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<u>**Final Report**</u>

Eurasian Watermilfoil Study at Drag and Spruce Lakes

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1. Introduction

1.1 Background

Eurasian Watermilfoil (EWM), *Myriophyllum spicatum*, is a rooted, submersed perennial macrophyte that is native to Europe, Asia, and Northern Africa (Cooper, 2018). It is not to be confused with its North American counterpart *Myriophyllum sibiricum* (Smith & Barko, 1990). EWM was introduced to North America in the early 1940's and is considered an invasive species here (Cooper, 2018). Its introduction may have been propagated by the aquarium and ornamental pond industries (Cooper, 2018). Excessive EWM has many undesirable effects. It impacts recreation by making it difficult to swim and boat, has a negative impact on sport fisheries, as well as generally reducing the aesthetics of a lake thereby reducing property values (Smith & Barko, 1990; Cooper, 2018). It also can clog the water intakes of industrial projects and power generation, lower the dissolved oxygen of a lake, and increase the population of mosquitos (Smith & Barko, 1990).

1.2 Biology

EWM reproduces both sexually and asexually. It produces small reddish flowers that extend above the water and disperse seeds (Martin & Valentine, 2014; Cooper, 2018). However, these seeds are thought to be only minorly spreading as EWM's most effective form of dispersal is through asexual stem fragmentation (Hamel, 2014; Smith & Barko, 1990). These stem fragments are spread through both physical damage and autofragmentation (Hamel, 2014; Smith & Barko, 1990). Though human intervention and disturbance may increase fragmentation, many fragments are already produced without human impact (Smith & Barko, 1990).

EWM prefers water depths of 1m to 4m but can be found at depths up to 10m (Sager et al., 2019; Smith & Barko, 1990). Distribution of EWM is impacted greatly by turbidity, with high turbidity restricting the plant to shallower waters (Smith & Barko, 1990). EWM must grow to reach the surface to undergo fragmentation. Therefore, EWM in shallow water can reach the surface and fragment in a month or so, whereas in deeper waters the plant may take the entire growing season to reach the surface and fragment (Smith & Barko, 1990). The plant has the ability to grow new shoots, even if the plant dies back to the crown roots in the winter. (Sager et al., 2019).

EWM is not unusually productive, and though it may replace some native species in an aquatic environment, it usually does not become widespread in habitats that are already unproductive (Smith & Barko, 1990). It tends to shade out native vegetation with its dense canopies (Cooper, 2018). It prefers locations with nutrient-rich sediments (Li et al., 2015; Smith & Barko, 1990).

EWM intakes nutrients from both the sediment and the surrounding water. EWM uptakes phosphorus (P) mainly from the sediment and can absorb nitrogen (N) from both the water and the sediment (Smith & Barko, 1990). Other elements identified as being important for EWM growth include the cations Na, K, Ca, and Mg (Smith & Barko, 1990).

1.3 Control Methods

There are a number of different control methods that have been used to curb EWM, with mixed results. Physical means of controlling EWM including both dredging and harvesting. Dredging is a rather invasive method that eliminates all plants, thereby disturbing sediment and increasing turbidity as well as reducing aquatic habitat (Minnesota Aquatic Invasive Species Research Centre, 2021). It is also very slow and expensive and is therefore not a favoured control option for EWM (Cooper, 2018). Harvesting the EWM either through manual or mechanical means is a way to directly remove plants and is relatively inexpensive (Cooper, 2018; MAISRC, 2021). However, it is also disruptive to the habitat, disturbing sediment and indirectly removing other plants and organisms (Cooper, 2018). It also has the unwanted side effect of aiding in further fragmentation. The disposal of fragmented or harvested materials requires special care, as fragments can re-establish if not properly disposed (Simkovic, 2020).

Finally, the methods seemingly under most study in the local Kawartha region are biological control. These tend to have a more positive public perception, and research has shown effectiveness in the long term (Cooper, 2018). One example is the use of the native milfoil weevil (*Euhrychiopsis lecontei*) to control EWM populations in Big Cedar Lake, which will be discussed below (Cooper, DeBues, & Sager, 2017). However, such biological control methods are quite costly and unpredictable, suggesting a large amount of research is needed to ensure viability (Frew, 2016).

