SHOULD HERBICIDE BE USED IN WETLANDS TO CONTROL CANADA’S WORST INVASIVE PLANT: INVASIVE PHRAGMITES?

by

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A thesis submitted in conformity with the requirements for the degree of Master of Forest Conservation
Faculty of Forestry
University of Toronto

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PHRAGMITES?

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Master of Forest Conservation
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Abstract

Identified as the nations ‘Worst’ invasive plant species by Agriculture and Agri-Food Canada, *Phragmites australis subsp. australis* (Phragmites) commonly known as European Common Reed, thrives in marshlands and lakeshores, overwhelming the local ecosystem with dense monospecific stands which seriously impact local habitats and biodiversity. Highways are rapidly becoming corridors due to disturbance and increase in soil salinity, raising possibility of a problem for rural and urban forestry.

Among several strategies to mitigate its spread, the use of herbicide followed by cutting and burning is found to be the most effective for established stands. Critically endangered biospheres such as in Long Point are on the verge of collapse, since spraying of herbicide is not authorized over aquatic habitats in Canada. An informal public opinion survey revealed that although there is significant awareness about Invasive Phragmites, there is a great deal of concern, and little support for aerial spraying of herbicides over wetlands. Could awareness programs to alleviate the concerns increase local support and influence policy to authorize herbicide spraying over wetlands?
Acknowledgments

I would like to thank my supervisors Dr. Sandy Smith, Dr. Janice Gilbert and Claire Paller for helping me structure my thoughts, identify and focus on the key objectives of this project. I could not have managed without their support and encouragement right through the process. A special thanks to Dr. Anne Koven for patiently guiding me through the hurdles I faced on numerous occasions, Dr. Tat Smith and Dr. Shashi Kant for always finding the time to clear my doubts and encouraging me throughout the course, especially during this project.

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Chapter 1
Introduction

1.1 Invasive Phragmites

*Phragmites australis* subsp. *australis* commonly known as European Common Reed, (referred to as Phragmites hereafter) is an invasive plant from Eurasia (Ontario Ministry of Natural Resources, 2011).

Identified as the nations ‘Worst’ invasive plant species by Agriculture and Agri-Food Canada (Nottawasaga Valley Watershed, 2016), it is very hardy and persistent species (High Park Nature, 2012). It’s dense monospecific stands negatively impacts local plant biodiversity and habitat of native flora and fauna. Its roots and rhizomes traps sediment reducing water flow resulting in poor drainage of wetlands. It impacts recreational activities such as swimming, boating and angling and causes fire hazards (The Ontario Phragmites Working Group, 2017).

Phragmites has multiple modes of propagation and is very resilient and hard to eradicate once established. It can grow up to 5m. tall, sprout seed heads each of which can disperse 2000 seeds over 10km by wind. The over ground biomass however is vastly surpassed by the roots and rhizomes underground, which make up 80% of the total biomass. These go 6 to 8 ft. deep, release allelopathic toxins killing local vegetation and spread rapidly. This species has no natural biological control (Jennifer M. Granholm, 1994). Heavy machinery brought in to destroy Phragmites often carry pieces of rhizome or stolon long distances on their tires and tracks. These pieces rapidly take root and flourish in locations further inland. Studies have found that highways are rapidly becoming corridors, due to soil disturbance and increase in soil salinity from road salt (Catling, 2011), (Yvon Jodoin, 2008). Road salt aids the process because Phragmites is far more salt tolerant than the local vegetation (Jacques Brisson, 2010). Often found for long stretches along highways, Phragmites is now reported to be encroaching into woodlands raising the question whether it is likely to become a problem for rural and Urban forestry (Smith, 2013), (Carbyn, 2006).
1.2 Problem definition

The rapid spread of Phragmites along lakeshores and water bodies poses a unique problem in Canada. Unlike in the USA, where aerial spraying of herbicides over Phragmites infested water bodies has been carried out since the 1980s (Lehman, 1987), in Canada, spraying of herbicides over water bodies is not yet permitted. The inability to conduct chemical control in aquatic areas is crippling the efforts to control Phragmites and critically endangering unique wetland biospheres (Ministry of Natural Resources and Forestry, 2017). The spread of Phragmites along highways is the other problem, and the question is: Are proactive control measures necessary to prevent Phragmites from becoming a problem for rural and Urban forestry?

1.3 Objectives of the study

This study aims to:

(i) Review the literature about Invasive Phragmites and methods to control it. The absence of a suitable method to control large scale infestations of Phragmites in and around precious aquatic habitats in Canada is of great concern and a case study will take a close look at an Emergency Use Registration (EUR) of herbicide pilot project at Long Point (ii) An informal, online, public opinion survey to test the following hypothesis:

(a) There is a lack of awareness among the public about the impact of Invasive Phragmites. (resulting in indifference about its control) and

(b) There is a lack of support for aerial spraying of herbicides over wetland areas infested with Phragmites.
Chapter 2
Literature Review

2.1 History & background

2.1.1 Global occurrence

Phragmites is a perennial reed which grows in most parts of the globe (Global Biodiversity Information Facility) and around the Great Lakes in North America (Figure 2).

