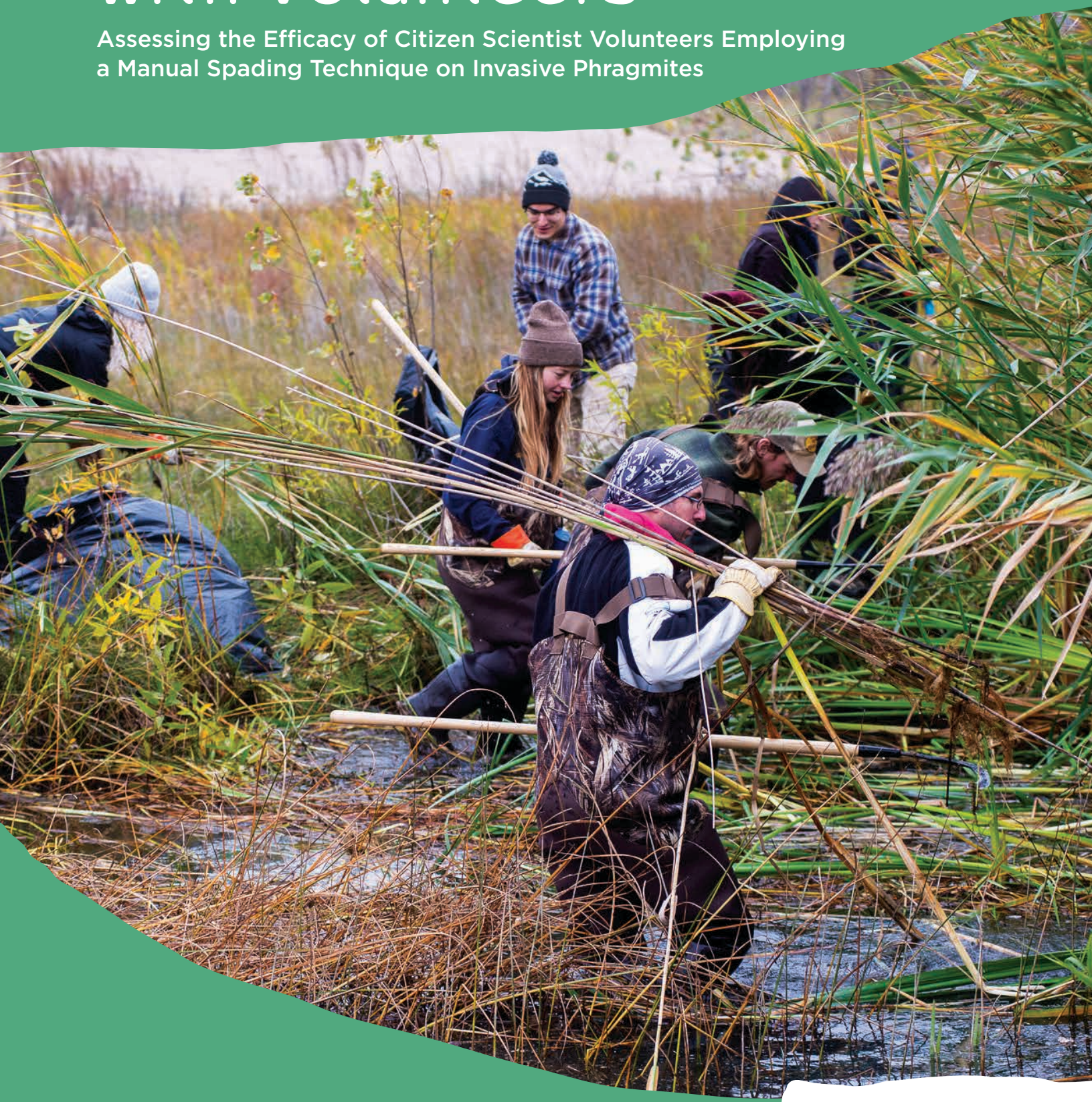
Managing Phragmites with Volunteers

Assessing the Efficacy of Citizen Scientist Volunteers Employing a Manual Spading Technique on Invasive Phragmites



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COVER PHOTOS: Matt Forsythe

EcoSpark
Managing Phragmites with Volunteers: Assessing the Efficacy of Citizen Scientist Volunteers Employing a Manual Spading Technique on Invasive Phragmites

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EcoSpark would also like to sincerely thank the City of Toronto and Lynn Short for their consultation, contributions, and assistance, which were instrumental in the success of this project overall, and in writing this report. This report was written by Sara Bowman (interim Citizen Science Coordinator), with assistance from Emily Heidendahl (City of Toronto - Parks Program Officer) and Professor Lynn Short (Humber College). This project was started, and initially carried out by Dana Buchbinder (Citizen Science Coordinator), with assistance from Joyce Chau (Executive Director).

Finally, this work would not have been possible without the generous financial support of the Ontario Trillium Foundation. Thank you for helping us better understand how powerful citizen scientists are when it comes to invasive species management and beyond!

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Design by comet art + design

The crew fighting the phrag.

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Executive Summary

EcoSpark and Lynn Short of Humber College successfully trained the City of Toronto's Community Stewardship Program volunteers in setting up a study area, collecting data, implementing treatments, and carrying out invasive species maintenance. Due in part to EcoSpark's engagement, individuals and communities are now primed and ready to engage in evidence-based environmental restoration activities.

Toronto's diverse urban forest creates healthy neighbourhoods, supports habitat and biodiversity and promotes clean air and water. Urban Forestry aims to continually improve and expand the natural environment areas in the city through sound urban forestry practices and community partnerships.

The Natural Environment & Community Programs unit of Forestry offers public volunteer programming in a natural environment setting. Their programs, such as the Community Stewardship Program, provide an existing base of dedicated volunteers that aim to improve and expand the natural environment. Promoting Citizen Science within their volunteer base has the potential to further inform our efforts of restoring biodiversity in Toronto greenspaces threatened by invasive species.

Community Stewardship Program volunteers started using a mechanical spading technique to manage invasive *Phragmites australis* in 2016, and though anecdotally, they could see the positive results of this technique. Our collaborative research project provided volunteers with an opportunity to use scientific testing to prove how effective it actually is.

The City of Toronto Ravine Strategy and Biodiversity Strategy both give mention to the rising need for environmental stewardship in Toronto. Through these strategies more attention and support is being given to stewardship efforts such as the Community Stewardship Program. Promoting Citizen Science within this program provides a methodology and training for the management of invasive species by volunteers and empowers them by providing the tools for education, monitoring and influencing positive change. Given this rising need, our study aimed to determine whether citizen scientist volunteers could *effectively* manage invasive phragmites using the spading technique.

Thanks to this partnership, and the hard work of CSP volunteers, City of Toronto now has 1714 pounds less invasive phragmites in its green spaces, 210 more people who can be informed stewards of the city's beautiful natural environment, and the knowledge that the mechanical spading technique is effective, and can be carried out by volunteers!

Citizen Science Coordinator Dana Buchbinder takes down data being collected by a CSP volunteer.

Citizen Science

Citizen science is real scientific research conducted by volunteers. It is public participation in science, often in collaboration with professional scientists. A citizen refers to a citizen of the world, and there are citizen scientists of all ages and experience levels. A citizen science project could be local or international, large or small, developed by professionals or created by anyone interested in answering any type of scientific question.

Many organizations use citizen science as a means of building regional, national, and even international datasets that can be used by researchers, land-managers, policy makers, educators, and other stakeholders. Citizen science does not stop at collecting and uploading data, however; environmental stewardship, such as invasive species removal, also qualifies as citizen science (henceforth 'CS'). The benefits, and those who receive them, are plentiful. Volunteers gain insight into the health of their local environment, exposure and access to the wider scientific community, directly participate in the understanding and management of their green space, and they engage with a network of like-minded individuals. Further, being engaged in CS imparts a feeling of empowerment leading to a citizenry that is more active in understanding and protecting the environment. Researchers, policy makers and so on benefit from a fine-scale dataset that would be otherwise unachievable.

The relevant CS project for this report is **E**arly **D**etection and **D**istribution **Map**ping **S**ystem (EDDMapS). This tool was created in 2005 by the Centre for Invasive Species and Ecosystem Health, based out of the University of Georgia, to help land managers better understand and track the distribution of invasive species in the state[1]. Eventually the use of this tool spread to other jurisdictions and into the sphere of CS.

EDDMapS Ontario was created thanks to government and non-government funding sources. Introducing the public to EDDMapS has been a great way to increase the number of observations, and the spread of observations throughout jurisdictions[2]. According to their website, as of September 2019 EDDMapS has received 4.9 million observations since 2005 - and over 51,000 of those are from Ontario[2]. Plant identification can be a challenge, even for taxonomic experts - that is why all submissions to EDDMapS Ontario are verified by staff from one of their funders - Ontario Federation of Anglers and Hunters, before it is loaded onto the map for other users to see[2]. This system of checking the submissions of volunteers is an effective way of ensuring that all 4.9 million of those data points are accurate and ready to be used by the stakeholders mentioned above.

A student records observations on the invasive Manitoba Maple tree, during a School Watch session.

Two students participate in EcoSpark's flagship Changing Currents program, which assesses stream health.

ECOSPARK: DISCOVER - ACT - CHANGE

EcoSpark empowers people to take an active role in protecting and sustaining nature. We do this by giving people the tools for education, monitoring and influencing positive change. Together, we create a healthy environment for all. EcoSpark was founded in 1996 by prominent scientists, including Dr. Ursula Franklin, in response to provincial budget cuts in environmental monitoring. Since then, EcoSpark has connected youth and their communities with scientific ideas and skills for environmental monitoring. We have a strong reputation in the areas of education, citizen science, community engagement and collaboration. To date, we have directly worked with over 85,000 youth and adults from across southern Ontario in over 20 watersheds. We achieve this with our effective, curriculum linked school programming, and through bringing citizen science programming to community groups like the Community Stewardship Program, thanks to partnerships with government and non-government organizations.