A study has also been conducted looking into preventative measures for controlling the spread of EWM. A study conducted in Lake Tahoe assessed potential dispersal pathways for EWM as well as the habitats with the greatest risk of having EWM established (Wittmann et al., 2015). They did this by assessing recreational boater movements as well as wave energy (Wittmann et al., 2015). This poses an option to be proactive in predicting EWM spread instead of the reactive control methods outlined above.

1.4 Local Research

There has been some research conducted into EWM in the local Kawartha region. In 1988 a study was done in response to the disappearing levels of EWM from three Kawartha lakes for unknown reasons (Buckhorn, Chemong, and Scugog) (Painter & McCabe, 1988). 49 sites were sampled and “No correlations between milfoil abundance and sediment pore water chemistry, sediment redox potential, sediment geochemistry and milfoil tissue chemistry were observed” (Painter & McCabe, 1988, p. 4). EWM collapses in this area have remained largely unexplained. The study did find that at Buckhorn Lake, sediments with low/declining EWM had relatively high concentrations of NH^{+}_{4}, K, DIC, and H_2S (Painter & McCabe, 1988). It also found that reduced EWM occurred in sediments with high organic content, suggesting adding organic matter to the sediment could be used as a control method (Painter & McCabe, 1988). The study also suggested that milfoil could be limited by sediment nitrogen (Painter & McCabe, 1988). Therefore, though there are some ideas that may explain what inhibits growth of EWM in the area, it seems many of these ideas are inconclusive and require further study.

As mentioned above, the milfoil weevil has been used in a substantial study conducted at Big Cedar Lake. The milfoil weevil is an insect native to the area that only consumes plants in the *Myriophyllym* genus and depends on plants in this genus for habitat and reproduction (Cooper, DeBues, & Sager, 2017). It damages EWM by removing stem tissue as larvae (Cooper, DeBues, & Sager, 2017). These weevils were thought to be a potential option for biological control as they are a native species of insect that can potentially curb the spread of an invasive species.

Beginning in 2011, a seven-year EWM control program began in which about 380,000 milfoil weevils were stocked in Big Cedar Lake (Cooper, DeBues, & Sager, 2017). This experiment had varying results. In 2015 25,000 weevils were stocked at four sites. EWM was almost eradicated at these sites for the 2016 season, but returned in 2017 (Cooper, 2018). In 2016 40,000 weevils were stocked at five sites, and at three of these sites a vegetated benthic mat was also installed (Cooper, 2018). These mats cover the lake bottom and prevent rooted plants (such as EWM) from getting sunlight for growth (Cooper, DeBues, & Sager, 2017).

In 2017, 40,000 weevil eggs were stocked at six sites with vegetated benthic mats placed at each site (Cooper, DeBues, & Sager, 2017). At this point evidence showed that EWM had gone from higher to lower every year since 2013 (e.g. 2016 was the lowest year of milfoil density while 2017 was relatively high, an alternating pattern that has been observed since 2013). It is thought that diversified control efforts were likely needed as EWM could probably not be curbed by weevils alone at Big Cedar Lake (Cooper, 2018). It is judged to be unlikely to reduce EWM much further in this area by using only weevils (Cooper, DeBues, & Sager, 2017).

This study provided further recommendations for controlling EWM including:

- "Primarily focus on encouraging native plants to compete with EWM
- Continue monitoring experimental patches (2015-present) and full-lake survey points
- Select material that can prevent EWM growth while allowing adequate spacing for native transplants
- Install vegetated benthic mats when EWM density is low" (Cooper, 2018, p. 32)

Such recommendations have aligned with others found in the literature. Boylen, Eichler, & Sutherland (1996) indicate that diversified management is necessary since singly employed techniques were not found to eliminate milfoil on their own. Laitala et al. (2017) also advocated for a combination of control methods in their benthic mats study.