2.1.2 History and Uses

Phragmites probably originated in the Middle East, and has been used in many cultures for thatching, fodder, cellulose production (Swearingen, 2010), to build fences, cattle pens (Angelika Wöhler-Geske, 2016), to make fishing rods and flutes, brooms, baskets, mats, pen tips, rough form of paper (Hans Brix, 2014) and even food and medicines (Kubiak-Martens, 1999), (Swearingen, 2010), (Peterson, 1999), (University of Michigan, 2016).

Traces of Phragmites in North America were found in a 40,000-year-old dung sample of a ground sloth (Milius, 2002) and 1,000 year old Phragmites mats were found in Colorado caves (Berger, 2009). Other studies, claim that Phragmites was probably introduced through ballast or packing material that came along with European ships (Swearingen, 2010).

In modern times it has been introduced as an ornamental plant, to control erosion (Frankenberg, 1997) and phytoremediation water treatment (Ailstock, 2000), (C. Todorovics, 2005). Gregory Zimmerman, a Professor of Biology at Lake Superior State University has been converting Phragmites into fuel pellets (Invasive plants as pellet feedstock, 2015) and the Interuniversity Research Center, Perugia, Italy is testing it as biofuel for thermal boilers (Petrozzi, 2014).

2.2 Local occurrence – Extent and areas affected

First recorded in southwestern Nova Scotia in 1910 and in 1948 in Southwestern Ontario (Nottawasaga Valley Watershed, 2016). A study by (Catling, 2011) found that Phragmites had limited distribution in the 1950s and spread slowly until 2010. Thereafter, it spread rapidly throughout much of Southern Ontario and Southern Quebec, Atlantic Canada and Western Canada (Figure 3).
2.2.1 New Corridors

The seeds of Phragmites can disperse over 10 km. by wind (Nottawasaga Valley Watershed, 2016). When pieces of its rhizomes or stolon are inadvertently transported inland with earth moving or agricultural equipment (Catling, 2011) they sprout and establish themselves locally, typically spreading along highways (Figure 4) and cover vast areas as in Quebec city (Yvon Jodoin, 2008) and in Ontario (Figure 5).

2.3 Distinction between Local and Invasive Phragmites

Mature stands of the invasive species form a dense impenetrable growth of thick and rigid, tan colored tall and rough stems. The native species has smooth reddish brown, narrow, flexible stems which grow relatively sparse and short. The native has narrow bright green leaves and sparse seed heads compared to, bluish green broad leaves and lush seed head of the invasive species (Figure 6) (Table 4).

2.4 Invasive characteristics

Phragmites occurs throughout non-tidal, tidal, aquatic and even upland of North America (Chambers RM, 1999) and can grow in undisturbed freshwater and brackish water (Rozsa, 1995), (Warren, 1996). The extreme length of the stolons and rhizomes helps it spread (Ontario Ministry of Natural Resources, 2011), (Alberta Invasive species Council, 2016) and it out competes local vegetation in many ways. 80% of its biomass in underground, (Figure 7) and Allelopathic, releasing gallotannin which converts to Gallic acid in the root zone which kills other vegetation (Figure 8 and Figure 9). Table 5 shows that the Invasive Phragmites secretes more gallotannin than the native Phragmites ). It’s height and density cuts off sunlight at the base and prevent most other species from surviving while it dominates the local ecosystem (Kirk J. HavensWalter I. Priest, 1997), (Uddin MN, 2014), (Jacques Brisson, 2010), (Ontario Ministry of Natural Resources, 2011).

2.4.1 Prolific and Resilient

Invasive Phragmites sends up around 200 shoots/m\(^2\), grows 4cm/day and grow up to 5m tall (Ontario Ministry of Natural Resources, 2011), (Alberta Invasive species Council, 2016). Each seed head has nearly 2000 seeds which can spread up to 10 km. by wind (Jennifer M. Granholm,
1994). Each stem can send out a number of stolons or runners each of which can be up to 50m long (Klimes, 2000) with nodes every few inches that sprout new shoots and roots. 80% of biomass is underground (Nottawasaga Valley Watershed, 2016). The thick dense network of Rhizomes can grow 6ft. per year or up to 60ft. long and burrow 6 to 8 ft. deep into the soil (Michigan Coastal Zone Management Program, 2014). Pieces of the rhizome or stolon can quickly sprout into a new plant (Mock, 2012) and stem densities often exceed 30 living stems/m² from a secondary rhizome (Ailstock, 2000). It is extremely salt tolerant, thriving in salt concentrations beyond 23,400 ppm, while most native species perish between 12,000 to 24,000 ppm (Figure 10), (Edward A. Vasquez, 2005). Once established it becomes very difficult to control (Kirk J. Havens, Walter I. Priest, 1997).

2.5 Local effects and impact of Phragmites

2.5.1 Biodiversity & Habitat

Phragmites is considered to be a biological pollution as it decreases the native plant diversity. (Chambers RM, 1999) resulting in reduced resting, feeding and breeding areas for migratory waterfowl and overall decline in species richness of birds (Askins, 1999), (Chambers RM, 1999). It also destroys habitats of toads, turtles and fish (Ailstock, 2000), (Kenneth W. Able, 2003).