Our flagship program, Changing Currents, engages students in grade 6 and up in assessing the health of local streams following a modified version of the Ontario Benthos Biomonitoring Network (OBBN). By looking at the assemblage of small aquatic invertebrates in the stream, along with water chemistry and other features of the area, we can learn a lot about the health of the stream.

With our School Watch program we are able to engage students from kindergarten to grade 12 in a whole suite of citizen science activities (including EDDMapS) right on school property. What's more - by giving teachers curriculum connected resources and training, schools are set up to carry out their very own citizen science projects all year long.

Campers participate in butterfly monitoring with EcoSpark's Park Watch program.

CITY OF TORONTO: COMMUNITY STEWARDSHIP PROGRAM

The **Community Stewardship Program** (CSP) connects the community to Toronto's amazing ravines through hands-on stewardship in sites across the city. Volunteers with the CSP participate in on-going naturalization, maintenance, and monitoring activities. After nearly two decades and countless volunteer hours, these sites are some of the most high quality habitats in the City, teeming with native flora and fauna.

Weekly stewardship activities include weeding invasive non-native plant species, planting native trees, shrubs, and wildflowers, monitoring and maintaining natural surface trails, watering planted vegetation, mulching, collecting litter, and monitoring specific site conditions. Volunteers can also learn and help with photo monitoring, water chemistry and levels, vegetation monitoring and mapping and benthic monitoring. Participants work in a team that is guided by City staff and an experienced volunteer (Team Leader). Each team visits their site weekly from May until September for 2 hours.

In addition to weekly stewardship sessions, educational workshops and tours on various topics like tree identification, butterflies, and benthic monitoring are available throughout the season. Volunteers are welcome to all workshops and are encouraged to attend as many as possible. We also organize a Volunteer Appreciation Event at the end of the season as a thank you for all your hard work!

The objectives of the Community Stewardship Program are:

1. **Restore native plant communities to a healthy and self-sustaining state**
   Care for native trees, shrubs and herbaceous plants by watering, mulching, and weeding plantings.
2. **Manage invasive plants so that the quality and functions of the habitat is improved**
   Cutting and pulling invasive plants to improve habitat for native species
3. **Promote the importance of restoration and naturalization**
   Keep the site clean by removing litter, reporting vandalism, and engaging with park users about stewardship and our restoration activities.
4. **Enhance habitat features to attract and maintain wildlife**
   Planting trees, shrubs, and wildflowers, creating mulch piles for turtle nesting, and more.
5. **Monitor vegetation and wildlife, assess the health of the site, and improve restoration techniques**
   Weekly reports and monitoring protocols are used to monitor our work.

CSP volunteers after an invasive species management session.

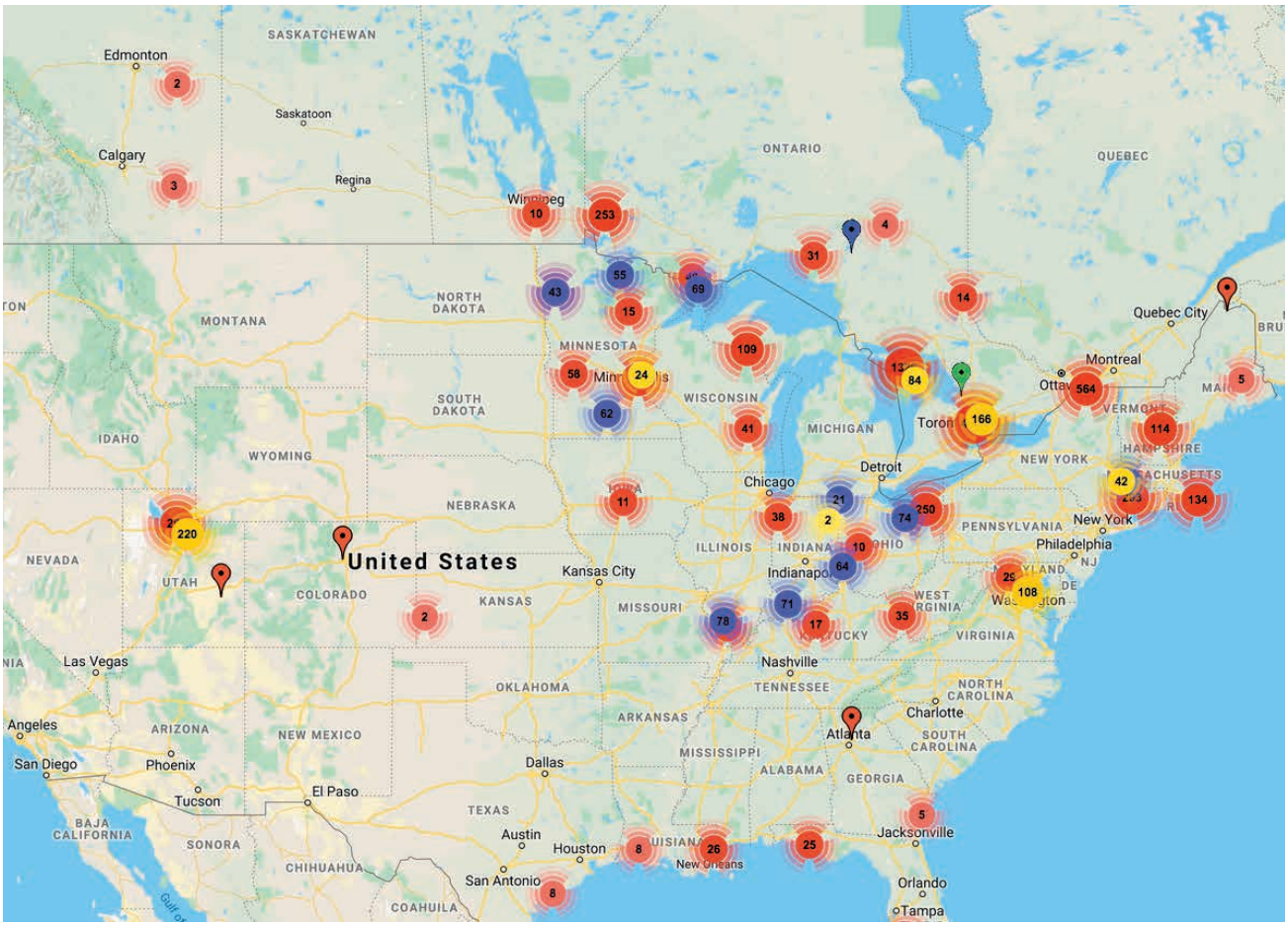
Invasive Phragmites

***Phragmites australis*, also known as common reed, or simply 'phragmites', is an invasive wetland grass species that has been dubbed the worst invader by Food and Agriculture Canada[3]. With dense monocultures measuring several square kilometers in size, and stalks that can be 15 to 20 feet tall, this grass has been a major concern to land managers, conservationists, and policy makers.**

ECOLOGY AND LIFE-HISTORY

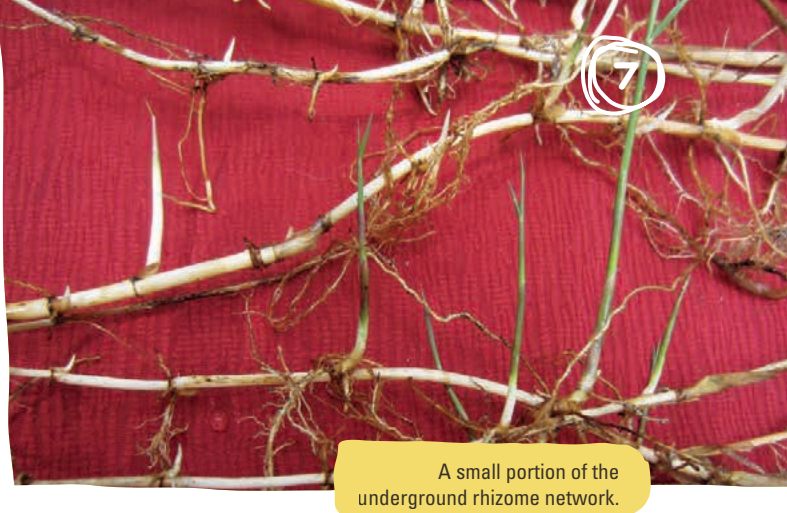
Phragmites is a perennial wetland grass that has a world-wide distribution in temperate and subtropical areas. It belongs to the canes and reeds family. A haplotype from a Eurasian population, "Haplotype M" or *Phragmites australis* subspecies *australis* was introduced in the late 1800s or early 1900s to eastern Canada, where it existed at low levels until approximately 40 years ago[4]. At that time it started aggressively expanding northward and westward, outcompeting native wetland plants[5]. The current range of phragmites in Ontario and beyond can be seen in the map below.

The ecology and life history of phragmites have allowed it to thrive in areas at the expense of plants and other organisms that have evolved in its absence. The creation of underground "spring buds" in the previous fall, rapid growth in early spring, allelopathic root exudates, both vegetative and reproductive spread,



A map showing the range of invasive phragmites in Canada and the United States. Courtesy of EDDMapS Ontario.

Phragmites rhizome - note the growth nodes.



