arrow Lake Generating Station, where Yellow Flag Iris (*Iris pseudacorus*) was surveyed and removed by CKISS summer staff.

Aquatic invasive plants (*N. odorata*) were mechanically treated by removing as much of the rhizome as possible at Mel Deanna Pond, Erie Lake, and Nancy Greene Lake. At Erie Lake, where plants were growing in open water, a containment apparatus was constructed out of rebar and mesh in order to prevent rhizomes from spreading. Known infestations of Yellow Flag Iris (*Iris pseudacorus)* were mechanically treated by the Salmo Watershed Streamkeepers Society within Erie Lake, the CKISS provided a stipend for their efforts.

Education and Outreach

The CKISS engaged in various outreach activities and media directed at specific target audiences and the general public, raising awareness about aquatic invasive species through education, and promoting the province-wide Clean Drain Dry, Don't Let it Loose, and PlantWise programs. Outreach strategies associated with these programs to prevent human-caused AIS introductions are based on the concept of community based social marketing, whereby key messages are promoted to encourage specific behaviours.

The CKISS participated in the Columbia Basin Environmental Education Network's (CBEEN) "Teach About Invasives" workshop. The workshop focused on developing new, or modifying existing school programs to be in line with the updated BC, K-12 curriculum by including place-based learning, community connections, "big ideas", and curricular competencies.

The CKISS would like to acknowledge that the FWCP was recognized as a funder at all relevant events and media.

SECTION V. RESULTS AND OUTCOMES

ZEBRA AND QUAGGA MUSSEL MONITORING

In 2016, the CKISS collected a total of 62 plankton samples. These samples were analyzed for any presence of dreissenid veligers using cross-polarized light microscopy by a certified analyst. This method has been identified by subject matter experts in many jurisdictions as the standard method that is required for veliger detection and appropriate monitoring for dreissenid mussels. The results of all samples were negative for dreissenid veliger presence (Table 3). For the two submerged substrate samplers that the CKISS monitored, no juvenile or adult dreissenid mussels were detected.

Table 3. Results of plankton samples that were analyzed for dreissenid veliger presence, Central Kootenay region, 2016. (Ostracoda are Metazoa belonging to the Phylum Arthropoda, Class Crustacea. They are found in almost all aquatic environments, both fresh and marine waters, within the water column as well as on (and in) the substrate).

Waterbody	UTM Zone	Easting	Northing	Date sampled	Common Site Name	Dreissenid veliger	Others
Columbia River	11 U	448332	5439045	July 8 2016	Gyro Park, launch, Trail	-	-
Columbia River	11 U	449159	5464857	July 8 2016	Robson Boat Launch	-	-
Columbia River	11 U	448332	5439045	Aug 2 2016	Gyro Park, launch, Trail	-	Ostracoda
Columbia River	11 U	448332	5439045	Sep 6 2016	Gyro Park, launch, Trail	-	-
Columbia River	11 U	449159	5464857	Sep 6 2016	Robson Boat Launch	-	-
Kootenay Lake	11 U	506611	5529018	July 7 2016	Kaslo Bay, visitor's dock	-	-
Kootenay Lake	11 U	491741	5495260	July 15 2016	Kokanee Ck. Prov. Pk. Launch	-	Ostracoda
Kootenay Lake	11 U	510285	5513027	July 15 2016	Riondel Marina	-	Ostracoda
Kootenay Lake	11 U	524508	5460867	July 15 2016	Kuksanook Marina launch	-	Ostracoda
Kootenay Lake	11 U	479610	5484065	July 15 2016	Lakeside Pk. launch, Nelson	-	Ostracoda
Kootenay Lake	11 U	491741	5495260	Aug 4 2016	Kokanee Ck. Prov. Pk. Launch	-	Ostracoda
Kootenay Lake	11 U	510285	5513027	Aug 4 2016	Riondel Marina	-	Ostracoda
Kootenay Lake	11 U	524508	5460867	Aug 4 2016	Kuksanook Marina launch	-	Ostracoda
Kootenay Lake	11 U	506611	5529018	Aug 5 2016	Kaslo Bay, visitor's dock	-	-
Kootenay Lake	11 U	479610	5484065	Aug 5 2016	Lakeside Pk. launch, Nelson	-	-
Kootenay Lake	11 U	504379	5549941	Aug 5 2016	Lost Ledge Prov. Pk. Launch	-	-

