The effect of *Myriophyllum aquaticum* on freshwater bodies in British Columbia

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Abstract

Myriophyllum aquaticum is an invasive plant species originating from the Amazon River and is currently found in British Columbia. We hypothesized that freshwater sources with *Myriophyllum aquaticum* would have lower dissolved oxygen content compared to areas without *Myriophyllum aquaticum*. During this experiment, 40 water samples were collected from each of our four sites: Serpentine Fen (Surrey, B.C.), Nicomekl River (Surrey, B.C.), Alpine Garden Pond and Meyer Glade at the University of British Columbia Botanical Garden (Vancouver, B.C.). Serpentine Fen had *Myriophyllum aquaticum* while the other three sites were control sites. The dissolved oxygen content (mg/L) was measured with an oxygen meter and recorded for comparison. When comparing the data from Serpentine Fen to Nicomekl River, Alpine Garden Pond and Meyer Glade, a paired t-test was used. P-values of 2.2753E-22, 1.082E-29 and 9.0394E-29 were obtained for these sites. Since they are all less than 0.05, the null hypothesis was rejected and support was provided for the alternate hypothesis that *Myriophyllum aquaticum* decreases the dissolved oxygen content in freshwater bodies. The results also suggest that a decrease in temperature may increase the dissolved oxygen content because numerous biota cannot survive the colder temperatures, thus less oxygen is being used.

Introduction

Myriophyllum aquaticum is a plant that originated from the Amazon River in South America and was first discovered in the Lower Mainland in 1980 (Invasive Species Council of British Columbia, 2015). Due to its fast growth rate and ability to out-compete native British Columbian species, *Myriophyllum aquaticum* has been documented as an invasive species. Over the last 37 years, *Myriophyllum aquaticum* has been collected in numerous districts in the Lower Mainland including North Vancouver, Richmond and Surrey, as shown in Figure 1 (Electronic Atlas of the Flora of British Columbia, n.d.). Aside from its ability to out-compete native species and deplete nutrients in the water bodies it grows in, *Myriophyllum aquaticum* is able to weave

into nets, which prevents the normal flow of water through streams and rivers (Stiers, Josens & Triest, 2011). *Myriophyllum aquaticum* has emergent shoots that contact the air, thin roots that are present in the water, and strong roots that anchor this species into the sediment as shown in Figure 2 and pictured in Figure 3 (Wersal & Madsen, 2011).

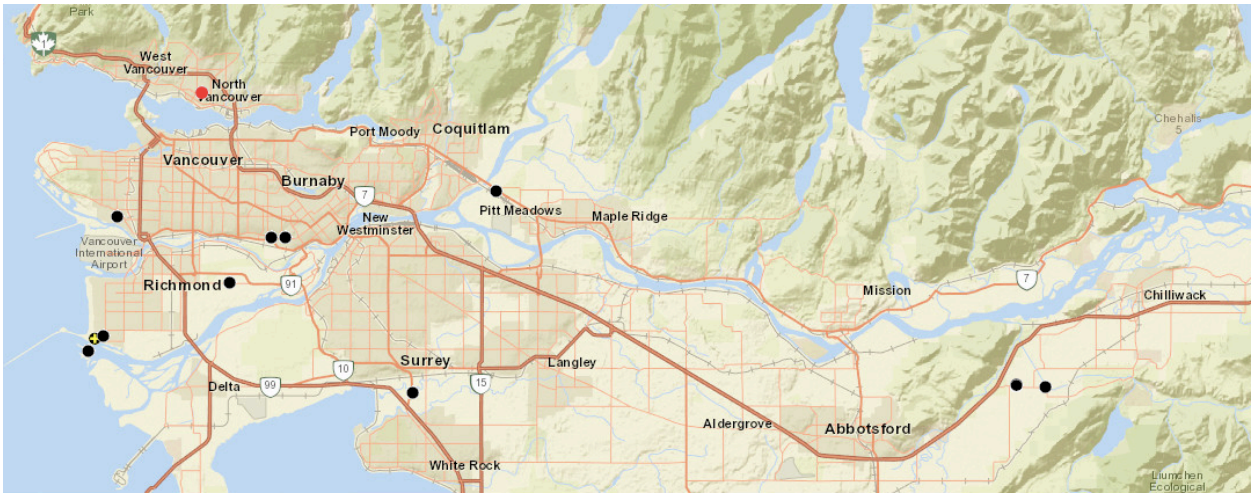

Figure 1. Distribution of *Myriophyllum aquaticum* in the Lower Mainland (Electronic Atlas of the Flora of British Columbia, n.d.).