A small portion of the underground rhizome network.

and the ability to grow in a variety of habitats, including disturbed habitats, all work together to give phragmites the ability to effectively outcompete native plants and form dense monocultures. Phragmites monocultures can cover many square kilometers, regardless of habitat type[6]. Stormwater management ponds, ditches, highway corridors, and urban streams and rivers provide excellent habitat for phragmites as these often represent disturbed areas, providing a foothold for phragmites to become established. Furthermore, human activities like digging, construction, driving, and foot traffic from recreation greatly lends itself to the spread of phragmites[7].

Seeds are light and fluffy and can easily be transported on clothing and footwear, or be shaken loose from seed heads by construction equipment or other physical disturbance. Fragments of dug-up rhizome can also facilitate spread, as they can take root and grow a new plant[7].

Within a single growing season, phragmites often reaches heights of 15 to 20 feet. This rapid growth is thanks to the energy stored in the plant's rhizomes, which can account for anywhere between 60-80% of the stand's total biomass[8,9,10]. While the stalks can grow 3-4 meters in height in a growing season, the rhizomes can grow upwards of 10 meters horizontally and 1 meter downward, in ideal conditions[13]. This is relevant, as many previous attempts at phragmites control have included attacking the above ground portion of the plant, leaving the majority of it underground, where previously developed growth nodes, each containing at least two buds, are ready to send up new stalks or create more rhizomes[11]. The rhizomes are the perennial tissue of the plant (i.e. the stalks die off every year making way for new stalks), and store the energy created through photosynthesis, and also produce and disseminate hormones that regulate the plant's life history[12]. The roots and rhizomes also send out allelopathic chemicals that directly inhibit the growth of surrounding plants.

The stalks of phragmites bear the dense heads of flowers, which are wind pollinated, and eventually the fluffy heads of seeds, which are predominantly wind dispersed. The seeds mature during fall, with each head having more than 2000 seeds - however, seed viability is quite low, at around 5%[10]. The stalks of phragmites are also of course the photosynthetically active portion of the plant. They remain active until late October or early November. The latter part of their growing season is important for the plant to create auxiliary buds that will be ready to send a new shoot above ground very early

The thick flower heads that form on invasive phragmites. Flowers are wind pollinated.

in the spring, before many other native plants have begun to leaf out. The initial role of these spring shoots is to divert energy created through photosynthesis to the development of spring buds that will be ready to grow in the event that the initial shoot is damaged[14].

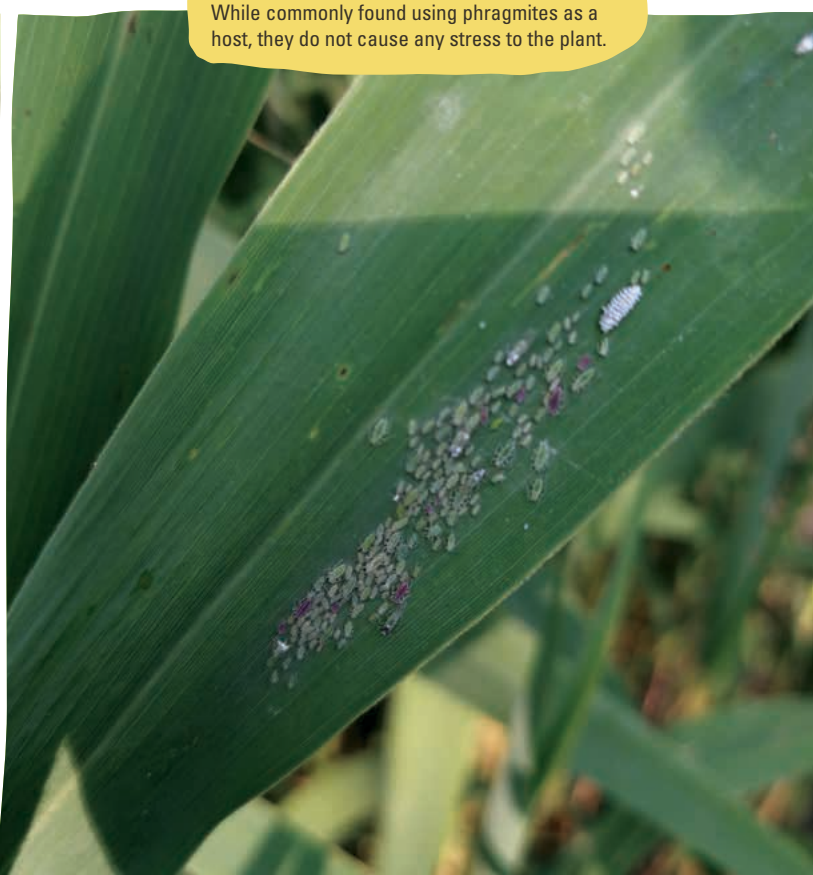
The stalks die back at the end of the growing season but remain standing. Overtime these dead, brittle stalks will break and snap, adding to the thatch depth found on the ground of phragmites stands. This thatch has several consequences: it impedes the growth of other plants and it shelters new phragmites shoots in warm air pockets in the early spring[16]. The dead standing stalks provide a benefit to the overall stand through an effect called pressurized ventilation, or "snorkeling". Snorkeling allows the influx of oxygen to the rhizomes via photosynthesis to continue by creating a pressure gradient that pushes oxygen up and out of the dead stalks, which are open to the air[15]. This is of particular importance when the plant is growing in water, where it would otherwise be drowned.

ECOLOGICAL, SOCIAL, AND ECONOMIC IMPACTS

High photosynthetic rates translate to high transpiration rates (water evaporating out of tiny pores on the leaves, as a by-product of photosynthesis). An area taken over by phragmites will be subject to overall higher water removal rates than before, lowering the water table[16]. The dense growth of phragmites stands can also cause blockages and damage to hydrological infrastructure, increasing the risk of flooding by diverting stormwater runoff, which can impede groundwater recharge, and can create undue economic pressure on municipalities to repair damages[9,17].

When phragmites colonizes an area, a subsequent decline in wildlife diversity is seen, as it is not chosen as a nesting or foraging site for many animals[13]. A notable exception are red-winged blackbirds, who use phragmites extensively for nesting. The dense stands impeded dispersal through and between

A red-winged blackbird nest woven into dead phragmites stalks from the previous year.



Mealy plum aphids feed on a phragmites leaf. While commonly found using phragmites as a host, they do not cause any stress to the plant.

habitats, further fragmenting the landscape for wildlife[16]. As the higher transpiration rates can change the hydrology of an area, wildlife that depends on shorelines and shallow water for feeding and breeding are also impacted[14].

An invasive species in Ontario is one that causes ecological, social, and economic harm[3]. As discussed earlier, phragmites causes significant ecological harm in the areas it has colonized, and the impacts on infrastructure and of flooding certainly pose social and economic concerns for humans. Additional human-based concerns include fire risk due to the dry, brittle stalks and thatch of previous years, invasion of agricultural fields, especially in the prairies, loss of culturally important foraging, hunting, and fishing grounds, and finally motor-vehicle and driver safety concerns along highway corridors[8,9,18].

PHRAGMITES MANAGEMENT

In order to completely kill a stand of phragmites, the entire plant, including all rhizomes, must be removed[14]. Given that stands of phragmites can often reach several square kilometers in size, this is typically not a possible solution, meaning land managers have to work with a variety of solutions, often employing multiple at a time (i.e. Integrated Pest Management)[14].

Black tarp covering a patch of phragmites in autumn.[19]

MECHANICAL REMOVAL: This includes brush-cutting (using a mower to cut at approximately knee height), mowing, physically digging up stalks, burning the stand, and covering with a tarp. Save for the physically digging up and removing the stalks, these methods are a good way to deal with a large stand, but have the consequence of not being specific to phragmites, and not harming the rhizome and auxiliary buds.

THATCH REMOVAL: Thatch is the accumulation of dry, dead stalks on the ground in a stand of phragmites. Thatch will build up naturally, and as a result of mechanical removal. Thatch build up prevents other plants from establishing, and protects the new phragmites shoots as they are growing. This should be done in conjunction with mechanical removal methods.

CHEMICAL TREATMENT: This typically includes the use of the herbicides glyphosate and imazapyr, which, according to the Ontario Ministry of Natural Resources and Forestry, are effective in the control of phragmites[6]. Typically land managers will mow or cut the stand prior to applying the herbicide to maximize the impact, as the stalks will more readily take up the chemical. The downside is that in Ontario, the use of herbicides near open water is strictly forbidden, except in very extraordinary circumstances. The herbicides are also not specific to phragmites.

BIOLOGICAL CONTROL: In Ontario only 3 insects use phragmite as a primary food source. Two insects in particular have been shown by Marks et al. (1993) to moderately impact density. Introducing more insects that would feed on phragmites is a risk, as with all biological control measures, because of the concern of those insects switching to native and naturalized vegetation.

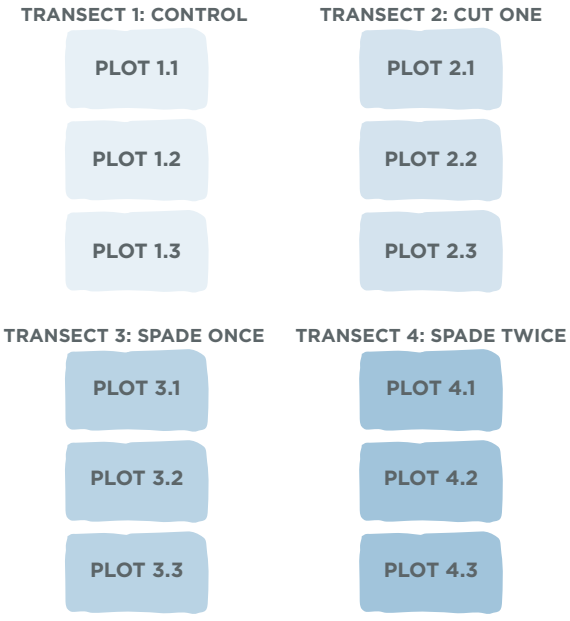
Methods

This study was designed to be conducted in Toronto public greenspaces with established invasive phragmites stands. The protocol was developed in 2018 for a citizen science research project coordinated by EcoSpark in partnership with Lynn Short of Humber Arboretum and the staff and volunteers of the City of Toronto Parks, Forestry & Recreation Community Stewardship Program (CSP). Methods were based on Lynn Short's prior research of the phragmites removal technique she developed for volunteers, which uses sharpened spades. The project was generously funded by the Ontario Trillium Foundation.