In terms of physical harvesting, the Boylen study involved hand harvesting and did not eliminate milfoil at any of their sites and regrowth required re-harvesting every few years (Boylen, Eichler, & Sutherland, 1996). In terms of herbicide methods, Poovey et al. (2004) found that treatments with the herbicide triclopyr was effective in reducing milfoil. However they recommended that larger treatment areas, higher triclopyr rates, and further applications be used to control the species (Poovey et al., 2004). In terms of benthic barriers, Laitala et al. (2017)

found that benthic mats were effective in reducing watermilfoil but barrier maintenance should include sediment removal when sediment depth reaches 4cm. In general, there are two different grades of benthic mats used for this purpose: hessian (burlap) and coconut fibre (Hofstra & Clayton, 2012). Coconut fibre mats have been most commonly used in the local area (Cooper, DeBues, & Sager, 2017; DSLPOA, n.d.).

1.5 EWM at Drag and Spruce Lakes

Drag and Spruce Lakes, being the study site for this project, are located adjacent to each other in the Haliburton Highlands in Haliburton, Ontario (Drag & Spruce Lakes Property Owner's Association, n.d.) (See Figure 1). Both lakes are located about 354m above sea level with a maximum depth of 55m and a mean depth of 18m (DSLPOA, n.d.). They have a combined surface area of 1003 ha and perimeter of 42 km (DSLPOA, n.d.). The area has been a cottaging and tourist destination since the 1920's as well as a prime fishing site (DSLPOA, n.d.). The lakes have been stocked with largemouth bass since 1977 (DSLPOA, n.d.).

The Drag & Spruce Lakes Property Owner's Association (DSLPOA) has been active in attempting to reduce the spread of EWM in Drag and Spruce Lakes (Tiffin, 2021). The first outbreak of EWM in the area was identified in 2015 near Harris Beach on Drag Lake (Tiffin, 2021). The Eurasian Watermilfoil Working Group, a sub-committee of the DSLPOA has been working on controlling this local spread by fundraising more than $40,000 through donations from property owners (Tiffin, 2021). They aim to control the spread of EWM rather than eradicate it.

In 2020, a project was conducted installing 13 biodegradable coconut fibre matting over the outbreak at Harris Beach as a control method (Tiffin, 2021). The working group plans to monitor this initiative to see if it was effective, and if so, may expand it into Drag Lake (Tiffin, 2021).

1.6 Research questions

This study aims to identify sediment and water conditions that may be favourable to Eurasian watermilfoil growth through sediment samples and water quality measurements. The main research questions this study will explore are:

- Is there a difference in organic matter content and/or particle size distribution in sediments at EWM sites and non-EWM sites?
- Is there a difference between pH, temperature, conductivity and dissolved oxygen content in water at EWM sites and non-EWM sites?
- What other aquatic plant species are present along with EWM?

2. Methods

There are three components to the methods portion of this project: sediment sampling, water quality measurements, and identifying Eurasian watermilfoil (EWM) patches/other plants in the weed beds on Drag Lake. Sediment sampling and water quality measurements were completed on June 2 and 19, 2021, while EWM identification was completed on July 14, 2021 in order to make it easier to identify the plant later in the growing season. Lab analysis of sediment samples was completed at Trent University on July 5, 6, 7, 15, 16, and 17.

2.1 Sampling Location

The sampling location was throughout Drag and Spruce Lakes in Haliburton, Ontario, Canada. Drag and Spruce Lakes have a combined surface area of 1003 ha and perimeter of 42km, with an average depth of 18m (Drag & Spruce Lakes Property Owner’s Association. n.d.). Four sites were sampled at existing EWM outbreaks, along with one control site at Drag Lake, one control site at Spruce Lake, and one Secchi disc site at Drag Lake. Specific sites are shown on the map in Figure 2. Coordinates and other information are shown in Table 1. Sites are discussed in further detail in section 2.2.1.