2.5.2 Property value

Lake front homes find their view blocked by dense stands of Phragmites which also impacts recreational activities like swimming, boating and angling, resulting in the loss of aesthetic and property value (Table 1) It impacts the habitat of migratory birds and waterfowl thus negatively impacting the economy of areas which depend on tourism, hunting and cottage life (Isely Paul, 2017).
2.5.3 Cost to Municipalities, an emerging rural/urban problem?

Many municipalities are already battling to control the invasion. The Kincardine Municipality is investing around $30,000/yr to control and eradicate Phragmites within its area. (Gilbert J. M., 2015). The Ontario Phragmites Working Group published a handbook on ‘Smart Practices for the Control of Invasive Phragmites along Ontario’s Roads’ to help control the spread of Phragmites along roads and Highways (The Ontario Phragmites Working Group, 2015).

2.5.4 Clogging

Agricultural fields and lawns near wetlands are often invaded by Phragmites due to soil disturbances and nutrients (Marcia A. Rickey, 2004), resulting in reduced water flow poor drainage and clogging irrigation systems (Chambers RM, 1999), (Ontario Ministry of Natural Resources, 2011).

2.5.5 Fire Hazard

Phragmites is a perennial reed and the stems can live for years, when it dries up naturally or after spraying herbicides, the dry stems can remain even longer and become a fire hazard. (Ontario Ministry of Natural Resources, 2011).
2.6 Control methods

2.6.1 Foraging

Some attempts have been made to control Phragmites by letting goats forage on it (Brian R. Silliman, 2014). This however, is unlikely to solve the problem of large, well established stands.

2.6.2 Biocontrol

Scientists at Cornell University and the University of Florida are studying insects known to feed exclusively on Phragmites in Europe. Similar studies are being conducted at the University of Rhode Island (The University of Rhode Island, 2017). It is unclear as yet whether any of these insects would attack the underground rhizomes as well.

2.6.3 Plastic Wrap

Phragmites requires access to direct sunlight and this fact is sometimes exploited by covering an infected area with dark plastic wrap (Ontario Ministry of Natural Resources, 2011). While this method may be viable over small, young and new patches of sparse growth, it is unlikely to scale.

2.6.4 Manual

Manual methods involve uprooting, wiping the stem with herbicide or cutting it with power shears (Ontario Ministry of Natural Resources, 2011). The methods are tedious and slow and are fruitful only in small patches with young and sparse growth of Phragmites.

2.6.5 Mechanical

Mowing and rolling by itself, it is not an effective way to control Phragmites. In fact there is some evidence that Mechanical methods may aggravate the spread of Phragmites (Eric L. G. Hazelton, 2014).

2.6.6 Cutting and Drowning

The best method to control Phragmites without using herbicides is to repeatedly cut of the stems below the waterline and drowning the plant (Eric L. G. Hazelton, 2014).
2.6.7 Prescribed Burning

Burning by itself is also not an effective method to control Phragmites. Normally, once the Phragmites dries up after being sprayed with herbicide, it is mowed down and burnt (Eric L. G. Hazelton, 2014), (Ontario Ministry of Natural Resources, 2011).

2.6.8 Herbicide

Since eighty percent of the Phragmites biomass is underground, rhizomes can persist through most disturbances. Herbicide is the only known method to effectively kill Phragmites roots and rhizomes and leave the area in a condition which can support other plants (Eric L. G. Hazelton, 2014).

2.6.9 Concerns about herbicides

The use of herbicides is always a controversial issue. The main concerns normally are (a) Health hazards, (b) Impact on local flora, fauna and aquatic life, (c) Bioaccumulation, (d) Soil contamination, (e) Water contamination and (f) Water and air borne drift. For this study we are focusing on glyphosate as it is widely used in forestry and agriculture worldwide and is used to control Phragmites in USA (Lehman, 1987).

2.6.9.1 Glyphosate

Glyphosate binds strongly to organic matter and is considered immobile in soils and sediments. thus reducing exposure of aquatic organisms. (Ministry of Natural Resources and Forestry, 2017a,b). A 2015 study by the (European food safety Authority, 2015) concluded that Glyphosate is “unlikely to pose a carcinogenic hazard to humans”. That same year (2015), the World Health Organization’s International Agency for Research on Cancer classified glyphosate as “probably carcinogenic” to humans, raising confusion and concern. A joint FAO-WHO meeting in 2016 however clarified that “Glyphosate is unlikely to be genotoxic at anticipated dietary exposures is unlikely to pose a carcinogenic risk to humans via exposure from the diet” (FAO/WHO, 2016).

2.6.9.2 Aerial spraying (Approved in the USA)

Aerial spraying is approved by the Department Environmental Quality (DEQ) in the USA. Early studies (1984) showed 58-99% reduction of Phragmites, and re-vegetation was documented in all
areas (Lehman, 1987). Studies published in the Journal of Toxicology and Environmental Health report that “Glyphosate is of small acute toxicity to aquatic invertebrates, fish and wildlife and that the risk to aquatic organisms is negligible or small at (suggested) application rates” (Solomon, 2003).