PHRAGMITES SPADING STUDY DESIGN

The study sites were the CSP stewardship sites of Riverdale Park East, Don Valley Brick Works Park, Beechwood Wetland, and Milne Hollow, along the Don River in eastern Toronto, ON. Research data collection and spading took place in June, July, August, September, and October 2018 and 2019. All sites are managed by the City of Toronto.

Study sites were characterized by noting GPS coordinates, slope aspect, shade cover, stand age if known, hydrology, management history if available, and other biotic or abiotic features of note. Study sites were continuous stands of phragmites that were large enough to fit four transects of 3-meter by 1-meter each, with a buffer zone between transects of 1 meter. Each transect is subdivided further into 3 replication plots, aligned adjacent to one another, and measuring 1-meter by 1-meter each. (Due to space constraints at the sites there was no buffer between Transect 1 and 2 or between Transect 3 and 4, which would be ideally 1-meter apart).



A graphic representation of transect and plot orientation. All transects had 3 plots, which were 1-meter by 1-meter. There was a 1-meter buffer zone between transects 1/2 and transects 3/4.

Data analysis included comparisons of phragmites regrowth (stem counts, height, and diameter, and percent flowering and/or seeding) between treatments and control transects before and after treatment to determine whether the spading reduced phragmites regrowth to a greater extent than would be expected due to background variation. We also assessed how well native and naturalized vegetation re-grew in each of the transects. We counted the number of species, and the number of individuals per species in the first plot of each transect, before any other work was completed (to avoid trampling small plants). Naturalized plants are defined as non-native but not invasive. They exist with other plants without forming a monoculture. Naturalized plants do have the capacity to take over an area, and should still be monitored to ensure this does not happen. Native plants are those that existed here prior to European colonization.

The stalks in Transect 2 were cut at 5 centimeters above the soil surface, simulating mowing or brush cutting. In Transect 3, the stalks were spaded once during the season, and twice in the season for Transect 4. These two transects were set up to test the efficacy of different frequencies of spading during a season. The treatment schedule can be seen in Appendix A.

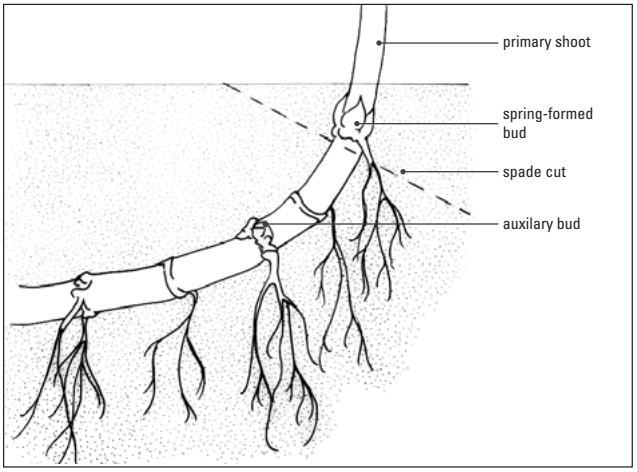
POTENTIAL STUDY LIMITATIONS

The two hour time-frame in each CSP event may be too short and the area of treatment may be too big for volunteers to complete meaningful removals. This could be adjusted to create a smaller focus area that is proportional to the volunteer efforts. There also should be a complete removal, or at minimum a buffer of several meters, around the transects to prevent interference or contributions from the surrounding phragmites growth.

Since these studies are taking place on public land, other groups may use the sites in ways that may not be compatible with our sampling protocol. It is important to communicate the purposes of the study, along with the study schedule, to all other parties that use or work in the park to ensure study areas are not interfered with. In several cases (Riverdale Park East and Milne Hollow), the sites had been brush cut by City staff, despite communication within and between City departments to prevent that from happening.

GENERAL NOTES ABOUT PHRAGMITES MANAGEMENT PROTOCOLS

The City of Toronto is bound by various legislation and policies that govern what work can be performed with volunteers, so best management practices for invasive species removal are often adapted. Below is a summary of the current and former protocols used by volunteers at the various stewardship sites in Toronto.



A drawing of the rhizome just below the soil surface, where the spading should occur.

Photographic representation of Lynn Short's spading protocol.

2000 – 2015 PHRAGMITES PROTOCOL

- Cut seed heads from the plant in late July-September or,
- Cut stem at the base
- Seed heads are bagged in black plastic and disposed of as regular waste based on municipal standards for invasive species
- All other material can be composted on-site

2015 – 2017 PHRAGMITES PROTOCOL[14]

- Identify Phragmites (PICTURE 1)
- In July – September, use a sharp square spade to cut 2-3 inches into the ground adjacent to a Phragmites stem to cut the rhizome below the soil surface (PICTURES 2–4)
- Stems can also be removed a second time if the ground is not frozen in October to November, but this is not essential
- Remove plant stalk and bag in black plastic or compost on-site if seed heads haven't formed (PICTURES 5–6) (if seed head is present, it should be cut off and placed in a black plastic bag, and the stalks can be composted)

CITIZEN SCIENCE STUDY DESIGN

We assessed the citizen science component of this project in two major ways. The first was through volunteer evaluations, completed at the end of the project. The second was by recording the amount of phragmites removed per volunteer event.

The purpose of the survey was to assess whether participants felt they had learned something about phragmites and the scientific process over the course of the past two years. It also aimed to determine how empowered volunteers felt with respect to public stewardship, by asking whether they think the effort they put in, in conjunction with EcoSpark and Humber College, was effective. Questions also included whether or not the volunteer had heard about phragmites before joining CSP, and whether or not they had previously participated in its management if they had heard of it.

Most times, phragmites was removed using extra large contractor garbage bags, with the following dimensions: 46.5 inches by 50 inches. When filled, each bag weighed approximately 10 pounds on average. There was variation in the weight of the bags depending on how full they were packed, whether the material was wet or dry (i.e. thatch would be lighter than freshly removed stalks, which still have water weight). In one instance at Beechwood, the total weight of phragmites removed was recorded by weighing the truck before and after garbage drop-off. Using that weight, along with the number of bags that were in the truck, we were able to come up with the average weight of 10 pounds. In most cases at Beechwood, the resulting debris was left in place, as the area was very wet and allowed for much faster decomposition compared to dryer sites. In these cases, we visually estimated the number of bags that would have been removed, based on experience from other sites.

Site Backgrounds and Results

RIVERDALE PARK EAST

A bird's-eye-view of the Riverdale Park East study area, with the transects overlaid.

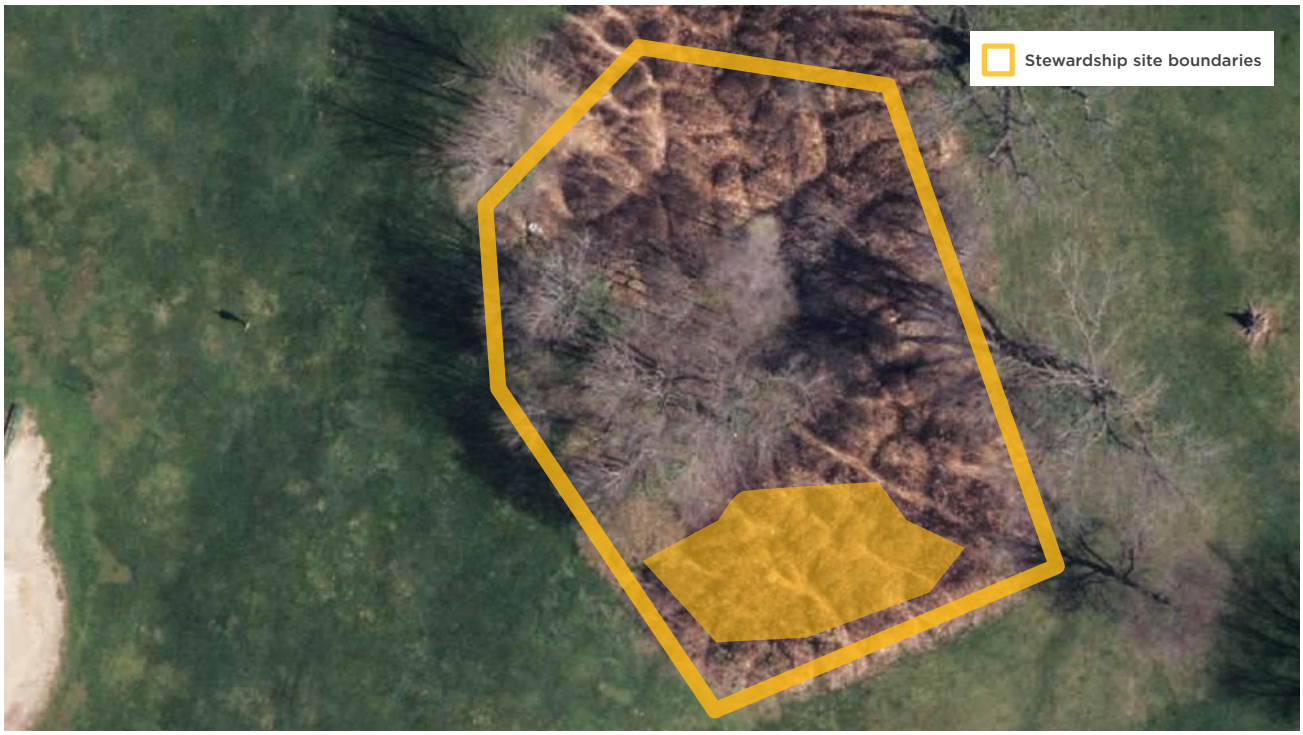
Site Details

Riverdale Park East is located at 550 Broadview Avenue, Toronto, Ontario. The coordinates of the study site are: 43.669074, -79.353841. The approximate size of the stand was 790 square meters. The EDDMapS record ID is 8020338.