Kootenay Lake	11 U	510285	5513027	Sep 2 2016	Riondel Marina	-	Ostracoda
Kootenay Lake	11 U	515246	5464080	Sep 3 2016	Tye Marina	-	-
Kootenay Lake	11 U	491741	5495260	Sep 2 2016	Kokanee Ck. Prov. Pk. Launch	-	-
Kootenay Lake	11 U	524508	5460867	Sep 2 2016	Kuksanook Marina launch	-	Ostracoda
Kootenay Lake	11 U	506611	5529018	Sep 8 2016	Kaslo Bay, visitor's dock	-	-
Kootenay Lake	11 U	479610	5484065	Sep 8 2016	Lakeside Pk. launch, Nelson	-	Ostracoda
Lower Arrow Lake	11 U	436701	5465721	July 8 2016	Syringa Ck. Prov. Pk. boat launch	-	-
Lower Arrow Lake	11 U	436701	5465721	Aug 2 2016	Syringa Ck. Prov. Pk. boat launch	-	Ostracoda
Lower Arrow Lake	11 U	439768	5465856	Sep 6 2016	Scottie's Marina, wharf	-	-
Upper Arrow Lake	11 U	442048	5553611	July 6 2016	McDonald Ck. Prov. Pk. Launch	-	-
Upper Arrow Lake	11 U	443096	5565192	July 6 2016	Nakusp public boat launch	-	-
Upper Arrow Lake	11 U	442048	5553611	Aug 3 2016	McDonald Ck. Prov. Pk. Launch	-	-
Upper Arrow Lake	11 U	443096	5565192	Aug 3 2016	Nakusp public boat launch	-	Ostracoda
Upper Arrow Lake	11 U	442048	5553611	Aug 31 2016	McDonald Ck. Prov. Pk. Launch	-	Ostracoda
Upper Arrow Lake	11 U	443096	5565192	Aug 31 2016	Nakusp public boat launch	-	-
Duncan Lake	11 U	503977	5572259	July 7 2016	Howser Ck. Rec. site launch	-	-
Duncan Lake	11 U	503977	5572259	Aug 5 2016	Howser Ck. Rec. site launch	-	-
Duncan Lake	11 U	505405	5569673	Aug 5 2016	Glacier Ck. Regional Pk. Launch	-	-
Duncan Lake	11 U	503977	5572259	Sep 8 2016	Howser Ck. Rec. site launch	-	-
Duncan Lake	11 U	505405	5569673	Sep 8 2016	Glacier Ck. Regional Pk. Launch	-	-
Slocan Lake	11 U	472925	5536943	July 6 2016	New Denver campground launch	-	-
Slocan Lake	11 U	473994	5533621	Aug 3 2016	Silverton public launch	-	-
Slocan Lake	11 U	465959	5513126	Aug 17 2016	Slocan City public launch	-	-
Slocan Lake	11 U	472925	5536943	Sep 7 2016	New Denver campground launch	-	-
Slocan Lake	11 U	473994	5533621	Sep 7 2016	Silverton public	-	Ostracoda

					launch		
Slocan Lake	11 U	465959	5513126	Sep 7 2016	Slocan City public launch	-	-
Summit Lake	11 U	453147	5556255	July 6 2016	Summit Lk. Prov. Pk. Launch	-	Ostracoda
Summit Lake	11 U	453147	5556255	Aug 31 2016	Summit Lk. Prov. Pk. Launch	-	Ostracoda
Box Lake	11 U	449195	5561760	July 6 2016	boat launch at campground	-	Ostracoda
Box Lake	11 U	449195	5561760	Aug 31 2016	boat launch at campground	-	Ostracoda
Cottonwood Lake	11 U	481482	5475302	July 14 2016	dock	-	-
Cottonwood Lake	11 U	481482	5475302	Sep 9 2016	dock	-	-
Champion Lake #3	11 U	455434	5448363	July 14 2016	boat launch	-	Ostracoda
Champion Lake #3	11 U	455434	5448363	Sep 9 2016	boat launch	-	Ostracoda
Rosebud Lake	11 U	480291	5932470	July 14 2016	boat launch	-	Ostracoda
Rosebud Lake	11 U	480291	5932470	Sep 9 2016	boat launch	-	Ostracoda
Pend D'Oreille River	11 U	464006	5431944	Aug 2 2016	Buckley Campground launch	-	Ostracoda
Pend D'Oreille River	11 U	464006	5431944	Sep 6 2016	Buckley Campground launch	-	Ostracoda
Nancy Greene Lake	11 U	431621	5456605	Aug 2 2016	outflow near beach	-	Ostracoda
Nancy Greene Lake	11 U	431621	5456605	Sep 6 2016	beach area	-	-
Whatshan Lake	11 U	422021	5548621	Aug 3 2016	Stevens Ck. Rec. site launch	-	-
Whatshan Lake	11 U	422330	5546808	Aug 31 2016	Richy Rec. site	-	-
Erie Lake	11 U	474320	5448793	Aug 12 2016	boat launch	-	Ostracoda
Erie Lake	11 U	474320	5448793	Sep 9 2016	boat launch	-	Ostracoda
Upper Little Slocan Lake	11 U	452559	5503356	Sep 1 2016	boat launch	-	-
Fish Lake	11 U	487081	5543753	Sep 7 2016	mid-lake	-	Ostracoda

Aquatic Invasive Plants

Survey data for each sampling point is presented in the attached MS Excel workbook titled: *AIS sampling points FWCP 2016,* with a separate worksheet allotted to each waterbody. Also included in each worksheet are Secchi depths, elevations, date, and access points for each waterbody. No submerged aquatic invasive plants were discovered at any of the waterbodies surveyed in the course of this study, and points sampled on Rosebud, Summit, Box, Fish, Beaver, Whatshan, Slocan, and Arrow Lakes were free of invasive plants, both riparian and aquatic.

At Nancy Greene and Erie Lakes, *N. odorata* was present, and at Mel Deanna Pond a newly reported infestation of the emergent plant was confirmed. In Erie Lake, two new, relatively small patches (20-25 m^2) of *N. odorata* were found growing tucked in amongst the native water lily (*Nuphar polysepala*) to the east of the boat launch (Fig. 3). These patches are less than 5 m apart and are represented by a single yellow dot in Figure 3. The known clump of *N. odorata* (discovered and treated in 2015's survey) on the west side of the boat launch had not changed in size and is most likely from a single rhizome. At Nancy Greene Lake, a lone patch of this plant has been mechanically treated since 2014 and has had its' area reduced from 6 m^2 to 0.6 m^2. In 2014, this was a thick mat of continuous plants and there are now only four sporadic clumps remaining. At Mel Deanna, the confirmed sighting of this plant was approximately 22 m^2, and was growing in a small pond isolated from the main body of water approximately 1 km west of the A-frame at the north end of the main pond. Several small clumps were also discovered in very shallow water (also isolated from the main pond) directly in front of the A-frame.