2.6.10 A Summary of control methods

A study of 40 years of methods and outcomes to control Phragmites (Eric L. G. Hazelton, 2014) (Figure 11) showed that treatment by herbicide constituted 51% of all the control studies during the period. A summary of control methods permissible in Canada with their pros and cons and most appropriate time has been published by the Ontario Ministry of Natural Resources (Table 6).

2.6.11 Herbicides in local studies:

A study site at MacLean’s Marsh, which was infested by Phragmites was sprayed using 5% Glyphosate in 2007 when the area was totally dry. A year later after the area had been cleared of the dead and dry remains, there was water in the area with a return of waterfowl (Figure 12).

In another study in 2011, 63.7% of the site was covered by Phragmites. A couple of subspecies were present with hardly any other species of vegetation present, leaving less than 11% of the area free. A year after spraying with Glyphosate, the Phragmites cover was reduced to 1.5%, native species were re-established and the open space had increased to 24% (Figure 13), (Gilbert J. M., 2012).
Chapter 3
Case Study: Emergency Use Registration Project at Long Point.

3.1 Long Point, A UNESCO Biosphere

Although many regions in the country, including UNESCO Biosphere reserves like Long Point and Rondeau are severely infested with Phragmites, the use of herbicides over wetlands and aquatic habitats is not yet permitted in Canada. Due to its sensitive nature, this area was taken up as a case study.

Long Point is a UNESCO biosphere reserve because it is home to many species unique to that area. Due to the explosive growth of Phragmites however, 23 species are now at risk.
From almost no presence before 2000, Phragmites spread exponentially within a few years and continues to spread threatening to take over the entire habitat (Figure 1). Experts have warned, that if Phragmites is not controlled, this unique habitat may be destroyed. Since the use of herbicide is not approved in aquatic areas, an EUR was applied for and approved. The OMNRF obtained authorization (Figure 14) from multiple organizations for the Implementation and will follow up with monitoring and evaluation after each spraying operation (Ministry of Natural Resources and Forestry, 2017).

A historical distribution and abundance of Phragmites at Long Point, Lake Erie shows that the Phragmites cover in the region grew from 4ha in 1945 to 18 ha in 1995, thereafter however the growth was exponential, covering 137 ha in 1999 (Kerrie L.Wilcox, 2003).

Local biologists and scientists had observed that the coastal marshes were at a critical tipping point if immediate action was not taken. Approval was obtained from the Pest Management Regulatory Agency to prevent the permanent loss of the significant natural values for which these areas are recognized. In 2016, the Ministry of Natural Resources and Forestry (MNRF) carried the first phase of EUR of herbicide to treat Phragmites in aquatic environments and control its exponential growth by aerial spraying. Due to the aggressive nature of Phragmites, it was necessary to continue the efforts to eradicate it in 2017 and prevent it from recolonizing areas treated in 2016 (MNRF, 2017).

Strict guidelines were followed in terms of weather conditions, chemical control, timing window and accuracy of spraying (Appendix-2) to ensure maximum efficacy an minimum collateral damage to the local flora and fauna. While the monitoring and analysis data is yet to be published, anecdotal update from one of the experts (Dr. Janice M. Gilbert) involved in the project suggests that water collected from the target area within one hour of the spraying was tested for the presence of Glyphosate and it was found to be well below the prescribed limit of 0.28mg/l by Health Canada, Standards (Health Canada, 1995).
Chapter 4
Public Opinion Survey

4.1 Method

An informal online public opinion survey about Invasive Phragmites was carried out between the 6th of November and the 4th of December 2017 on ‘Survey Monkey’.

Ten questions were asked regarding awareness about Invasive Phragmites, its impact, use of herbicides in general, use of herbicides specifically to control Phragmites and aerial spraying of herbicides over wetlands infested by Phragmites (Appendix-1 pg 22-25).

The survey was distributed online among students, and through a number of local groups and individuals concerned about Phragmites: Frederick W. Schueler (Founder, Bishops Mills Natural History Centre), Dan Shire (Pickering Naturalists group), Tineasha Brenot (Lake Huron Coastal Centre), Silvia Pedrazzi (Nottawasaga Futures), Karen Alexander (Great Lakes Phragmites collaborative), Nancy Vidler (Lambton Shores Phragmites Community Group -LSPCG) and Jim Oliver (Norfolk county Municipal councilor).

Since the survey was distributed through online groups interested in Phragmites, a large number of professionals were to be expected. It was assumed that forestry/ environmental professionals and students may be expected to be more aware about Phragmites and herbicides than the rest of the population. As such they were filtered out to avoid a bias while testing the hypothesis. The remaining groups, ‘locals and other/professionals’ (local & others) include local residents, seasonal residents, retirees, teachers and professionals offering various services, including some biologists and naturalists (The questions could have been better designed!).