This site was historically a landfill that has since been converted to a park used for cultural and recreational use, including sports fields, park benches, trails etc.

The phragmites here forms a single stand in a semi-wet area that includes some mature trees, partway up a steep, western facing hillside. Water from the road drained into the site, making it much wetter after rain events. The trees are mostly in the center of the phragmites stand, and due to the trees forming a rough boundary through the stand and the management history of dividing the stand into 2 areas, the northern part of the phragmites stand is called the North Patch and the southern part (south of the trees) is called the South Patch. It is important to note that the North Patch and South Patch are likely a single phragmites patch, with other species (trees and smaller plants) mixed throughout. The North Patch includes dead and dying ash trees (emerald ash borer). Surrounding the entire patch is mown grass and sparse, mature trees, such as willow.

This area of Riverdale Park East has intermittent puddling throughout the hillside, including the study site, because it was previously a landfill and the engineered covering material shifted during grading. The area was noticeably dryer in the 2019 season compared to 2018. The North and South Patch is the only area of Riverdale Park East with phragmites historically or currently. North of the patch is a constructed wetland, which is the typical stewardship site for CSP volunteers. So far no phragmites has been found growing there.



Boundaries of the entire Riverdale Park East phragmites stand, with the study area shaded in orange.

Lynn Short demonstrates the spading technique to CSP volunteers.

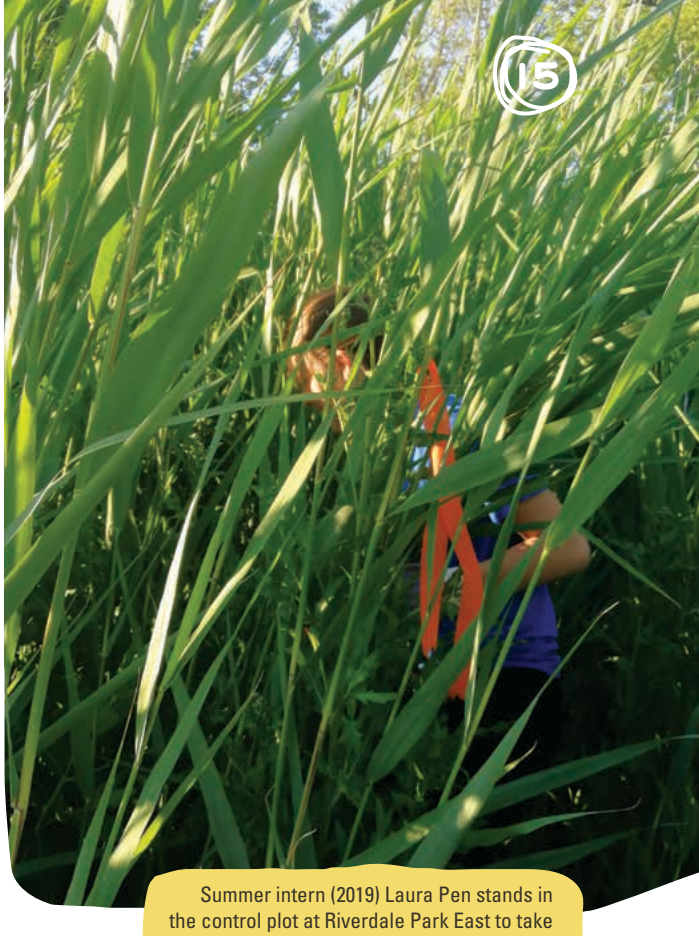
Management History

In June 2017 phragmites was removed from the patch that would become the study site (shaded in orange) by brush cutting and removing the debris. CSP volunteers used the 2015 - 2017 Phragmites Protocol on the cut stems and new growth between June and September, and once in November. Park staff collected the bagged waste after each event.

In the summer of 2018, the north side of the study site (un-shaded portion) was brush cut by city staff. Planting occurred in the study area (shaded) in the spring of 2018. Plants used included pasture rose, meadow sweet (prefers wet soil so was chosen for this site), elderberry, nannyberry, willow trees, and ninebark (all of the ninebark died off). In September 2018 a total of 214 native shrubs were planted. The study area was spaded in June and July once a week for three weeks, then bi-weekly until the end of August. In August the study area measured 17.8-meters along its southern edge (east to west) by 14.1-meters along its western edge (north to south). The following year, on June 26, 2019, approximately 1/4 of the south patch was spaded, starting from the eastern edge of the patch and moving west.

RIVERDALE PARK EAST RESULTS: PHRAGMITES SPADING PROTOCOL

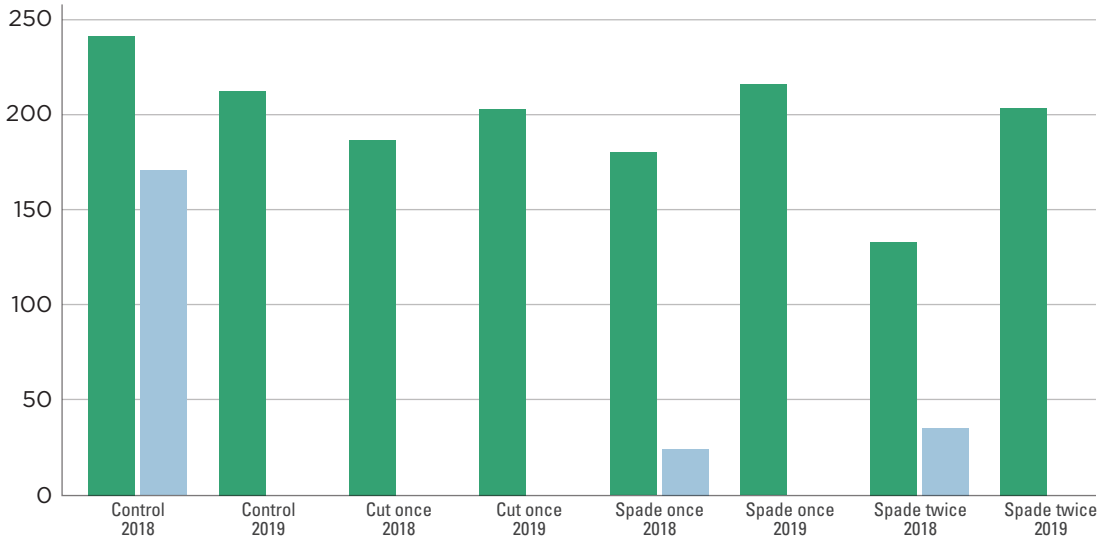
Despite a miscommunication resulting in the study area being brush cut before the second round of data collection and treatment was able to be performed in 2019, the results here are consistent with Short's work, albeit to a lower degree. This stand had significant phragmites growth surrounding the transects, which could influence the growth of phragmites within transects through the recruitment of resources from surrounding rhizomes. Overall, however, transects that were spaded twice had a lower density, smaller diameter and shorter height compared to the other transects. Further - overall flowering across the stand was reduced, particularly in the areas of transects 2, 3 and 4, and on the eastern portion of the stand. In August 2018 the control plot had approximately 40% flowering, while the "cut once" plot had about 50% flowering. In 2019 there were only a handful of stalks flowering within the treatment transects. However, stalks that were outside the transects on the western side of the study area were about 75 - 80% in flower in August 2019. Although anecdotal, volunteers noticed an east-west gradient in stalk height, flowering, and stalk density. This could have been because spading started from the eastern side of the stand and moved west. Because the second round of data treatment was not able to be completed in 2019, the chart below only shows the results for stalk density before the 1st treatment. Although you will see that the results here are less significant than other sites, it still shows that spading twice was the most effective, and that moving from nothing, to cutting, to spading once, to spading twice, produces increasingly favourable results.



Summer intern (2019) Laura Pen stands in the control plot at Riverdale Park East to take measurements.