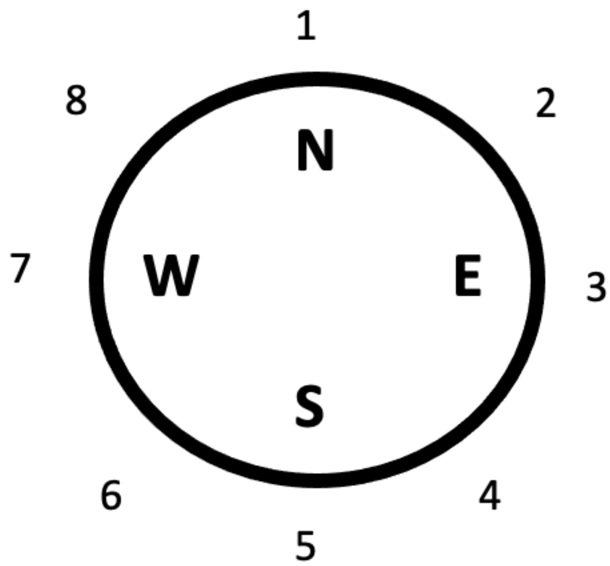
Figure 1: Map of Drag and Spruce lakes with red line denoting the border between the lakes. Map obtained from Google Maps.

Figure 2: Sampling sites on Drag and Spruce lakes. Sites include Podmore Beach (Plot 1), Bonhams Bay (Plot 2), Harris Beach (Plot 3) and East Bay (Plot 4), plus one control at Drag Lake, one at Spruce Lake, and the Secchi disc site. Map obtained from Google Earth (n.d.).

Table 1: Table displaying the GPS coordinates of each of the four sampling sites as well as the two control sites and the Secchi disc site. Depth is also indicated, as well as a randomly generated direction for the sampling method (see Figure 3). Control sites did not have

Plot	R Direction		Depth	Northing	Easting	Plot Names
			m	*mN*	*mE*	
1	1	N	2.9	4995639	0704664	Podmore Beach
2	3	E	2.3	4995639	0704664	Bonham's Bay
3	8	NW	2.9	4994583	0704332	Harris Beach
4	8	NW	2.4	4994960	0705163	East Bay
CDL	/	/	2.7	4994590	0703552	Control Site Drag Lake
CSL	/	/	2.6	4992434	0699606	Control Site Spruce Lake
			4.8	4993960	0702125	Secchi Site Drag Lake

Figure 3: Diagram shows method used for randomly generated direction in sampling methods. For each EWM site, a number was randomly generated between 1 and 8. These numbers correspond with a cardinal direction. The boat was then moved to the corresponding point at the perimeter of the patch. The marker was tossed towards the centre of the site (shown in the diagram as a circle) and this was where the sample measurements were taken from.



2.2 Sediment sampling

2.2.1 Sediment sampling field methods

Sampling was completed randomly within the four EWM sites identified previously by the Drag and Spruce Lake Property Owner's Association (DSLPOA): Podmore Beach (Plot 1), Bonhams Bay (Plot 2), Harris Beach (Plot 3) and East Bay (Plot 4) on June 2. Specific sampling locations are shown on the map (Figure 2). We were unable to collect an adequate sediment sample from the Harris Beach site due to underwater mats laid on the lakebed.

One control sample not in an EWM patch was collected each from Drag and Spruce lakes on June 19. A second sampling attempt at Harris Beach was also made on June 19 but a sample could not be collected again.

A 12" Eckman dredge was used to grab each sediment sample (Mudroch & MacKnight, 1994). Samples were then stored in a labelled container until they could be analyzed in the lab. Two subsamples were taken from each Eckman sample. Depth and GPS coordinates were recorded for each sample.