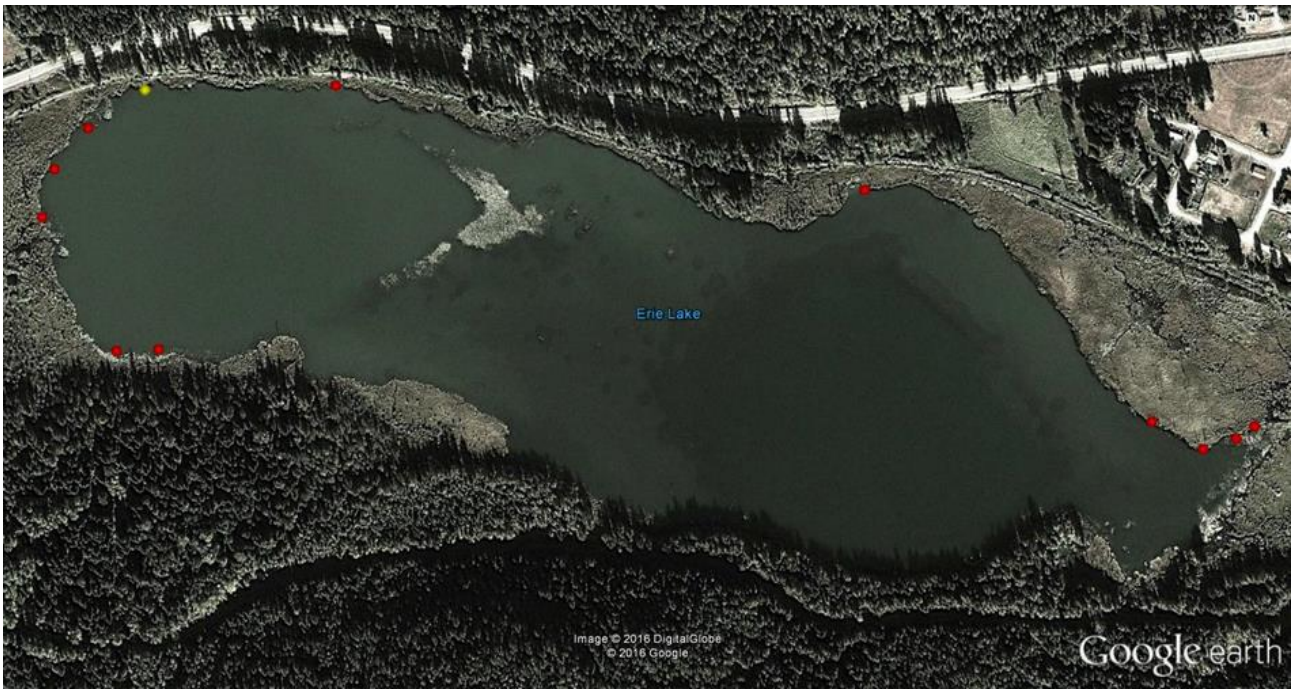

Figure 2. Sampling points on Erie Lake from 2015 indicating presence of ● Iris pseudacorus and ● Nymphaea odorata.

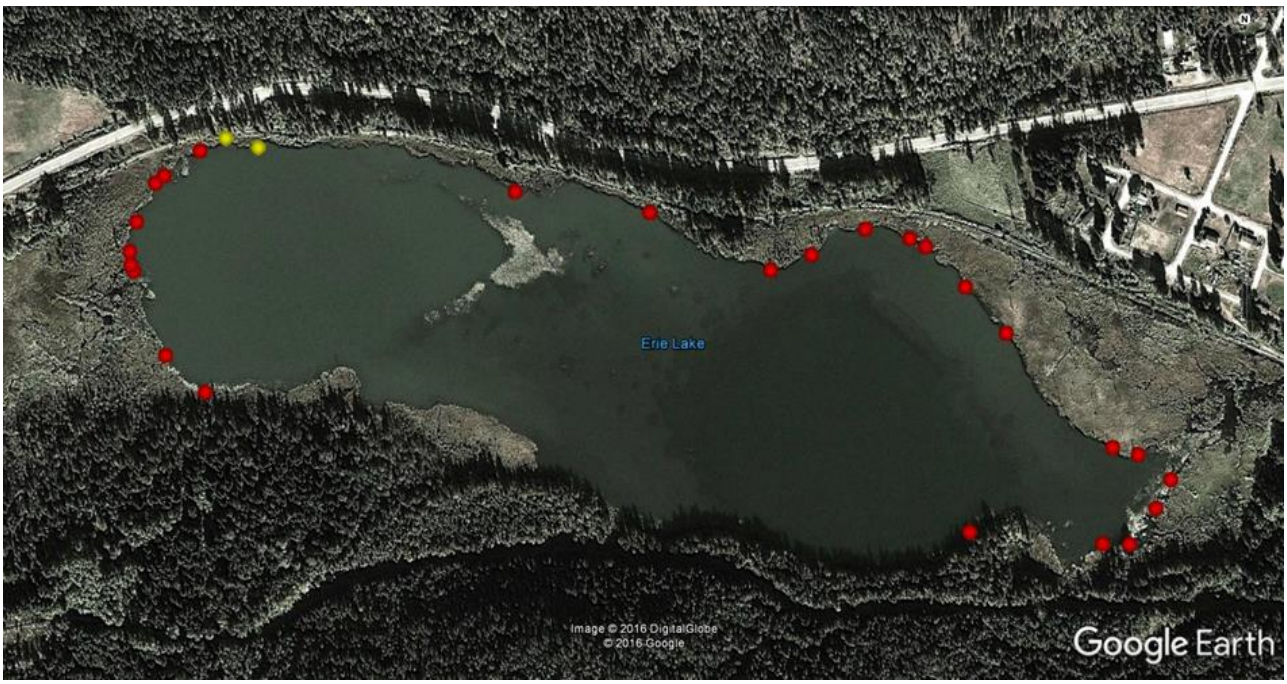

Figure 3. Sampling points on Erie Lake from 2016 indicating presence of ● Iris pseudacorus and ● Nymphaea odorata.