4.2 Limitations of the Opinion Survey

The online survey was designed to get a quick sampling of public opinion and as such was an informal survey without the formal processes mandated for a large scale opinion surveys. The questions were not scientifically designed to eliminate bias or ambiguity and the survey was distributed through local groups interested in Phragmites (and therefore turned out to be an almost targeted survey).
4.3 Results

4.3.1 Distribution of respondents

In all, 337 responses were received from the opinion survey. Of these, 41% were found to be Forestry and Environmental professionals and 7% were students. The remaining 52% was made up of other professionals, local residents and any other locals like seasonal residents and retirees.

4.3.2 Awareness and concern about Phragmites

Responses to the key questions about awareness, concerns and support were tabulated to test the two hypothesis mentioned earlier (Results of all the respondents is also presented alongside for a comparative study (Table 2).

Almost 98% of the ‘local & others’ responded that they were aware of Invasive Phragmites. Over 93% of the same group are aware that Phragmites impacts Biodiversity. Although this group may not be expected to be aware of methods to control Phragmites, some of them claim to have experience in controlling Phragmites.

Based on these results, we may conclude that our first hypothesis:

‘There is a lack of awareness among the public about the impact of Invasive Phragmites’ (resulting in indifference about its control) is false.

The survey results indicate that the public (local & others) are not only significantly aware about Phragmites and its impact, they are not indifferent either, some of them actually have experience in controlling Phragmites.
Table 2: Awareness and concern about Phragmites

<table>
<thead>
<tr>
<th>Impact</th>
<th>Local &amp; Others % (173/175)</th>
<th>All % (329/337)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiversity</td>
<td>93.64</td>
<td>95.44</td>
</tr>
<tr>
<td>Fire</td>
<td>34.10</td>
<td>41.34</td>
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<tr>
<td>Drainage</td>
<td>46.24</td>
<td>49.54</td>
</tr>
<tr>
<td>Property Value</td>
<td>42.20</td>
<td>49.85</td>
</tr>
<tr>
<td>Recreation</td>
<td>54.91</td>
<td>65.05</td>
</tr>
<tr>
<td>Municipality cost</td>
<td>69.36</td>
<td>74.47</td>
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<tr>
<td>No Risk</td>
<td>1.16</td>
<td>1.22</td>
</tr>
<tr>
<td>Other</td>
<td>18.50</td>
<td>14.29</td>
</tr>
</tbody>
</table>

Q3: Are you aware of Invasive Phragmites?

<table>
<thead>
<tr>
<th></th>
<th>Local &amp; Others (175/175)</th>
<th>All % (337/337)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>97.71%</td>
<td>96.74%</td>
</tr>
<tr>
<td>No</td>
<td>2.29%</td>
<td>3.26%</td>
</tr>
</tbody>
</table>

Q7: Experience in controlling Phragmites

<table>
<thead>
<tr>
<th></th>
<th>Local &amp; Others % (175/175)</th>
<th>All % (337/337)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>54.8</td>
<td>44.21</td>
</tr>
<tr>
<td>Mechanical</td>
<td>10.86</td>
<td>11.57</td>
</tr>
<tr>
<td>Mechanical + Spraying</td>
<td>18.29</td>
<td>23.74</td>
</tr>
<tr>
<td>Mechanical Inadequate</td>
<td>19.4</td>
<td>24.93</td>
</tr>
<tr>
<td>Aerial spraying in Aquatic Habitat</td>
<td>10.29</td>
<td>17.80</td>
</tr>
<tr>
<td>Other</td>
<td>37.14</td>
<td>43.62</td>
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</tbody>
</table>

4.3.3 Awareness and concern about herbicides

Over 51% of the ‘local & others’ group is aware that herbicides are used in Agriculture, significant numbers are also aware that herbicides are also used in Forestry and Aquatic habitats. Nearly 49% have little or no concern about spraying herbicides to control Phragmites, this excludes 22% who are moderately concerned. When it comes to support for aerial spraying of herbicides over wetlands however, over 54% show little or no support. Again this excludes all those who show moderate support (Table 3).

Based on these results, we may conclude that our second hypothesis: ‘There is a lack of support for aerial spraying of herbicides over wetland areas infested with Phragmites’ is true.

Although the public (local & others) are aware of herbicides being used in other areas like Agriculture and Forestry, and are not very concerned about spraying it on land, their concern about spraying it over aquatic habitats is quite high.
Table 3: Awareness and support for Herbicides

<table>
<thead>
<tr>
<th>Q6. Aware of Herbicides in...?</th>
<th>Local &amp; Others% (173/175)</th>
<th>All % (330/337)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>51.45</td>
<td>60.00</td>
</tr>
<tr>
<td>Forestry</td>
<td>38.15</td>
<td>53.64</td>
</tr>
<tr>
<td>Aquatic Habitats</td>
<td>44.51</td>
<td>58.48</td>
</tr>
<tr>
<td>Not Aware</td>
<td>31.79</td>
<td>20.00</td>
</tr>
<tr>
<td>Mention herbicides aware of &amp; concerns</td>
<td>38.15</td>
<td>41.52</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q8: Concern about spraying</th>
<th>Local &amp; Others% (173/175)</th>
<th>All % (329/337)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No concern</td>
<td>26.59</td>
<td>28.27</td>
</tr>
<tr>
<td>Slight</td>
<td>21.97</td>
<td>25.53</td>
</tr>
<tr>
<td>Moderate</td>
<td>21.97</td>
<td>21.58</td>
</tr>
<tr>
<td>High</td>
<td>11.56</td>
<td>12.16</td>
</tr>
<tr>
<td>Extremely</td>
<td>17.92</td>
<td>12.46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Q9: Support Aerial spraying over aquatic habitats</th>
<th>Local &amp; Others % (170/175)</th>
<th>All % (323/337)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>20.00</td>
<td>20.74</td>
</tr>
<tr>
<td>High</td>
<td>7.65</td>
<td>10.84</td>
</tr>
<tr>
<td>Moderate</td>
<td>18.24</td>
<td>20.74</td>
</tr>
<tr>
<td>Low</td>
<td><strong>17.65</strong></td>
<td>15.79</td>
</tr>
<tr>
<td>No support</td>
<td><strong>36.47</strong></td>
<td>31.89</td>
</tr>
</tbody>
</table>