2.2.2 Sediment sampling lab methods

Sediment laboratory work was completed in the Trent School of the Environment laboratory from July 5 to 7, 2021. Sediment samples were initially weighed, and then dried in the drying oven (VWR) at Trent University at 90°C for 24 hours. After this, the samples were weighed again. Then, the samples were ignited in Trent University's muffle furnace (Lindberg Blue) at 550°C for another 2 hours. They were weighed again in order to determine the amount of organic matter that was burned away. Percentages of organic and inorganic matter were determined by weight loss-on-ignition (LOI) methods. This means an estimate of the amount of soil organic matter was made by the loss of weight in a sample heated enough to burn organic matter but not carbonates (Combs & Nathan, 1998; Schulte & Hopkins, 1996).

The dried samples from the LOI were then sieved to conduct a particle size analysis from July 15-17. This was done to determine the grain size of samples.

Samples were placed in a Menzer II Sieve Shaker at Phi sizes -1.0 φ and 4.0 φ (2.0mm and 0.0625mm respectively). This separated soil samples between sand size class and silt/clay size class, based on Wentworth size classes outlined in Wentworth (1922).

2.3 Water quality measurements

2.3.1 Water quality measurement field methods

At each of the four sediment sampling locations (Harris Beach, Podmore Beach, East Bay, and Bonhams Bay) various water quality measurements were completed as well.

Dissolved oxygen readings were taken using a YSI Pro20 dissolved oxygen meter at the bottom of the lake. The measurement device was calibrated to the True Barometric Pressure (TBP) using the following calculation:

TBP = (Corrected BP in mmHg) – {2.5*(Local Altitude in feet/100)}

The Corrected BP was retrieved from Environment of Canada and then converted from mb to mmHg (x mb converted to mmHg = mb *0.75006). The local altitude was obtained from Google Earth and converted from m ASL to ft ASL (360 m ASL to1181.1 ft. ASL).

Temperature, pH, and conductivity measurements were also taken at each site at surface level as well using an Oakton PCTSTestr 50 device. Water clarity was measured in one location on Drag Lake (Figure 2) using a Secchi disc (UNEP & WHO, 1996).

2.4 Identifying aquatic plants

On July 14, 2021 aquatic plants were systematically identified for each EWM location. An aquatic rake was randomly thrown from the boat and reeled in within each patch of aquatic plants. Rake was thrown using same methods outlined in Figure 3. Samples were then collected from the lake and identified later to assess presence of other species with EWM patches. The rake was thrown two to three times at each site.

3. Results

3.1 Sediment sampling results

Table 2: Loss on Ignition (LOI) data for three EWM sampling sites (plot 3 at Harris Beach could not be collected) as well as the two control sites. Data is an average of 2 replicates per site (see Appendix).

Plot	Wet	Oven	Furnace	Δ Oven - Furnace	LOI
	Grams				*%*
1	89.9892	15.0858	12.3852	2.3790	**17.96**
2	98.4777	8.3246	3.3360	5.3230	**59.90**
4	88.0099	12.3214	9.9864	2.7548	**18.88**
CDL	118.9692	67.2761	65.6844	1.9835	**2.35**
CSL	172.4602	84.7575	81.7815	2.7662	**3.57**

LOI Equation: $\left(\frac{Oven - Furnace}{Oven}\right) * 100$

Control sites were areas where depth is equivalent to sample location without presence of weeds. As seen in Table 2, the LOI for the EWM sites were much higher than the control sites.

This means the control sites have lower organic matter in sediment samples than the EWM sites. Plot 2 (Bonham's Bay) had the highest LOI by far, meaning it has a high organic content.

After approximately 20 attempts, plot 3 (Harris Beach) was deemed unable to obtain any sediment samples. Further investigation of the site found the lakebed matting for EWM and large cobbles/boulders prevented the dredge from accessing the substrate.

Table 3: Particle size distribution data for three EWM sampling sites (plot 3 at Harris Beach could not be collected) as well as the two control sites. Data is an average of 2 replicates per site (see Appendix).

Plot	Sand	Silt/Clay
	%	%
1	42.4	55.7
2	82.9	15.4
4	51.2	44.4
CDL	94.4	5.5
CSL	89.6	10.0

As seen in Table 3, all EWM sites had lower percentages of sand and higher percentages of silt/clay than control sites. There was no gravel found at any of the sample sites. Plot 2 (Bonham's Bay) was closest in particle size distribution to the control sites but still followed this pattern. Plots 1 (Podmore Beach) and 4 (East Bay) differed a great deal from the control sites in particle size distribution. After samples were weighed again there was a loss of ~2.3% from the particle size distribution sieving.