On Nancy Greene Lake, known infestations of *I. pseudacorus* that have been mechanically treated for several years were monitored and the riparian zone was scanned in the course of a littoral survey. No plants were found growing at any of these sites for the second year in a row, suggesting there is a possibility this species may have been eradicated from this

waterbody. On Erie Lake, clumps or individual *I. pseudacorus* were present at 25 separate sampling points. This is an increase in sites over previous years with a number of new, immature (lacking flowers) individual plants on the northeast shore and clustered around the outflow of the lake (Figs. 2 and 3). Many of these sites were young, lone individual or small clumps of plants.

Nasturtium officinale was confirmed to be growing in a small creek and ditch on Hepher Road close to the community of Boswell. A thick carpet of plants began at 11U 516733E 5480295N where a creek exited the forest from private property into a ditch on the eastside of the road. It continued for 40 m to a culvert under the road. Beyond the culvert, the creek entered the forest again and no watercress was found. Where the creek entered the ditch along Highway 3A, the gradient decreased and thick mats of *N. officinale* began again. The water then traversed the highway through a culvert into the woods on private property with no plants visible. In speaking with a local couple, they mentioned that *N. officinale* was present along the shoreline of Kootenay Lake where this creek enters. There was no public access to the water at this location. In addition to *N. officinale*, Himalayan Blackberry (*Rubus armeniacus*) was present in dense stands along and between Hepher Road and Highway 3A.

Education and Outreach

In 2016, the CKISS' educational messages reached over 12,000 people directly through various community events, workshops, field tours, presentations, and exhibition activities (~ 70% more people than in 2015), while our regional and province-wide (except Lower Mainland and Vancouver Island) media activities had the potential to reach millions of people through in-print and on-line publications, as well as radio and television interviews (Table 4). Clean, Drain, Dry educational signage was donated to the Regional District of Central Kootenay for installation at Glacier Creek Regional Park on Duncan Reservoir.

Participation in the CBEEN's "Teach About Invasives" workshop provided the knowledge, tools, and resources for the CKISS to begin development and delivery of workshops for school teachers on educating about invasive species both inside and outside of their classrooms according to the new BC curriculum's place-based learning format. The workshops will encourage teachers to take their students outdoors to engage in activities such as plant ID hikes, weed pulls, mapping and restoration projects. Throughout 2016, the CKISS contacted several school boards within the region to promote delivery of these workshops in 2017.

Table 4. Aquatic invasive species focused education and outreach activities undertaken by the Central Kootenay Invasive Species Society throughout 2016.

Date	Details	Target Audience/Topic	Number of people reached
February 4	Presentation: West Kootenay Fly Fishing Club members	Anglers	12
March 5	Hosted CKISS educational booth: Slocan Wetlands Assessment and Mapping Project open house	Researchers and general public	85
March 19 & 20	Hosted CKISS educational booth: Fly Fishing Symposium	Anglers	1300
April 6	Radio Interview: EZ Rock	Topic: ZQM and Provincial watercraft inspection stations	-
April 7	Radio Interview: Juice FM	Topic: ZQM and Provincial watercraft inspection stations	-
April 14	Presentation: 19th International Conference on Aquatic Invasive Species (AIS)	Researchers, educators, industries, and organizations involved with AIS	237
April 21	Youth Pulling Together event: Wildflower School	Earth Day restoration project	25
April 29	Youth Pulling Together event: Redfish Elementary School	Grades K - 4	85
April 29 & 30	Hosted CKISS educational booth: Creston Spring Trade Show	General public	1675
May 3	Field Tour & Invasive Species ID	Selkirk College ASE class	5
May 7	Hosted CKISS educational booth: FWCP Critter Day	General public	300
May 7	Hosted CKISS educational booth: Nelson Garden Fest	General public	500
May 14	Hosted CKISS educational booth: Nelson Cottonwood Market	General public	500
May 18	Field Tour & Invasive Species ID: Rossland Summit School	Grades 2 - 5	25
May 24	Presentation: Columbia River Basin (CRB) Team meeting	Government and non-government agencies and organizations that are members of the CRB Team	65
May 25	Field Tour & Invasive Species ID: Nakusp Elementary School	Grades 4 - 7	130
May 28	Hosted CKISS educational booth: Castlegar Garden Fest	General public	150
June 3	Radio Interview: EZ Rock	Topic: ZQM and Provincial watercraft inspection stations	-
June 10	Hosted CKISS educational booth: New Denver Friday Market	General public	25
June 18	Hosted CKISS educational booth: Family Fishing Weekend Event, Champion Lakes	General public	45
June 19	Hosted CKISS educational booth: Family Fishing Weekend Event, Cottonwood Lake	General public	231
June 20	Radio Interview: CBC Radio West	Topic: American bullfrogs	-