4.4 Conclusion

The ‘Worst Invasive plant species in Canada’, Invasive Phragmites, has been spreading along wetlands and more recently along highways and roads. Its aggressive characteristics threatens local biodiversity and habitats wherever it establishes itself. Of special concern however, are valuable biospheres like Long Point and Rondeau which have been pushed to the brink of collapse, putting at least 23 unique species at risk. With no natural biological controls and limited efficacy of mechanical controls, aerial spraying of herbicide over these wetlands seems to be the only available option to save and restore these habitats.

A small and informal public opinion survey suggests that the local population is significantly aware of the impact of Phragmites and even supportive of spraying herbicides to control it on land. Over aquatic regions however, there seems to be significantly lower levels of support. Although this needs to be verified by a larger formal survey, could outreach and awareness programs help in alleviating concerns, and influence policy to authorize the spraying of herbicide over wetlands to control ‘Canada’s Worst Invasive plant species’, and save our unique wetland species and habitats?
Bibliography


Lehman, W. L. (1987). Phragmites Control and revegetation following aerial applications of glyphosate in Delaware. *Waterfowl and wetlands symposium* (pp. 185-199). Delaware: Department of Natural Resources and Environmental Control, Dover, Delaware, USA.


Appendix – 1. Opinion Survey questions

Questions posed in an informal, online public opinion survey on:

‘Awareness about Invasive Phragmites and ways to control it’.

1. Please describe yourself.

   (Local resident/ Student/ Environment / Forestry Professional/ Other Professional/ Other 
   (please specify)

2. *Which Province/ City/ Town/ County are you from?

3. Are you aware of Invasive Phragmites?

   (Sometimes called 'Common Reed', it grows very densely along lake fronts and shorelines and can grow up to 3 meters tall. It is often found growing along highways and roadside ditches.) If you are not aware of Invasive Phragmites, please select 'No' to this question, ignore all the other questions and end the survey (Yes/ No).

4. What is the extent of invasive Phragmites growing on your property/ community?

   (1 : minimal, 3 : moderate and 5 is extensive.)

5. What risks & hazards you perceive due to Invasive Phragmites?

   (please select all options that apply)

   Loss of biodiversity / ecological damage, Increased fire hazard, Poor drainage, Loss in property value/economic damage, Affects recreation like swimming, fishing, boating and aesthetic value, Cost to Municipality to manage/ control Phragmites, No Risk, No Hazard, Other (please specify)

6. Are you aware of herbicides being used to control of invasive species:

   (select all options that apply)
In Agriculture, In Forestry, Aquatic habitats / Lake fronts/ Shorelines, Not Aware, Please mention any herbicide(s) you are aware/ concerned about. Listing the highest concern first.

7. Your experience in controlling Invasive Phragmites:

We would appreciate if you take the time to fill up your contact details in the last question in this survey.

I have no experience in controlling Invasive Phragmites

I have found Manual / Mechanical methods adequate to control Invasive Phragmites:

I have found Manual / Mechanical methods followed by spraying herbicide, necessary to control Invasive Phragmites:

I have found Manual/ Mechanical methods inadequate in controlling Phragmites

Aerial spraying of herbicide followed by mechanical removal is necessary to control Invasive Phragmites in aquatic habitats and water-bodies.

Please indicate the name of your organization along with the location/ county and year in which you implemented the procedure to control Invasive Phragmites.

8. Would you be concerned about spraying herbicides to control Invasive Phragmites?

(1: little or no concern , 2: moderately concerned, 5: extremely concerned)

9. How strongly would you support aerial spraying of herbicide on Invasive Phragmites growing in aquatic habitats or water-bodies ?

(1 : would not recommend , 3: moderately recommend , 5: Strongly recommend)

10. If you'd like to share your name and contact details or add any other comment in support of or against the use of herbicides to control Invasive Phragmites, we’d like to know more.

Full Name, Profession, Phone number, email id, Comment.
Appendix – 2. EUR Guidelines

Guidelines for conducting Emergency Use (EU) aerial spraying of Glyphosate at Long point.