3.2 Water quality measurement results

- The Secchi disc depth at Drag Lake was 4.8 m.

Table 4: pH, temperature, conductivity and dissolved oxygen measurements at for four EWM sampling sites as well as the two control sites. Depth of measurements are also shown.

	Oakton PCTSTestr 50			YSI Pro20	
Plot	pH	Temperature	Conductivity	DO	Depth
		°C	us/cm	mg/L	m
1	7.8	17.6	71.1	8.4	2.9
2	7.3	18.1	61	9.8	2.3

3	7.6	18.4	62.6	7.5	2.9
4	7.5	21.2	63.1	8	2.4
CDL	8.2	19	64.2	7.1	2.7
CSL	7.4	22.9	34.6*	7.2	2.6

** Significant outlier (P < 0.05)*

As shown in Table 4, with one exception, there were no large differences in pH, temperature, conductivity and dissolved oxygen between EWM sites and control sites. All measurements were taken at similar depths. The single outlier was the conductivity measurement for control site 2, which was a great deal lower than measurements at all other sites. A Grubb's test was completed with a $P<0.05$, and this outlier was significant.

3.3 Aquatic plant identification results

Table 5: Aquatic plants observed at each of the four EWM sites. Eurasian watermilfoil (*myriphyllum spicatum)* was the only plant observed at all sites.

Species		*Bonham's Bay*	*East Bay*	*Harris Beach*	*Podmore Beach*
Scientific	*Common*				
Myriophyllum spicatum	Eurasian Watermilfoil	✓	✓	✓	✓
Myriophyllum sibiricum	Northern Watermilfoil	✓	✓		
Potamogeton amplifolius	Largeleaf Pondweed	✓			
Potamogeton robbinsii	Fern Pondweed	✓	✓		
Potamogeton sp.	Pondweed		✓		✓
Elodea canadensis	Common Waterweed		✓	✓	✓

Six species of aquatic plants were observed across all four sites. Eurasian Watermilfoil (*myriphyllum spicatum)* was the only plant observed at all sites. Common waterweed (*elodea canadensis)* was observed at three sites. Northern watermilfoil (*myriophyllum sibiricum)*, Fern pondweed (*potamogeton robbinsii)*, and Pondweed (*potagogeton sp.)* were each observed at two sites. Largeleaf pondweed (*potamogeton amplifolius)* was only observed at one site.

4. Discussion

4.1 Organic matter

We found EWM sites had higher organic matter (OM) in sediment than the control sites. One thing to note is that control sites were areas without any aquatic plants at all, which may introduce a bias. Future studies should incorporate sites with submerged aquatic plants not including EWM for a more comprehensive comparison.

OM levels can be indicative of beneficial growing conditions for aquatic plants in general, as OM is correlated with nutrients (Li et al., 2015). However, OM levels in sediment influences the growth of aquatic plants in varying degrees (Silveira & Thomaz, 2015). Individual species growth rates respond differently to OM levels in sediment. Sediment with lower OM levels is not indicative of no growth or impeded growth, as growth requirements vary from species to species (Wang et al., 2018).

Above a certain threshold of high OM levels, the growth of submergent plants is impeded and conditions can reach a state of eutrophication (Silveira & Thomaz, 2015). This is reflected in the in the LOI percentages of the EWM sites, as they ranged between 15-60% LOI. The control sites (non-plant sites) had an LOI of <4%, which also is reflective of Silveira & Thomaz's study (2015).

4.2 Particle size distribution

During particle size distribution analysis we were unable to distinguish between the silt and clay to provide a broad analysis of the sediment structure. The required mass for the hydrometer method is 25 grams of fines, and most samples retrieved had <10 g. There is an alternate method of using a laser refractor with small sample sizes, however this device in the Trent labs was broken and not available for use. Thus, we could not differentiate between silt and clay for this project.