June 21	Radio Interview: CBC Local News	Topic: American bullfrogs	-
June 21	CKISS' American Bullfrog open house, Creston	General public	14
July 6	Article: The Nelson Star newspaper	Topic: Clean Drain Dry	Distribution: In print and 500,00 online viewers
July 7	Hosted CKISS educational booth: Rossland Mountain Market	General public	200
July 8	Hosted CKISS educational booth: Trail Market	General public	300
July 23	Hosted CKISS educational booth: Kaslo Market	General public	300
July 24	Article: Castlegar Source online newspaper	Topic: Fragrant water lily and yellow flag iris	Distribution: 100,000 online viewers monthly
July 27 & 28	Hosted CKISS educational booth: Toadfest	General public	200
August 2	Article: Arrow Lakes News	Topic: American bullfrogs	Distribution: In print and 500,00 online viewers
August 3	Community Weed Pull event for Yellow Flag Iris, Creston	Eco Action volunteers	9
August 4	Hosted CKISS educational booth: Salmo Farmers Market	General public	50
August 5	Article: Castlegar News	Topic: Fragrant water lily and yellow flag iris	Distribution: In print and 500,00 online viewers
August 8	Radio Interview: Juice FM	Topic: Fragrant water lily and yellow flag iris	-
August 8	Radio Interview: The Goat	Topic: Fragrant water lily and yellow flag iris	-
August 8	Article: My Nelson Now online newspaper	Topic: Fragrant water lily and yellow flag iris	-
August 8	Article: My Kootenay Now online newspaper	Topic: Fragrant water lily and yellow flag iris	-
August 28	Hosted CKISS educational booth: RedFish Festival	General public	500
September 9	Eco-Action Weed Pull event for Yellow Flag Iris, Creston	Selkirk College RFW students	15
September 11	Hosted CKISS educational booth: Hills Garlic Festival	General public	5060
September 20	Eco-Action Weed Pull event for Yellow Flag Iris, Creston	Prince Charles Grade 11/12 students	11
September 20	TV Interview: Shaw	Topic: Eco Action Weed Pull for yellow flag iris by Prince Charles students	Broadcast in the West & East Kootenays and online

October 15	CKISS Field Tour and AGM	General public, CKISS Board of Directors, partners	60
October 22	Presentation and educational booth: Friends of Kootenay Lake Stewardship Society's (FOKLSS) Annual Summit	FOKLSS members, general public	102
November 10	Presentation: Selkirk College	Second-year Recreation, Fish and Wildlife students	28
Spring 2016	Advertisement: West Kootenay Go & Do magazine, Spring 2016 issue	Tourists, general public	Distribution: 40,000 publications

SECTION VI. DISCUSSION

Through engagement in various outreach methods and media activities, such as, but not limited to, community events, field tours, presentations, and interviews, the CKISS disseminated thousands of educational resources; raised awareness about AIS and their ecological, economic, and social impacts; improved the public's ability to identify and report AIS; promoted best practices such as Clean, Drain, Dry (water-based recreationists), Don't Let it Loose (pet and aquarium owners), and PlantWise (gardeners and horticulture industry); and brought attention to the purposes of and legislation associated with the provincial mandatory watercraft inspection stations. These activities provide the opportunity for Columbia Basin residents to play an important role in preventing the introduction of new AIS, as well as reducing or eliminating the spread of existing AIS.

The preventative actions associated with the aforementioned programs can drastically reduce the introduction and spread of AIS, and because human activities, such as the movement of AIS fouled watercraft from one body of water into another, pose the greatest risk for AIS movement between in-land waterways (CCFAMAISTG 2004), the absence of dreissenid mussels suggests that our education about AIS and best practices is effective at preventing the introduction of these species into the region's waterways. This in turn contributes to the conservation of the biodiversity and overall ecological integrity of the region's waterbodies. In 2016, two new infestations of aquatic invasive plants (*N. odorata* and *N. officinale*) were confirmed based on reports by concerned citizens educated in the threat of invasive species. These plants were discovered in somewhat remote locations and therefore may not have been found if it were not for the incidental sightings by educated members of the public. Unfortunately, the *N. odorata* reported at Mel Deanna Pond was growing beneath an interpretive sign describing the significance of native water lilies, which could erroneously lead the public to believe that *N. odorata* is a native species, subsequently causing people to see no harm in transplanting it to other locations. While it is known that waterfowl, turtles, and ducks will consume the fruit of this plant, thereby spreading the seed

to new locations (Schneider and Chaney 1981), deliberate plantings by humans are still the primary source of introductions into new bodies of water (NWCB 2013).

The Central Kootenay region has an abundance of freshwater ecosystems, most of which are still free from the negative impacts caused by aquatic invasive species. These waterbodies provide many social benefits for the local communities in addition to the economic benefits that are derived from the water-based recreational opportunities that generate tourism. Many local businesses rely on the income generated by sport fishing, rafting, watercraft rentals, moorage and marina usage. However, the presence of non-native, invasive aquatic plant and animal species can negatively impact the aforementioned benefits by reducing or eliminating recreational opportunities, as well as reducing waterfront property values and degrading water quality, thereby affecting drinking water sources (LSWG 2014; Ecosystems 2016). Furthermore, water-based infrastructure that is contaminated with AIS requires increased maintenance and these additional costs impact regional economies. Therefore, by changing people's behaviours through education on the best practices that prevent the movement of AIS, and through pro-active monitoring and management activities, this program is protecting the social and economic values of the region.

The results of treating the small infestation of *N. odorata* at Nancy Greene Lake highlights the importance and effectiveness of the Early Detection Rapid Response (EDRR) program. The patch of water lilies was discovered as a single dense patch in 2014 and was immediately mechanically treated. It was treated again in the fall of 2014, and again in 2015 and 2016, resulting in a substantial reduction in the patch's area and density. If left to grow unchecked, *N. odorata* will rapidly colonize the entire littoral zone up to a depth of approximately 2.75 m. The littoral zone provides critical habitat for native plants, wildlife, fish, and invertebrates. The leaves and flowers produced from a single rhizome can cover up to 15 m^2 of the water surface in as little as five years (Seago et al. 2000). In Griffin Lake (a 55 ha lake in eastern Washington), *N. odorata* cover increased from approximately 10% to 100% of the surface area within 20 years (TCLP 2014). Mel Deanna Pond, Erie Lake and Nancy Greene Lake are all highly vulnerable to extensive colonization by *N. odorata* due to their large areas of shallow littoral habitat. *N. odorata* can have negative impacts on many levels of organization, including population, community, and ecosystem. This species also acts as an ecosystem engineer, which is any organism that significantly modifies or destroys the native physical habitat. Large mats of floating leaves decrease available sunlight, prevent mixing of the littoral zone by wind, and increase water temperatures resulting in an altered pH and lower levels of dissolved oxygen (Northey 2014). The large amount of decaying leaves undoubtedly adds a significant amount of detritus to the benthic zone altering the benthos and substrate. Preventing the spread of *N. odorata* throughout the littoral zone therefore ensures the

protection of native fish and associated wildlife communities while preserving ecosystem function.