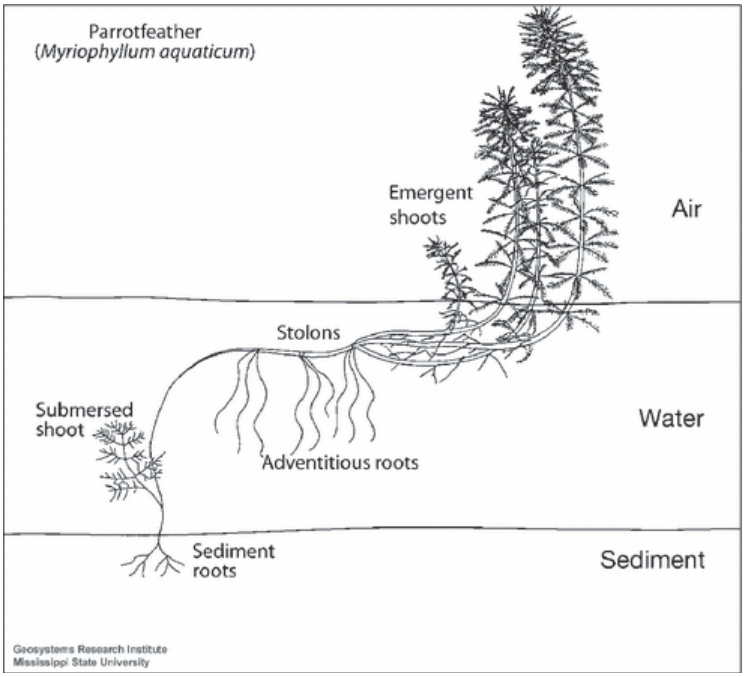

Figure 2. *Myriophyllum aquaticum* growing with shoots that contact the air and thinner roots that are submerged in water (Wersal and Madsen, 2011).

Figure 3. Dense stands of *Myriophyllum aquaticum* that out-compete native species (Invasive Species Council of British Columbia, 2015).

The Serpentine River located in Surrey, B.C. is an important location for salmon spawning on the West Coast. Three species of salmon: Coho, Chinook and Chum inhabit this water source between October and December (Fisheries and Oceans Canada, n.d.). According to the Electronic Atlas of the Flora of British Columbia (n.d.), *Myriophyllum aquaticum* was recorded in the adjacent Serpentine Fen on July 1, 2014. Since *Myriophyllum aquaticum* is present in Serpentine Fen, the salmon may be negatively influenced by depleted nutrients in water sources and physical barriers created by *Myriophyllum aquaticum*.

Based on previous work with *Myriophyllum aquaticum,* our hypotheses are as follows:

H_O: *Myriophyllum aquaticum* has no effect on dissolved oxygen content at the Serpentine Fen in Surrey, British Columbia.

H_A: *Myriophyllum aquaticum* has an effect on dissolved oxygen content at the Serpentine Fen in Surrey, British Columbia.