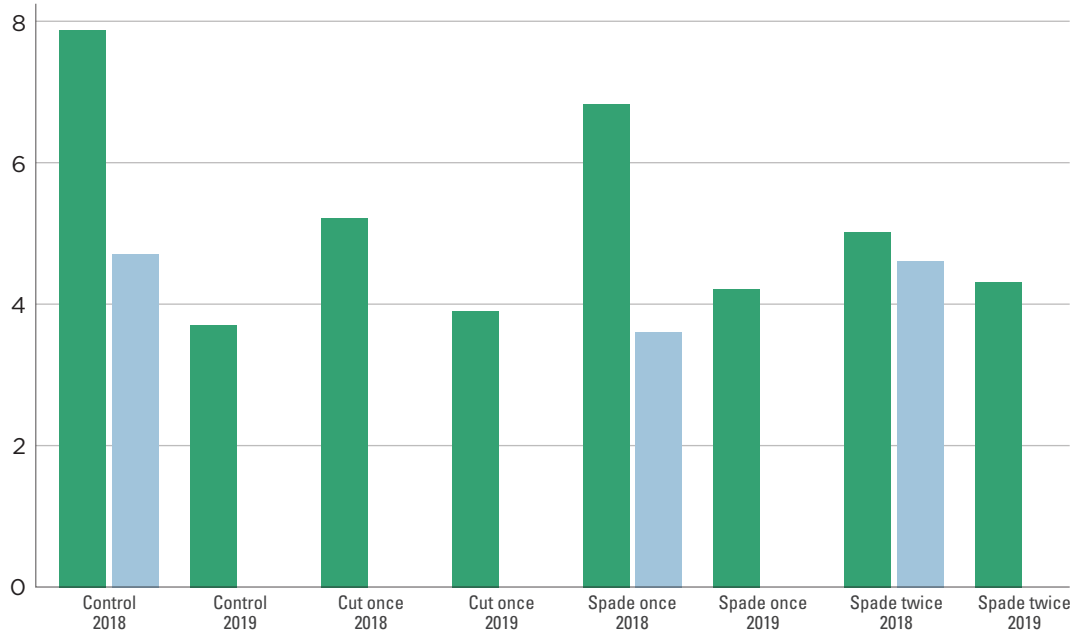
AVERAGE STALK DENSITY				
Control 2018	**Control 2019**	**Difference**	**% Difference**	
46	83.3	37.3	**81.09%**	Before 1st Treatment
Cut once 2018	**Cut once 2019**	**Difference**	**% Difference**	
45	67.3	22.3	**49.56%**	Before 1st Treatment
Spade once 2018	**Spade once 2019**	**Difference**	**% Difference**	
45	59	14	**31.11%**	Before 1st Treatment
Spade twice 2018	**Spade twice 2019**	**Difference**	**% Difference**	
74	48	-26	**-35.14%**	Before 1st Treatment

AVERAGE STALK HEIGHT: 2018 AND 2019



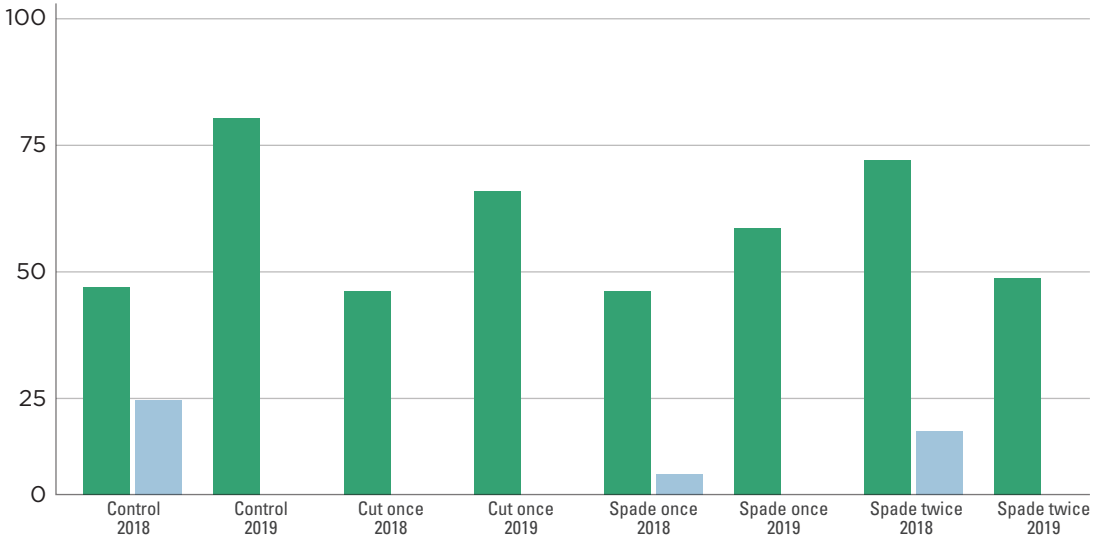
Graph showing the average phragmites stalk height measured in centimeters over the course of the 2018 and 2019 seasons. Note that since the City had mistakenly brush cut our study site, we were not able to collect data for 2019 "Before 2nd Tx". In 2018 there was no growth in "Cut once" for the second round of measurements.

AVERAGE STALK DIAMETER: 2018 AND 2019



Graph showing the average stalk diameter measured in millimeters over the course of the 2018 and 2019 seasons. Note that since the City had mistakenly brush cut our study site, we were not able to collect data for 2019 "Before 2nd Tx". In 2018 there was no growth in "Cut once" for the second round of measurements.

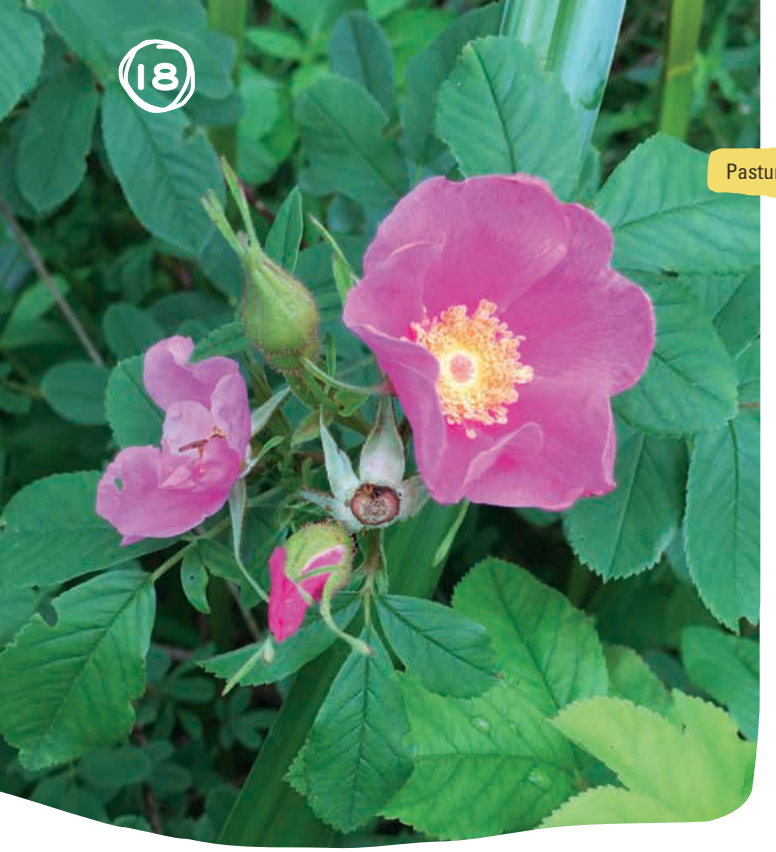
AVERAGE STALK DENSITY: 2018 AND 2019



Graph showing the average stalk density over the course of the 2018 and 2019 seasons. Note that since the City had mistakenly brush cut our study site, we were not able to collect data for 2019 "Before 2nd Tx". In 2018 there was no growth in "Cut once" for the second round of measurements.

RIVERDALE PARK EAST RESULTS: BIODIVERSITY

TRANSECT	AUGUST 22 2018	OCTOBER 3 2018	JUNE 26 2019
1	Dogbane - 13 Canada thistle - 5 Cocklebur - 17	Canada thistle - 23 Dogbane - 6 Garlic mustard - 5 Queen Anne's Lace - 6	Canada thistle - 29 Garlic mustard - 75 Indian hemp - 18 Queen Anne's lace - 13
2	Only phragmites present	Only phragmites present	Canada thistle - 58 Garlic mustard -250 Cocklebur - 11 Indian hemp - 8
3	Cocklebur - 62 Pasture rose - 1 Garlic mustard - 10 Manitoba maple - 1 Spiny plumeless thistle - 1	Garlic mustard - 6 Canada thistle - 5 Dandelion - 1 Dogbane - 3 Manitoba maple - 1 Cocklebur - 14 Pasture rose - 4 Canada thistle - 16 Turf grass - 10% coverage	Swamp rose - 3 Dandelion - 14 Plantain - 3 Cocklebur - 36 Indian hemp - 4 Canada thistle - 21 Canada goldenrod - 3 Bluegrass sp. - 40% coverage
4	Only phragmites present	Only phragmites present	Swamp rose - 9 Dandelion - 12 Indian hemp - 3 Cocklebur - 21 Canada thistle - 13 Silver maple - 2 Bluegrass sp. - 75% coverage



Pasture Rose

Biodiversity showed a marked increase over the course of the study period for this site. Overall biodiversity increased, along with abundance. Some of the plants seen, such as pasture rose, were planted. Many of the others were naturally recruited from either an existing seed bed, or through seed dispersal from elsewhere. Thatch depth here was approximately 6 centimeters mid-summer 2018. This is thick enough to prevent growth of other plants, giving phragmites an even bigger edge to colonize the area. Removing thatch throughout the 2018 and 2019 seasons, while also removing live stalks, and planting native vegetation, is an effective way to bring floral biodiversity back to an area, which is reflected in our results.

RIVERDALE PARK EAST RESULTS: CITIZEN SCIENCE STEWARDSHIP METRICS

DATE	NUMBER OF VOLUNTEERS AND STAFF	AMOUNT REMOVED IN 2 HOURS	AMOUNT REMOVED PER PERSON
August 22 2018	10	Unknown	Unknown
October 3 2018	11	Unknown	Unknown
June 26 2019	11	9 bags (90 lbs)	8.1 lbs
August 21 2019	6	12 bags (120 lbs)	20 lbs

Unfortunately there is no record of the total amount that was removed from the site in 2018. For the August 21 spading event most of the removed debris was thatch from the brush cutting the previous week, but several of those bags were filled entirely with freshly spaded stalks.

A total of 21 contractor bags of phragmites were removed during the 2019 season at Riverdale Park East.