The riparian zone at Nancy Greene Lake also benefitted from a proactive EDRR program. In this lake, the introduction of *I. pseudacorus* was detected when only five small clumps were present surrounding the lake. These clumps were mechanically pulled for three years and this species may now be eradicated from this waterbody. In contrast, the populations of *I. pseudacorus* at Erie Lake were most likely well established prior to detection, thereby eliminating rapid response opportunities. There are other contributing factors to the expanding populations of *I. pseudacorus* in Erie Lake, including a larger proportion of suitable habitat around the shoreline. The majority of the shoreline at Nancy Greene Lake is mildly sloping, dry, and forested. In contrast, Erie Lake is dominated by areas of moist, low-gradient, marsh-like substrate, providing a large amount of suitable habitat for the establishment and proliferation of this plant. The presence of many new individual plants at Erie Lake suggests that there may be a persistent seedbank present, or that new seeds are being released. Unfortunately, there is a lack of information available on the persistence of *I. pseudacorus* seeds in the soil (Stone 2009). Removal efforts by a team of volunteers from the Salmo Watershed Streamkeepers Society has been ongoing for several years, and if left unchecked, dense stands of *I. pseudacorus* would greatly impact access for species of birds, amphibians and the blue-listed western painted turtle to and from large sections of Erie Lake.

Nasturtium officinale is restricted to colder, gently flowing freshwater streams and can become highly invasive, outcompeting native species (Barker 2009). This species is also considered to be an ecosystem engineer, creating a dense mat that can block stream flow and cause flooding (Les and Mehrhoff 1999). In this study, the infestation was confined to a ditch along Hwy 3A and Hepher Road, and most likely has little impact. The extent of colonization along the shore of Kootenay Lake is unknown and there is a risk of this plant being transported to other areas where impacts may be increased. *N. officinale* can be spread by watercraft, wind and water currents, birds and other wildlife, as well as intentional movements by humans.

The movement of aquatic invasive species is not hindered by jurisdictional boundaries; therefore, AIS monitoring and management activities cannot occur within a bubble. In order to understand the natural pathways of introduction and the current distribution of species, as well as to facilitate collaboration and coordination to ensure resources are not lost to duplicative efforts, the CKISS partners with many government and non-government agencies and organizations, stakeholders, regional stewardship groups, and other relevant partners, both within BC and from neighbouring provinces and states such as Alberta, Idaho,

Washington, and Montana. As a member of the multi-jurisdictional Columbia Basin Regional AIS Program Steering Committee, we are active in species-specific working groups established for priority AIS such as American Bullfrog and Northern Pike; utilizing a comprehensive list of priority species with their associated known locations and pathways of introduction to facilitate work planning; ensuring consistency of key behaviour change messaging so as to be most effective; promoting provincial watercraft inspection stations with the attendance of inspection crews at public outreach events; utilizing basin-wide criteria for identifying high priority waterbodies for surveying and monitoring activities; and identifying, supporting, and partnering with innovative research projects.

SECTION VII. RECOMMENDATIONS

Prevention is the first line of defence against the introduction of AIS, as well as the most cost-effective and ecologically protective measure (WRPAIS 2010); however, prevention cannot be 100% effective (Locke et al. 2011). It is documented that invasive mussel fouled watercraft have been destined for BC waters since 2011 (Therriault et al. 2013), and while the provincial watercraft inspection stations provide an important first line of defence, they are not always in operation; therefore, it is only a matter of time before a mussel fouled vessel launches within BC. In order to address this risk, and facilitate the enactment of the second line of defence – rapid response – a long-term, early-detection monitoring program must remain in place. In addition, we recommend that the monitoring program be extensive in scope with high sampling frequency because the more samples that are collected from a waterbody, the greater the confidence level of presence/absence sampling. It has been stated that an estimated 300 – 400 samples would need to be collected from a waterbody in order to have a 95% confidence level that dreissenid mussels were not present (M. Herborg, Ministry of Environment, personal communication, November 19, 2015).

While immediate eradication of dreissenid mussels from BC waterways is the province's primary goal (IMISWG 2015), eradication of aquatic species in general is a possibility only in extremely limited circumstances, for example, before a species has the opportunity to disperse. Species that are allowed to spread make future eradication efforts virtually impossible (Locke et al. 2011); therefore, early-detection monitoring is critical to identify new incursions and enable the activation of a rapid response that can maximize the opportunity for eradication. Dreissenid mussels in particular are extremely problematic to control, and virtually impossible to eradicate once they have become established and widespread in a waterbody. These mussels have been present in North America since 1986 and yet there has been only one documented case of a complete eradication of an established population from a waterbody. In this case, the waterbody was small and contained, and eradication was achieved by application of 174,000 gallons of potassium

chloride solution (Heimowitz and Phillips 2014). The current lack of chemicals approved for open water use reduces the options available for eradication in BC, and in turn highlights how critically important it is that dreissenid mussels be detected at the primary point of introduction, well before dispersal occurs.