There was also an issue with retrieving samples at Site 3 (Harris Beach), as the dredge was obstructed by matting on the lakebed and boulders/larger rocks in the areas near the site. Therefore, we could only collect sediment samples at sites 1, 2, and 4.

With the distribution analysis available we found that most EWM sites had a higher percentage of silt and clay (fines) than the control sites. According to Li et al. (2015) EWM colonization is more effective in areas with a higher fines to sand ratio. Therefore, this finding makes sense.

4.3 Site 2 (Bonham's Bay)

Site 2 showed a higher LOI percentage and a higher percentage of sand in comparison to the other EWM sites (1 and 4). It should be noted that this site is within a bay that has an inlet from another lake and next to a wetland. This likely explains the higher OM levels in the sediment when compared to sites 1 and 4, which are not near a wetland (Wang et al., 2018). The high OM level is likely to increase the possibility that EWM could colonize in the higher sand to fines ratios (Li et al., 2015).

4.4 Water quality

There is little variation of the water quality between samples. The Spruce Lake control site was an exception as this site showed significantly lower conductivity. To examine this further, another sample location should be selected on Spruce Lake for comparison. Conductivity is a relative measurement of dissolved ions in the water. This measurement can fluctuate due to several factors: changes in temperatures, precipitation levels, and water levels (Horne & Goldman, 1994). Water clarity and total dissolved solid (TDS) measurements are also correlated with conductivity. Conductivity measurements can be used to calculate TDS. There is an inverse relationship with TDS/conductivity measurements and water clarity (Gholizadeh et al., 2016).

The measure of conductivity can be an indicator of pristine water with <200 µS/cm (Horne & Goldman, 1994).

4.5 Turbidity

The Secchi disc depth measurement was 4.8 metres. Secchi disc depth is a means of quantifying water clarity/turbidity. This denotes areas with a depth of less than 4.8 m which have available access to sunlight essential for submergent plants to photosynthesize (Davies-Colley & Smith, 2001). As the depths within the EWM patches were less deep than the Secchi disc depth this can help isolated areas to search for further EWM presence. Further studies have been using remote sensing to estimate Secchi disc depth, and aquatic vegetation (Binding et al., 2007). This information can be used to increase the scale of detection potential site with aquatic vegetation, and therefore potential EWM outbreak areas to monitor. Other methods to measure water clarity/turbidity are a light meter or turbidity meter.

4.6 Aquatic submergent plants

Each site found other submergent plants along with the EWM. EWM is known to shade out native submergent species and reduce biodiversity (Cooper, 2018). There is also a concern of hybridization between EWM and the native Northern watermilfoil as Hybrid watermilfoil (*M. spicatum* × *M. sibiricum*), which may be difficult to distinguish without DNA analysis (Patterson et al., 2017).

4.7 Research Questions

In terms of addressing our research questions, we found that there was a difference in organic matter content and/or particle size distribution in sediments at EWM sites and non-EWM sites, as sites with EWM had higher organic matter content and more clay/silt particles. We found that there was no significant difference between pH, temperature, conductivity and dissolved oxygen content in water at EWM sites and non-EWM sites, with the exception of the conductivity of the Spruce Lake control site (SLC). We also found that there was other aquatic plant species are present along with EWM, see Table 5.

5.0 Recommendations

5.1 Study design

Things to improve upon in regard to study design would include identifying control sites with submergent aquatic plants without EWM presence. This would likely result in more accurate control data that would differentiate between favourable conditions for all aquatic plants in general, and EWM in particular. Sampling more sites of both EWM and control sites would be beneficial in order to establish statistical significance.

Larger sediment samples should also be collected in order to obtain enough sample to provide a minimum of 25g silt and clay (after LOI). This would allow for the differentiation between silt and clay during particle size distribution analysis using the hydrometer method.