**Chemical Control:**

- Herbicide application followed all requirements outlined by PMRA, MOECC and product label
- Application occurred during vulnerable life stages of Phragmites (after seed-set)

**Reducing non-target impact to wildlife and plants:**

- Herbicide application occurred over dense Phragmites stands
- Timing window factors
  - Outside of bird breeding/nesting window
  - Critical insect life stages complete
  - Most native plants passed maturity and in decay
  - Amphibians and reptiles will be staging
  - Outside of hunting days

**Conditions:**

- Wind and Weather
- No rain or forecasted for 12 hours
- No morning dew present
- Winds less than 16km/hour
- Speed & Height Restrictions
  - Maximum helicopter speed while spraying is 60km/hour
  - Treatment occurs at 3m above plant

**Accuracy:**

- MNRF provided GIS data mapping of high density Phragmites cells; data was loaded into an automated navigation system
- Boom width is not more than 65% of the propeller diameter (down draft)
Appendix – 3. Figures, Images and Maps

Extent and areas affected by Invasive Phragmites.

**Figure 2**: Invasive Phragmites around the great lakes (NASA Earth Observatory, 2017).

**Figure 3**: Spread of Phragmites across Canada from 1950 to 1914 (updated data by J.M.Gilbert in red) and prediction for 2030 (Catling, 2011).
New Corridors: Local spread of Invasive Phragmites

**Figure 4:** Highway Phragmites corridor in Quebec Photo: (Yvon Jodoin, 2008).
Inset: Rhizomes and stolons moving with heavy machinery (Catling, 2011)

**Figure 5:** Distribution of Invasive Phragmites in Ontario (EDDMapS, 2017)
Figure 6: Physical characteristics of Native and Invasive Phragmites (Ontario Ministry of Natural Resources (2011). Photos by: Erin Sanders and Janice Gilbert.

The native species grows sparse and short with narrow, smooth, flexible and reddish brown stems. Its leaves are green and narrow and the seed head is small and sparse.

The Invasive species grows in tall dense stands. It has thicker rigid tan stems which are rough. The leaves are broad and bluish green and the seed head is large and dense.
Figure 7: Density of Invasive Phragmites rhizomes underground.

(Delaware Invasive Species Council Inc, 2013)
Figure 8: A schematic showing gallotannin (GT) degradation by tannase(T). Phragmites releases GT, which reacts with T released by other plants and bacteria and degrades to Gallic Acid which kills the local vegetation (Amutha Sampath Kumar, 2010).

Figure 9: Effect of Gallic acid on roots. “Pace of the effect of gallic acid on A. thaliana roots, with time. The results showed that by 10 min after treatment, ROS was generated on the root surface and increased further over the time period (a). Correspondingly, the disruption of the microtubule assembly also appeared to be initiated by 10 min, and it reached the maximum level by the 40th min (b)” (Rudrappa T, 2007).
Figure 10: Salt tolerance of Invasive Phragmites (Edward A. Vasquez, 2005). While most native species perish at salinity between 12,870 and 23,400 ppm, Phragmites remains totally unaffected.

Figure 11: A 40 Year study of methods and outcomes to control Phragmites (Eric L. G. Hazelton, 2014).
Figure 12: Before & after spraying 5% Glyphosate at MacLean’s Marsh - Photo: J.M.Gilbert (Ontario Ministry of Natural Resources, 2011). The site was not water logged when sprayed.

Figure 13: Percentage Vegetation cover before and after spraying herbicide (Gilbert J. M., 2012).

*sampled in the same 10 x 1x1 m² plots*
Figure 14: Emergency Use of Herbicide Registration process (MNRF, 2017).

PMRA: Pest Management Regulatory Agency
DFO: Fisheries and Oceans Canada
MOECC: Ministry of the Environment and Climate Change
## Appendix – 4. Tables

### Table 4: Differences between native and Invasive Phragmites *(Ontario Ministry of Natural Resources, 2011)*

<table>
<thead>
<tr>
<th></th>
<th>Native Phragmites</th>
<th>Invasive Phragmites</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stand height</strong></td>
<td>No taller than 2m</td>
<td>Upto 5 m</td>
</tr>
<tr>
<td><strong>Stand density</strong></td>
<td>Sparse, interspersed with native vegetation</td>
<td>Dense monoculture, upto 100% invasive Phragmites</td>
</tr>
<tr>
<td><strong>Stem Color</strong></td>
<td>Reddish brown</td>
<td>Beige, tan</td>
</tr>
<tr>
<td><strong>Stem texture</strong></td>
<td>Smooth and Shiny</td>
<td>Rough and dull</td>
</tr>
<tr>
<td><strong>Stem flexibility</strong></td>
<td>High flexibility</td>
<td>Rigid</td>
</tr>
<tr>
<td><strong>Leaf color</strong></td>
<td>Yellow-green</td>
<td>Blue-green</td>
</tr>
<tr>
<td><strong>Leaf sheaths</strong></td>
<td>Fall off in fall, easily removed</td>
<td>Remain attached, difficult to remove</td>
</tr>
<tr>
<td><strong>Lower glume</strong></td>
<td>3.7-7mm</td>
<td>2.6-4.2mm</td>
</tr>
<tr>
<td><strong>Flower timing</strong></td>
<td>Early (July-August)</td>
<td>Intermediate (August-September)</td>
</tr>
<tr>
<td><strong>Seedhead density</strong></td>
<td>Sparse, small</td>
<td>Dense, large</td>
</tr>
</tbody>
</table>
**Table 5:** Concentration of gallic acid and gallotannin in native and invasive Phragmites. “Different letters on the columns indicate statistically significant difference between isolates. Means with common letters are not significantly different at $P \leq 0.05$ according to Duncan’s multiple range test. Pop, Population” (Gurdeep Bains, 2009).