The expansion of the Provincial Mussel Defence Program's mandatory watercraft inspection stations has been an important contributing factor to keeping Columbia basin waters free from dreissenid mussels, with the interception of 17 watercrafts that were confirmed to have Zebra or Quagga Mussels in 2016. However, we recommend that these stations be in operation 24 hours/day during operating season in order to intercept 100% of the watercraft being transported.

Current infestations of *P. crispus, N. odorata* and *M. spicatum* in the region allow for easy dispersal and spread to other waterbodies. New discoveries of species such as *M. aquaticum*, Water Hyacinth (*Eichhornia crassipes*), and *B. umbellatus* in neighbouring jurisdictions can also be easily transported into the region's waterbodies. Therefore, annual monitoring of priority waterbodies should continue in order to facilitate early detection and rapid response should new infestations of aquatic invasive plants be discovered. Utilizing Early Detection and Rapid Response methods is strongly recommended as the cost and effort required to treat established populations of AIS increases exponentially over time and eradication becomes difficult, if not impossible. For example, control efforts for *M. spicatum* in Christina Lake (RDKB Area C) have been occurring since 1987, and yet complete eradication has never been achieved. This control program costs the taxpayers of that region as much as $289,454 annually (Maki 2016). In Champion Lake (a small lake under 15 ha), *M. spicatum* control has been ongoing for over thirty years without achieving eradication.

The existing populations of *N. odorata* at Nancy Greene Lake, Erie Lake, and Mel Deanna Pond should continue to be treated and monitored. New patches of *N. odorata* can arise from a small piece of cut rhizome or stem, so removal must be done with great care to prevent dispersal of plant fragments (DiTomaso and Kyser 2013). Plants and rhizomes should be removed in mid-July prior to seed development and again in mid-September. The littoral zone of the lake should be surveyed at these times in order to detect new infestations. On the periphery of infestations in Erie Lake and Mel Deanna Pond, plants are growing in close to 2 m of water and therefore cannot be effectively treated without the use of divers or snorkelers. Benthic barriers have been used to effectively treat *N. odorata* if deployed early in the spring and could be used in these circumstances. At Erie Lake there are two patches of *N. odorata* side by side of approximately the same area. This provides an excellent opportunity to compare the efficacy and efficiency of hand removal versus benthic barriers.

The littoral zone of the lake should be surveyed at these times in order to detect new infestations.

The shore of Kootenay Lake near Boswell should be surveyed by watercraft in order to determine the extent of colonization by *N. officinale*. This is a popular edible plant for water gardeners, and education efforts should include the risks associated with the escape of this plant into the natural environment. Reporting of sightings of this plant should be encouraged in order to determine its impacts on a site by site basis.

The existing populations of *I. pseudacorus* at Erie Lake should continue to be treated and monitored. With the presence of many new individual plants suggesting that there may be a persistent seedbank, or that new seeds are being released, we recommend that continued control efforts for this species include seed head removal by clipping prior to seed maturity. In addition, removal of the rhizomes by digging and hand-pulling should continue.

The CKISS has assessed restoration at many of the sites where annual control of riparian invasive species control is taking place. We have determined that most of these sites do not require restoration post treatment as native vegetation quickly infiltrates within a year. As such restoration within these sites is not required. However, large scale removal of invasive riparian infestations such as the Yellow Flag Iris infestation at Creston Valley Wildlife Management Area would require restoration if such a project was undertaken.

Genetic testing of *Myriophyllum sp*. populations in the Kootenay-Columbia system should be conducted in order to determine if hybridization is occurring. Milfoil hybrids have morphological characteristics that are intermediary to Eurasian and native milfoils. This makes traditional methods of field identification (number of pairs of leaflets, distance between leaflets on rachis, etc.) more difficult. A clump of milfoil growing at McDonald Creek Provincial Park on Arrow Lake was identified as *Myriophyllum sibricum* (a native milfoil) by its flower. However, there often are no flowers present and field identification has relied on leaflet pairs.

M. spicatum and *M. sibricum* grow together in a bay close to Martha Creek Provincial Park on Lake Revelstoke (Harkness 2015), which may be resulting in hybrids. It is highly likely that *M. spicatum* is continuously being introduced to Arrow Lake passively from Lake Revelstoke, and there is a possibility that hybrids are entering as well. Boaters may also be unintentionally transporting *M. spicatum* through the navigational lock at the Hugh Keenleyside Dam from known infestations on the Lower Columbia River. LaRue et al. (2012) have demonstrated that hybrid milfoils are more invasive than parental pure *M. spicatum* lineages. Should hybrid milfoils be present in the region, there is a chance that they could go undetected if introduced to a new system, particularly if native milfoils are already present in said system.

Currently, the geographical extent of invasive hybrid watermilfoils in North America is unknown and should be pursued by additional sampling (Moody and Les 2002). Available funding was allocated to monitoring and treatment and therefore no genetic testing was conducted in 2016.

Communicating and collaborating with multi-jurisdictional partners is a critical component in preventing and managing the spread of aquatic invasive species via natural and human-assisted pathways. Through continued involvement with other agencies and organizations that are also involved in AIS prevention and management activities, we can ensure that our AIS program remains consistent with, and complimentary to, the efforts of the Province of BC and neighbouring jurisdictions, thereby reducing redundancies and focusing resources where they are most effective. Partnerships with regional stewardship groups should continue to be explored and expanded in order to increase the regional capacity for actions such as monitoring and treatment of AIS. For example, assistance from the Salmo Watershed Streamkeepers Society has been valuable for managing the high number of *I. pseudacorus* plants in Erie Lake. The CKISS currently lacks the capacity or funding to undertake large scale removal of submerged plants and therefore should continue to explore opportunities to collaborate with other organizations, similar to the collaborative project between the Okanagan Nation Alliance, Golder Associates, and CKISS for *M. spicatum* removal in the Lower Columbia River, which has received funding and will commence in 2017.