BEECHWOOD WETLAND

Birds-eye-view of the site, with the entire patch, including the transects, highlighted.

Site Details

Beechwood Wetland is located at 44 Beechwood Drive, Toronto, Ontario. The coordinates of the study site are: 43.69424, -79.35691. The EDDMapS Record ID is 8020342. This study site features a large stand (3080 square meters) of phragmites in a predominantly wet area. There is a slight slope, resulting in wet ground at the northern end, moving into actual standing water at the southern end of the study site. During periods of heavy rain, most of the site can become flooded, sometimes up to 30 centimeters deep. The area is surrounded by predominantly deciduous forest, and cattails. As the study progressed, the southern end of the study site became even more flooded, to the point of small fish and frogs being observed in Transects 3 and 4 during the last day of data collection and treatment in the 2019 season.

Unlike other sites, removed plant matter was left in place because the wetness of the site allowed for quick decomposition. Debris was removed once spading progressed further into the northern part of the study site, where the ground became increasingly dry.

Boundaries of the stewardship site at Beechwood Wetland, with the study area and previous management areas shaded in orange.

Summer intern (2019) Laura Pen carefully records measurements taken in transect 3 of Beechwood Wetland.

Management History

This site was previously managed between 2015 and 2017 using the *2000 - 2015 Phragmites Protocol.* Starting in 2018, when EcoSpark and the CSP partnered together, the spading protocol was used. Working from the centre of the study area and moving outwards, phragmites was being removed at roughly the same rate in all directions. Native planting was also carried out within the study area but not near the transects. This included spreading seeds of cattails and cup plant *(Silphium perfoliatum).*

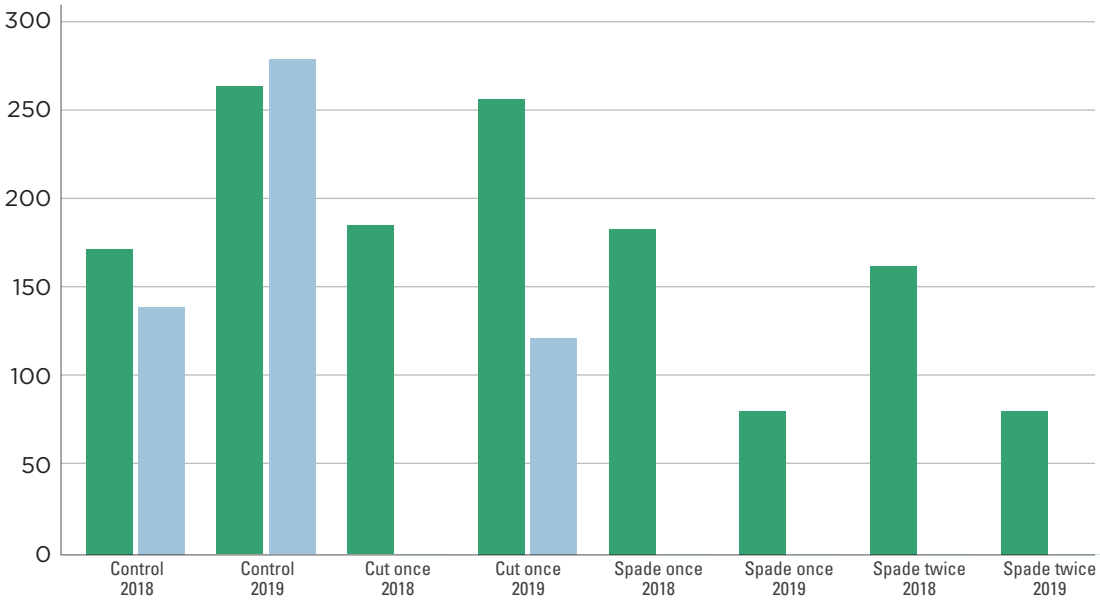
BEECHWOOD WETLAND RESULTS: PHRAGMITES SPADING PROTOCOL

Visually, this site was the most drastically changed over the 2018 - 2019 period - there were more volunteers per session at this site, typically, and the area was quite wet, especially in the southern portion. This helped to drown the phragmites and slow its regrowth, or prevent regrowth all together. In August 2018 about 60% of stalks were flowering in the control and “cut once” transects, and about 20% of stalks were flowering in the spaded plots. By October of 2018 about 40% of stalks in the control were flowering, but none had gone to seed. The stalks in the other transects had no flowers or seeds. The control and “cut-once” plots were the only ones that flowered in 2019. Approximately 70% of stalks in the control were flowering in August, and about 50% were flowering in the “cut-once” plot. Because transects 3 and 4 were mostly drowned, the very few stalks that were produced in those areas did not produce any flowers, and rarely reached taller than waist height. The percent difference for average stalk density (the most important metric for judging management efficacy), shows that spading is the most effective.

A view of transects 1 and 2 surrounded by a large spaded area, and more phragmites in the background, at Beechwood Wetland.

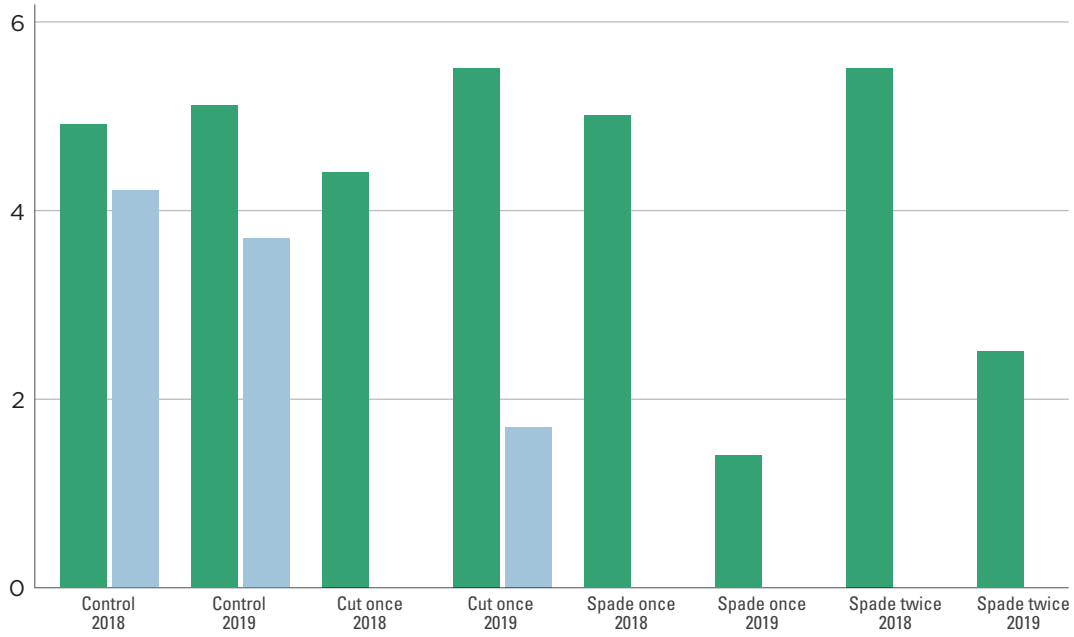
AVERAGE STALK DENSITY				
Control 2018	**Control 2019**	**Difference**	**% Difference**	
37.6	95	57.4	**152.66%**	Before 1st Treatment
37	57	20	**54.05%**	Before 2nd Treatment
Cut once 2018	**Cut once 2019**	**Difference**	**% Difference**	
49.3	88	38.7	**78.50%**	Before 1st Treatment
0	55.6	55.6	**5560.00%**	Before 2nd Treatment
Spade once 2018	**Spade once 2019**	**Difference**	**% Difference**	
72	9.6	-62.4	**-86.67%**	Before 1st Treatment
0	0	0	**0.00%**	Before 2nd Treatment
Spade twice 2018	**Spade twice 2019**	**Difference**	**% Difference**	
48	18	30	**62.50%**	Before 1st Treatment
0	0	0	**0.00%**	Before 2nd Treatment

AVERAGE STALK HEIGHT: 2018 AND 2019



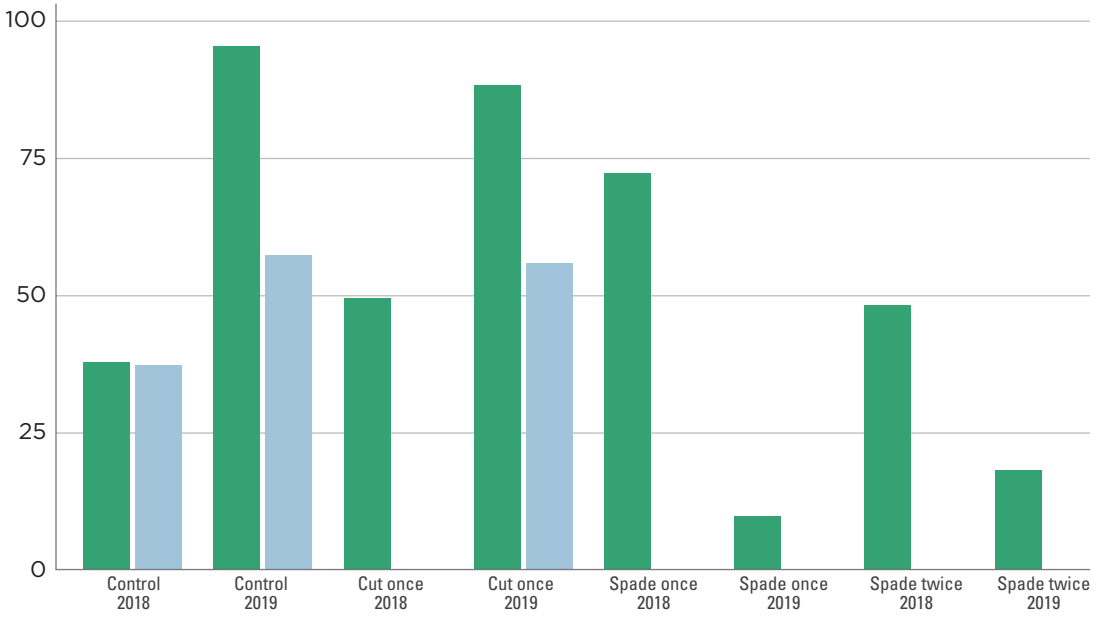
Graph showing average stalk height in centimeters over the 2018 and 2019 seasons. Note the sections where there is no blue bar - the phragmites in these transects had been drowned (there was standing water at the site)

AVERAGE STALK DIAMETER: 2018 AND 2019



Graph showing average stalk diameter in millimeters over the 2018 and 2019 seasons. Note the sections where there is no blue bar - the phragmites in these transects had been drowned (there was standing water at the site)

AVERAGE STALK DENSITY: 2018 AND 2019



Graph showing average stalk density over the 2018 and 2019 seasons. Note the sections with no blue - the phragmites in these transects had been drowned (there was standing water at the site

Cattails and other native grasses started to dominate the study site. The southern end of the study site was completely flooded by the end of the 2019 season.