Methods

Our fieldwork consisted of visiting four sites: Serpentine Fen (*Myriophyllum aquaticum* present), Nicomekl River, Alpine Garden Pond, and Meyer Glade. We collected ten water samples from the edge of two subsites at each site. The samples from each collection date are shown in Figures 5, 6, 7, and 8. We used sampling cups to eliminate differences in oxygen between a moving and stationary water source. Then, we took an oxygen probe and swirled it in the sampling cup to determine the oxygen content in each water sample, as shown in Figure 4. Between each reading, we rinsed the oxygen probe with distilled water to ensure that there was no contamination from the previous sample. We recorded the dissolved oxygen content after the reading stabilized for at least three seconds. After collecting ten water samples at the first subsite, we moved to another subsite to gain a better representation of the site. Before leaving the site, we used a thermometer to record the temperature of the water. To reduce sources of error, one group member retrieved all the samples and swirled the oxygen probe while another recorded the dissolved oxygen content for all samples.

We analyzed the data using Microsoft Excel and the GraphPad paired t-test calculator. Please see the appendix for a sample calculation.

Figure 4. Water samples from Serpentine Fen in Surrey, B.C. on October 28, 2017. The oxygen probe is being used to measure the dissolved oxygen content (mg/L) of the sample.

a) b)

Figure 5. Water samples from Serpentine Fen in Surrey, B.C. collected on October 28, 2017 (a) and November 4, 2017 (b). Temperature was 1.5°C and ice was present at the surface of the water in (b).

a) b)

Figure 6. Water samples from Nicomekl River collected on October 28, 2017 (a) and November 4, 2017 (b).

a) b)

Figure 7. Water samples from Alpine Garden Pond collected on November 1, 2017 (a) and November 8, 2017 (b).

a) b)

Figure 8. Water samples from Meyer Glade collected on November 1, 2017 (a) and November 8, 2017 (b).

Materials

The materials used for this experiment include an oxygen meter, dissolved oxygen electrolyte solution, distilled water, a graphing calculator, a thermometer, and sample collection cups.

Results

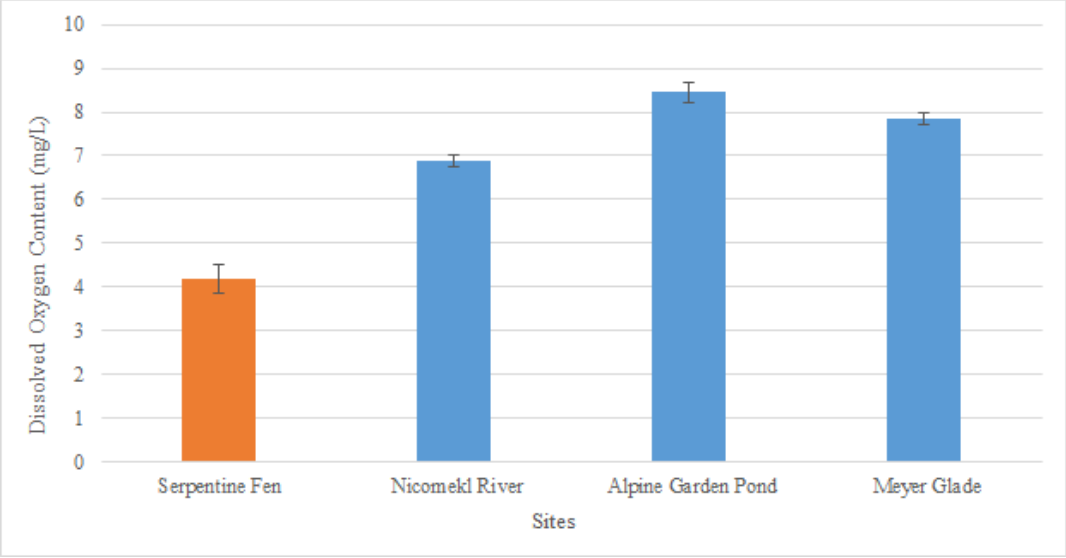

Figure 9. Mean dissolved oxygen content (mg/L) from 40 samples collected at each site. *Myriophyllum aquaticum* was present at Serpentine Fen and can be compared to three sites without the invasive species. The error bars indicate a 95% confidence interval.