Many of the aquatic invasive species that cause problems intra and internationally are not yet present in our region, providing an exceptional opportunity to prevent the introduction of these species. Through the continued use of targeted education using proven behaviour change programs, species such as dreissenid mussels can be addressed through the Clean, Drain, Dry program for water recreationalists; *M. aquaticum* can be addressed through the Don't Let it Loose program for aquarium owners; and *B. umbellatus* can be addressed through the PlantWise program for gardeners and horticulturalists. To date, all known occurrences of *N. odorata* in the CKISS region are suspected to be intentional plantings or disposals due to their close proximity to roads and trails, which highlights the importance of continuing education programs that focus on changing behaviours and preventative actions. Public awareness about AIS can also be increased through installation of new aquatic and riparian invasive plant identification signs at waterbodies throughout the region, or for existing signs, adding information on relevant invasive species. For instance, the *N. polysepala* interpretive sign at Mel Deanna Pond could be improved by incorporating information on invasive lilies.

As dreissenid mussels continue to expand their range across North America, becoming ever closer to BC (discovered in Manitoba in 2013 and Montana in October 2016), and invasive

aquatic plants continue to be discovered in new locations in the region, the pressure to educate the public, proactively monitor, and work collaboratively ever increases in order to protect our waters from aquatic invasive species.

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- Columbia Basin Trust
- Columbia Power
- FortisBC Electric Inc.
- BC Hydro
- Canadian Columbia Basin Regional Aquatic Invasive Species Program Steering Committee
- Invasive Species Council of BC
- Kuskanook Harbour Society
- Village of Slocan
- Fish and Wildlife Compensation Program

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APPENDIX

APPENDIX A: TARGET AQUATIC AND RIPARIAN INVASIVE PLANT SPECIES FOR BC

Common Name	Scientific Name	Type
American beachgrass	*Ammophila breviligulata*	Semi-aquatic tidal
Amphibious yellow cress	*Rorippa amphibian*	Semi-aquatic emergent
Bigfoot clover	*Marsilea macropoda*	Semi-aquatic emergent/terrestrial
*Brazilian elodea	*Egeria densa*	Aquatic submerged
*Cabomba	*Cabomba caroliniana*	Aquatic submerged
*Common cordgrass	*Spartina anglica*	Semi-aquatic tidal
Common frogbit	*Hydrocharis morsus-range*	Aquatic submerged
Curly leaf pondweed	*Potamogeton crispus*	Aquatic submerged
*Dense-flower cordgrass	*Spartina densiflora*	Semi-aquatic tidal
Eurasian watermilfoil	*Myriophyllum spicatum*	Aquatic submerged
European beach grass	*Ammophila arenaria*	Semi-aquatic tidal
*European common reed	*Phragmites australis s. australis*	Semi-aquatic freshwater/tidal
European lake sedge	*Carex acutiformis*	Semi-aquatic emergent
European water clover	*Marsilea quadrifolia*	Aquatic
European waterlily	*Nymphaea alba*	Aquatic emergent
Evergreen blackberry	*Rubus laciniatus*	Semi-aquatic freshwater/tidal
Fanwort	*Cabomba caroliniana*	Aquatic submerged
Feathered mosquito-fern	*Azolla pinnata*	Aquatic/free floating
*Flowering rush	*Butomus umbellatus*	Aquatic submerged/emergent
Fragrant water lily	*Nymphaea oderata*	Aquatic emergent
*Garden yellow loosestrife	*Lysimachia vulgaris*	Semi-aquatic emergent
Giant chickweed	*Myosoton aquaticum*	Semi-aquatic emergent
Giant knotweed	*Fallopia sachalinensis*	Semi-aquatic emergent
Giant manna grass	*Glyceria maxima*	Semi-aquatic emergent
*Giant reed	*Arundo donax*	Semi-aquatic emergent
Giant salvinia	*Salvinia molesta*	Aquatic/free floating
Himalayan balsam	*Impatiens glandulifera*	Semi-aquatic emergent
Himalayan blackberry	*Rubus armeniacus*	Riparian/terrestrial
*Hydrilla	*Hydrilla verticillata*	Aquatic submerged
Japanese knotweed	*Fallopia japonica*	Semi-aquatic emergent
Johnson grass	*Sorghum halepense*	Semi-aquatic emergent
*Kudzu	*Pueraria montana*	Semi-aquatic emergent
*Major oxygen weed	*Lagarosiphon*	Aquatic submerged
Parrot feather	*Myriophyllum aquaticum*	Aquatic submerged
Purple loosestrife	*Lythrum salicaria*	Semi-aquatic emergent
Russian olive	*Elaeagnus angustifolia*	Riparian

*Salt meadow cordgrass	*Spartina patens*	Semi-aquatic tidal
Saltcedar/Tamarisk	*Tamarix ramosissima*	Semi-aquatic emergent
*Smooth cordgrass	*Spartina alterniflora*	Semi-aquatic tidal
Variable-Leaf-Milfoil	*Myriophyllum heterophyllum*	Aquatic submerged
*Water chestnut	*Trapa natans*	Aquatic emergent
*Water hyacinth	*Eichhornia crassipes*	Aquatic emergent
*Water lettuce	*Pistia stratiotes*	Aquatic/free floating
*Water soldier	*Stratiotes aloides*	Aquatic submerged/emergent
Watercress	*Nasturtium officinale*	Semi-aquatic emergent
Yellow flag iris	*Iris pseudacorus*	Riparian
Yellow floating heart	*Nymphoides peltata*	Aquatic submerged

*Species that have no known or limited distribution within British Columbia and for which EDRR should be initiated.