There was difficulty in using the Eckman's dredge in collecting sediment samples at Harris Beach due to the benthic mats. Since DSLPOA occasionally employs divers to install/maintain these mats, perhaps get them to collect sediment samples in these hard to access areas.

5.2 EWM management

The study identified that sites close to wetland areas had higher OM content in sediment. It is suggested that sites adjacent to wetland areas be monitored particularly closely as they may be more conducive to EWM growth due to higher OM.

EWM growth was still observed in areas with benthic mats installed. Other research suggests that one means of EWM management is not as effective on its own, and that it should be combined with diversified ways to manage EWM (Boylen, Eichler, & Sutherland, 1996; Cooper, 2018; Poovey et al., 2004). Therefore, it is recommended that other management tactics be used in addition to benthic mats. This could include biological control (i.e. milfoil weevils), chemical control (i.e. pesticides) and/or physical removal (Boylen, Eichler, & Sutherland, 1996; Cooper, 2018; Poovey et al., 2004).

5.3 Further research

Again, further research is needed to identify optimal growing conditions for EWM that may differ from other aquatic plants. This may make it easier for EWM growth to be managed without impeding native plant growth.

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Appendix

Appendix i: Raw data for LOI

Plot	Rep	ID	Wet	Oven	Furnace	Oven-Furnace	LOI
			Grams	*Grams*	*Grams*	*Grams*	*%*
1	1	A	82.4690	12.9428	10.5638	2.3790	18.38
1	2	B	97.5093	17.2288	14.2065	3.0223	17.54
2	1	C	97.3977	8.8336	3.5106	5.3230	60.26
2	2	D	99.5576	7.8155	3.1614	4.6541	59.55
4	1	E	91.6150	14.2427	11.4879	2.7548	19.34
4	2	F	84.4047	10.4001	8.4849	1.9152	18.42
C1	1	G	128.5760	68.8724	66.8889	1.9835	2.88
C1	2	H	109.3623	65.6798	64.4798	1.2000	1.83
C2	1	I	148.9232	70.4223	67.6561	2.7662	3.93
C2	2	J	195.9972	99.0927	95.9069	3.1858	3.21

Appendix ii: Raw data for sediment samples

Plot	Rep	ID	Post LOI Sediment	Sand	Sand	Silt/Clay	Silt/Clay
			Grams	*Grams*	*%*	*Grams*	*%*
1	1	A	14.3176	4.251	40.24	6.145	58.17
1	2	B	17.9719	6.326	44.53	7.575	53.32
2	1	C	7.2769	2.855	81.33	0.609	17.35
2	2	D	6.9319	2.669	84.42	0.424	13.41
4	1	E	15.3281	5.755	50.10	4.772	41.54
4	2	F	12.3192	4.441	52.34	4.008	47.24
C1	1	G	70.7594	62.445	93.36	4.394	6.57
C1	2	H	68.3294	61.508	95.39	2.862	4.44
C2	1	I	71.5250	60.000	88.68	7.322	10.82
C2	2	J	99.7527	86.846	90.55	8.872	9.25

Appendix iii: Plant identification (5mm grid)

Bonham's Bay
Northern Watermilfoil (*Myriophyllum sibiricum*)

Largeleaf (Broadleaved) Pondweed (*Potamogeton amplifolius*)

Fern (Robbins') Pondweed (*Potamogeton robbinsii*)

Eurasian Watermilfoil (*Myriophyllum spicatum*)

East Bay
Northern Watermilfoil (*Myriophyllum sibiricum*)

Pondweed (*Potamogeton sp.*)

Common Waterweed (*Elodea canadensis*)

Fern (Robbins') Pondweed (*Potamogeton robbinsii*)

Eurasian Watermilfoil (*Myriophyllum spicatum*)

Harris Beach

Common Waterweed (*Elodea canadensis*)

Eurasian Watermilfoil (*Myriophyllum spicatum*)

Podmore Beach

Eurasian Watermilfoil (*Myriophyllum spicatum*)

Common Waterweed (*Elodea canadensis)*

Pondweed (*Potamogeton sp.*)