Figure 9 shows the average dissolved oxygen content for the following sites:

Serpentine Fen: 4.175 mg/L

Nicomekl River: 6.8675 mg/L

Alpine Garden Pond: 8.4475 mg/L

Meyer Glade: 7.8525 mg/L

Serpentine Fen, the site with *Myriophyllum aquaticum,* has the lowest average dissolved oxygen content. The calculated p-values of Serpentine Fen and Nicomekl River, Alpine Garden Pond and Meyer Glade were 2.2753E-22, 1.082E-29 and 9.0394E-29 respectively. Since each of the p-values were less than 0.05, these results are statistically significant. The error bars are small and do not overlap, denoting high precision.

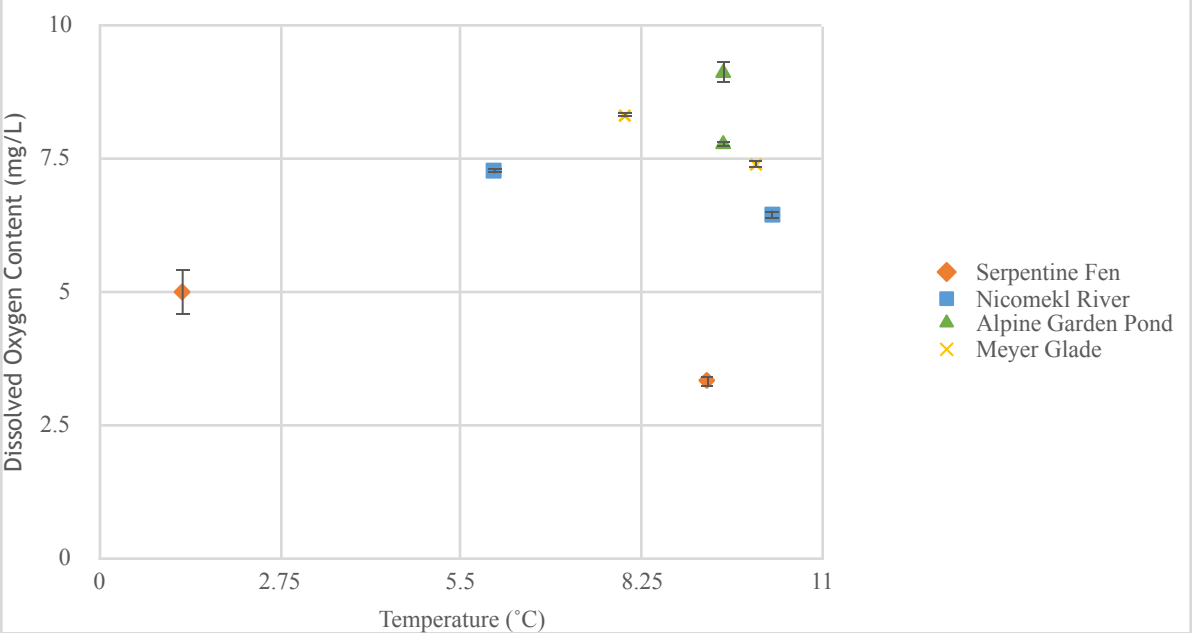

Figure 10. Mean dissolved oxygen content (mg/L) from 20 samples collected at each site on two days with different temperatures. The error bars indicate 95% confidence interval.

Figure 10 shows that as temperature increases, the dissolved oxygen content decreases at Serpentine Fen, Nicomekl River and Meyer Glade. The temperature recorded for both sampling days at Alpine Garden Pond was 9.5°C. Although the temperature remained consistent at Alpine Garden Pond, there was a difference in the average dissolved oxygen content from both days. The error bars for Nicomekl River are small and do not appear in Figure 10.

Discussion

Based on the results from a paired t-test, we rejected the null hypothesis that *Myriophyllum aquaticum* did not have an effect on the Serpentine Fen since the p-values were less than 0.05. The data provides support for the alternate hypothesis, which showed that the presence of *Myriophyllum aquaticum* resulted in lower dissolved oxygen content. *Myriophyllum aquaticum* grows best in slow-moving or still water, explaining their presence at Serpentine Fen

(Hussner & Champion, 2012). The stems are able to reach the water surface easily and consume the oxygen output from the photosynthesis of plants in the water (Hussner & Champion, 2012).