<table>
<thead>
<tr>
<th></th>
<th>Gallic Acid $\mu$m/g FW</th>
<th></th>
<th>Gallotannin $\mu$m/g FW</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rhizome</td>
<td>Rhizospheric Soil</td>
<td>Rhizome</td>
<td>Rhizospheric Soil</td>
</tr>
<tr>
<td>Native</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pop 1</td>
<td>8.70 ± 0.42 c</td>
<td>5.80 ± 0.28 d</td>
<td>41.30 ± 0.99 c</td>
<td>23.80 ± 0.85 b</td>
</tr>
<tr>
<td>Pop 2</td>
<td>11.20 ± 1.41 c</td>
<td>7.40 ± 0.28 cd</td>
<td>22.20 ± 7.64 c</td>
<td>21.56 ± 4.19 b</td>
</tr>
<tr>
<td>Pop 3</td>
<td>9.90 ± 1.56 c</td>
<td>7.60 ± 1.41 cd</td>
<td>38.45 ± 17.47 c</td>
<td>35.95 ± 1.20 b</td>
</tr>
<tr>
<td>Pop 4</td>
<td>10.90 ± 0.42 c</td>
<td>9.50 ± 0.99 c</td>
<td>47.60 ± 15.41 c</td>
<td>38.75 ± 0.21 b</td>
</tr>
<tr>
<td>Invasive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pop 1</td>
<td>15.40 ± 0.28 b</td>
<td>8.20 ± 0.28 cd</td>
<td>240.31 ± 40.01 ab</td>
<td>210.93 ± 0.41 a</td>
</tr>
<tr>
<td>Pop 2</td>
<td>11.30 ± 0.14 c</td>
<td>14.80 ± 1.13 b</td>
<td>213.45 ± 2.84 b</td>
<td>228.70 ± 0.00 a</td>
</tr>
<tr>
<td>Pop 3</td>
<td>12.16 ± 0.62 bc</td>
<td>22.50 ± 2.97 a</td>
<td>194.61 ± 0.41 b</td>
<td>238.80 ± 46.95 a</td>
</tr>
<tr>
<td>Pop 4</td>
<td>48.80 ± 3.39 a</td>
<td>7.20 ± 0.57 cd</td>
<td>263.70 ± 37.57 a</td>
<td>254.90 ± 62.93 a</td>
</tr>
</tbody>
</table>
### Table 6: Summary of Control methods (Ontario Ministry of Natural Resources, 2011)

<table>
<thead>
<tr>
<th>Control methods</th>
<th>Pros</th>
<th>Cons</th>
<th>Timing</th>
<th>Notes/Cautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide Application</td>
<td></td>
<td>Must be used in conjunction with other methods</td>
<td>Spring to late fall (pre-senescence)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Most effective method</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Can be cost-effective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Can only be used in dry areas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-specific</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mowing/Cutting</td>
<td>Low cost</td>
<td>Can be labor-intensive</td>
<td>If using as part of an IPM: At least 2 weeks after herbicide application</td>
<td>If using alone: when the plant is flowering/producing seeds</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not effective when used as a standalone method</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-specific</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compression/Rolling</td>
<td>Low cost</td>
<td>Non-specific</td>
<td>If using as part of an IPM: At least 2 weeks after herbicide application</td>
<td>If using alone: when the plant is dead and dried</td>
</tr>
<tr>
<td>Prescribed burning</td>
<td></td>
<td>Not effective when used as a standalone method</td>
<td>If using as part of an IPM: At least 2 weeks after herbicide application</td>
<td>Should always be performed by authorized personnel, following federal and provincial guidelines and regulations as necessary.</td>
</tr>
<tr>
<td>Hand-pulling/Mechanical Excavation</td>
<td>Can easily target specific Phragmites plants</td>
<td>Very labor-intensive</td>
<td></td>
<td>Caution regarding soil disturbance</td>
</tr>
</tbody>
</table>

35
<table>
<thead>
<tr>
<th>Method</th>
<th>Effectiveness</th>
<th>Benefits</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td>More effective on small, isolated stands of plants less than 2 years old</td>
<td>Good for dry, sandy soils</td>
<td>Must ensure all portions of the rhizomes are removed from the ground</td>
</tr>
<tr>
<td>Tarping</td>
<td>Minimum effects on wildlife</td>
<td>Can be used in areas where water levels can be controlled or are naturally prone to floods</td>
<td>None - specific</td>
</tr>
<tr>
<td>Biological control</td>
<td>Target specific plants</td>
<td>Very long timelines</td>
<td>More research needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not yet available</td>
<td></td>
</tr>
</tbody>
</table>