According to Stiers et al. (2011), the rapid growth rate of *Myriophyllum aquaticum* results in the formation of densely weaved mats that inhibits oxygen exchange and restricts sunlight in water bodies where it is present. This decreases the dissolved oxygen content and limits the number of native plant and animal species in the water body. Consequently, this phenomenon could be responsible for the low dissolved oxygen content observed at Serpentine Fen.

Myriophyllum aquaticum can survive at least six weeks below ice cover but will die when submerged in ice (Hussner & Champion, 2012). Growth begins when the temperature is above 8°C but slows during winter (Hussner & Champion, 2012). At Serpentine Fen, a thin layer of ice was present on the surface of the water, as seen in Figure 5 (b). In Figure 10, the dissolved oxygen content was lower at 9.25°C compared to 1.25°C, suggesting that the large decrease in temperature slowed the growth of *Myriophyllum aquaticum.*

Water temperature is an important factor in determining dissolved oxygen content, in which the solubility of oxygen decreases as water temperature increases (RAMP, n.d.). Since water temperature may be different throughout a water body, we measured temperature and oxygen levels at two subsites during each site visit. The Regional Aquatics Monitoring Program (RAMP) notes that maximum solubility of oxygen in water at 1 atm pressure is at 15 mg/L at 0°C, which is much higher compared to 8 mg/L at 30°C (RAMP, n.d.). Thus, the mean temperature and dissolved oxygen content outlined in Figure 10 shows that lower temperatures yield higher dissolved oxygen content at sites 1, 2 and 4.

During our sampling on October 28, we noticed that there was a thin layer of grease on the surface of Serpentine Fen, which indicated that it may be polluted. According to Ji et al. (2017), pollution results in a lower dissolved oxygen content and negatively impacts the aquatic ecosystem. The results we collected on this day had the lowest dissolved oxygen content across all sites on all dates, with pollution as a possible cause. Future studies should aim to quantify the amount of pollution at sites allowing for a more accurate understanding of the correlation between *Myriophyllum aquaticum* and dissolved oxygen content.

, *Myriophyllum aquaticum* has the ability to disrupt the salmon ecosystem by depleting dissolved oxygen content in water bodies. When there is a decrease in dissolved oxygen content in a water source, salmon and other fish species may experience physiological changes which influence their metabolic rate and result in them avoiding these regions (Ruggerone, 2000). According to Ruggerone (2000), when salmon were placed in water during winter with controlled oxygen saturation, only 45% of the Sockeye salmon samples survived with a dissolved oxygen content of 3.0 mg/L – 3.3 mg/L. This study also showed that when dissolved oxygen content was greater than 9 mg/L, the entire Sockeye salmon sample survived. Based on this study, we suggest that it is likely that a significant portion of the salmon population will not be able to inhabit the Serpentine Fen where we found a low average dissolved oxygen content of 4.175 mg/L.

We anticipate that a source of error in our experiment includes changes in the volume of the water source due to weather, which may decrease the amount of biota present. For example, on November 4, there was ice and snow present at Serpentine Fen, yielding a higher dissolved oxygen content reading. In addition, on November 8, at Alpine Garden Pond, there was minimal

water remaining at the site due to renovations occurring at the Botanical Garden. The low water level could potentially be a misrepresentation of the water body. Since our data for Serpentine Fen and Nicomekl River was collected on different days than Alpine Garden Pond and Meyer Glade the differences in temperature could have influenced the dissolved oxygen content. To avoid discrepancies, further studies should collect data on the same day.

Conclusion

After collecting and analyzing data from four different sites, we rejected the null hypothesis as the p-values of all sites were less than 0.05. Thus, we were able to provide support for our alternate hypothesis. Our results suggest that the presence of *Myriophyllum aquaticum* decreased the dissolved oxygen content in freshwater bodies. Our results also indicate the number of biota may have decreased due to lower temperatures, yielding a higher amount of dissolved oxygen content as a function of both temperature and biomass.

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Appendix

Raw Data Tables from Field Sampling

Date: October 28, 2017

	Serpentine Fen with Parrot's Feather		**Nicomekl River** without Parrot's Feather	
	O_2 (mg/L)	Temp (°C)	O_2 (mg/L)	Temp (°C)
	SITE 1 @ 10:50am NO SHADE		**SITE 3 @ 11:50am NO SHADE**	
1	3.3	8.5	6.4	10
2	3.0		6.6	
3	3.1		6.7	
4	3.1		6.5	
5	3.2		6.3	
6	3.2		6.4	
7	3.2		6.3	
8	3.1		6.5	
9	3.5		6.6	
10	3.3		6.4	
	SITE 2 @ 11:10am SHADED		**SITE 4 @ 12:00pm NO SHADE**	
11	3.7	10	6.3	10.5
12	3.2		6.3	
13	3.4		6.2	
14	3.3		6.5	
15	3.5		6.5	
16	3.4		6.5	
17	3.7		6.6	
18	3.5		6.4	
19	3.7		6.6	
20	3.5		6.5	

Date: November 1, 2017

	UBC Botanical Garden (Alpine Garden Pond) Site 3 without Parrot's Feather		**UBC Botanical Garden (Meyer Glade)** Site 4 without Parrot's Feather	
	O_2 (mg/L)	Temp (°C)	O_2 (mg/L)	Temp (°C)
1	8.1	9.5 @ 1:50pm	7.3	10 @ 2:15pm
2	7.7		7.4	
3	7.9		7.3	
4	7.8		7.2	
5	7.8		7.2	
6	7.8		7.3	
7	7.9		7.3	
8	7.8		7.7	
9	7.8		7.3	
10	7.9		7.2	
11	7.7	9.5 @ 2:00pm	7.4	10 @ 2:25pm
12	7.9		7.4	
13	7.7		7.4	
14	7.9		7.5	
15	7.6		7.5	
16	8.0		7.5	
17	7.6		7.5	
18	7.5		7.6	
19	7.6		7.4	
20	7.6		7.5	

Date: November 4, 2017

	Serpentine Fen Site 1 with Parrot's Feather		**Nicomekl River** Site 2 without Parrot's Feather	
	O_2 (mg/L)	Temp (°C)	O_2 (mg/L)	Temp (°C)
1	5.6	1.5 @ 11am	7.4	6 @ 11:45am
2	6.1		7.1	
3	5.9		7.0	
4	5.7		7.1	
5	5.9		7.2	
6	5.9		7.5	
7	5.9		7.3	
8	5.8		7.3	
9	5.7		7.2	
10	5.7		7.1	
11	4.1	1 @ 11:15am	7.3	6 @ 12pm
12	3.9		7.3	
13	4.6		7.3	
14	4.9		7.3	
15	4.2		7.3	
16	4.4		7.4	
17	5.0		7.3	
18	4.2		7.4	
19	3.3		7.4	
20	3.3		7.4	

Date: November 8, 2017

	UBC Botanical Garden (Alpine Garden Pond) Site 3 without Parrot's Feather		**UBC Botanical Garden (Meyer Glade)** Site 4 without Parrot's Feather	
	O_2 (mg/L)	Temp (°C)	O_2 (mg/L)	Temp (°C)
1	8.0	9.5 @ 1:50pm	8.4	8 @ 2:15pm
2	7.9		8.2	
3	9.2		8.3	
4	9.2		8.2	
5	9.6		8.2	
6	9.3		8.4	
7	9.2		8.3	
8	9.4		8.2	
9	9.2		8.4	
10	9.4		8.4	
11	9.3	9.5 @ 2pm	8.2	8 @ 2:25pm
12	9.2		8.3	
13	9.0		8.2	
14	9.1		8.7	
15	9.2		8.3	
16	9.0		8.4	
17	9.1		8.3	
18	9.1		8.4	
19	9.9		8.2	
20	9.0		8.2	