BEECHWOOD WETLAND RESULTS: BIODIVERSITY

Within our study area (but outside of the transects), we saw a marked increase in the amount of cattails growing, as well as various smartweed species, purple loosestrife, stinging nettle, Atriplex species, and slender rush. Within the transects themselves, however, there seemed to be less overall growth, compared to what we had seen at the other study sites. Throughout the entire study (2018 and 2019), toadlets and froglets were seen in both the flooded and non-flooded areas. In July 2019 there was a red-winged blackbird nest built in the phragmites with small hatchlings inside. The phragmites in that area was left so as not to disturb the birds. The nest was empty by the time the second spading was held in August. In the 2018 and 2019 seasons deer and raccoon tracks were noted. In August 2019, when transects 3 and 4 had duckweed coverage, we also noted very small silvery fish and leopard frogs in the water.

TRANSECT	AUGUST 27 2018	OCTOBER 20 2018	JULY 6 2019	AUGUST 20 2019
1	Sedge sp. - 1 Purple loosestrife - 1 Plantain - 1	Only phragmites present	Smartweed - 7 Slender rush - 1 Atriplex sp. - 1 Stinging nettle - 1 Plantain - 1	Plantain - 1 Slender rush - 5 Cattail - 1 Smartweed - 4
2	Only phragmites present	Only phragmites present	Atriplex sp. - 4 Smartweed - 2	Smartweed - 3 Cattail - 1
3	1 species 1 individuals	Only phragmites present	FLOODED	FLOODED Duckweed (<5% coverage)
4	0 species 0 individuals	Only phragmites present	FLOODED	FLOODED Duckweed (<5% coverage)

Deer tracks in the mud just outside of transect 2 at Beechwood Wetland.

A buttonbush doing well at the entrance of the spading area.

BEECHWOOD WETLAND RESULTS: CITIZEN SCIENCE STEWARDSHIP METRICS

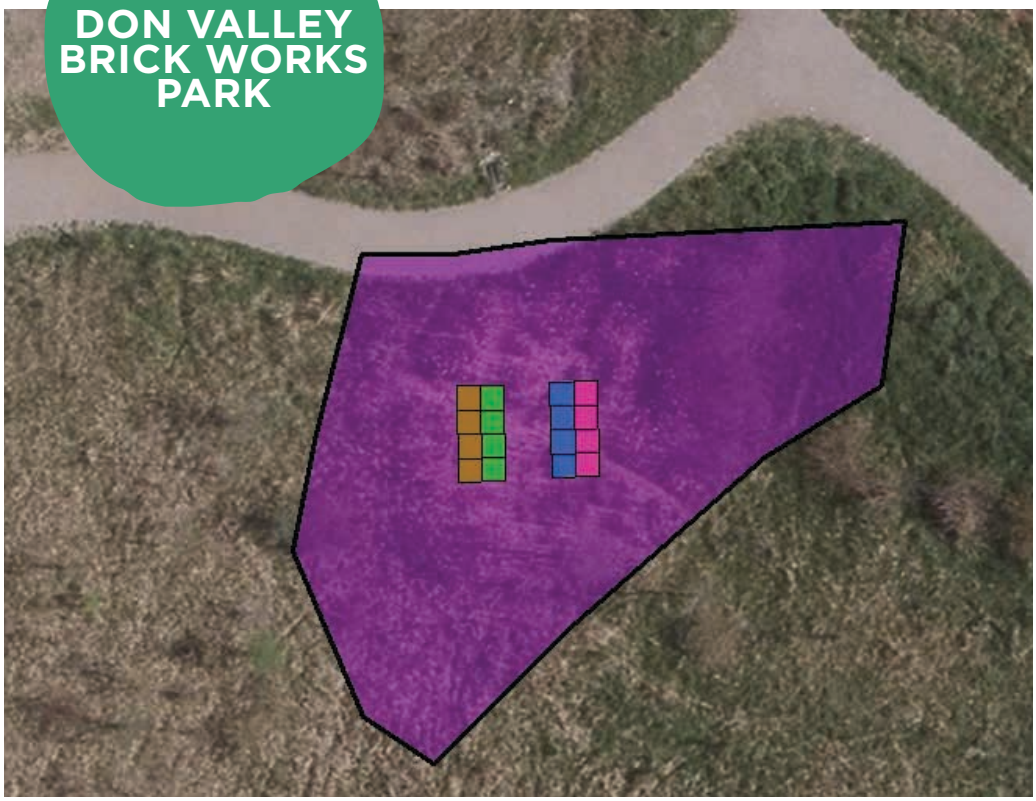
DATE	NUMBER OF VOLUNTEERS AND STAFF	AMOUNT REMOVED IN 2 HOURS	AMOUNT REMOVED PER PERSON
August 27 2018	4	(7.5 bags) 75 lbs	18.75 lbs
October 20 2018	31	429 lbs (weighed truck)	13.8 lbs
July 6 2019	12	(13 bags) 130 lbs	10.8 lbs
CSP public stewardship day July 27 2019	4	(8 bags) 80 lbs	20 lbs
August 20 2019	27	(30 bags) 300 lbs	11.1 lbs

This was the most efficient site for two major reasons. One being that this site usually had more volunteers per event. Also, the removed vegetation was left in place to rot, as opposed to bagging, which can take a considerable amount of time. The hard work of the Beechwood CSP volunteers has completely transformed the way the study area looked from when management first started. Cattails are starting to become the dominant aquatic vegetation, and wildlife like frogs, toads, and fish are starting to use the area more, as it becomes wetter. We also observed an eastern phoebe (a type of flycatcher) hunting for insects in the area in 2019.

Transects 3 and 4, and surrounding area, in August 2019.

Transects 3 and 4, and surrounding area, in August 2018.

DON VALLEY BRICK WORKS PARK



The initial site map is pictured to the left. Due to time constraints, a detailed map of the new study area was not created, however, the general area can be seen in the site management history section below, where the 2018 glyphosate treatment is indicated.

Site Details

Initially, the GPS coordinates for this site were: 43.688773, -79.366351. The EDDMapS record ID for that site is 8020337. The site was located at the northernmost point of the park. The stand that made up the total study area was approximately 575 square meters (note: in EDDMapS the stand size is indicated as being approximately 250 square meters, in reality, the area is larger).

Multiple stalks emerging out of a single shoot in the 2nd study area at Brick Works.

The initial Don Valley Brick Works Park study site that was used in 2018 had to be abandoned in the 2019 season for two major reasons. A large amount of thistle and stinging nettle was present in our transects, making it very difficult to navigate through the stand and to take measurements. The second reason is due to the size of the stand surrounding the transects. Because there were only a small handful of volunteers at this site, the rate of spading was not enough to counter the rate of energy recruitment from the photosynthesis and energy storage of surrounding plants.

We moved to a nearby location that had been cut and sprayed with glyphosate in the summer of 2018. There was a significant amount of thatch in the area, which was removed during a CSP public stewardship event (with over 30 volunteers), along with spading of phragmites outside of the transect area. The GPS coordinates for this site are: 43.688444, -79.365775. The total study area (the total area that was cut and sprayed last year) is approximately 75 square meters. East of that area there is a patch of untouched phragmites that is quite tall and dense.

The 2019 study site had many small stalks of phragmites emerging through the thatch, but were quite sparse. Most shoots also had many stalks coming out, as opposed to only one (see photo). Lynn Short proposed a possible explanation. The herbicide that was used - glyphosate - acts on the plant by preventing it from making the proteins it needs to grow, so it does not seem likely the herbicide caused a mutation in the plant. Rather, it is possible that the live shoots that remained had such little competition with other stalks, they were able to produce many stems per shoot.

Management History

Phragmites management throughout the Don Valley Brick Works Park has been quite varied over the years. Phragmites is extremely dominant there, so manual spading is not feasible throughout the park. Phragmites is mostly found surrounding the ponds, and is also found on the eastern end of the park, especially as you move north. This could be because of the very steep hills at these edges of the park, which lack large trees to buffer water flowing downward, creating wetter conditions compared to other areas of the park. The north pond was managed between 2013 and 2017 following the earlier protocol, (i.e. cutting off seed heads, and above ground management). The more southern ponds were managed using Lynn Short's spading method. The most recent management strategy was employed by City Staff in the north eastern section of the park, which comprised our study area in the summer of 2018. The City flattened the stalks, and then applied herbicide to the area. Visually, this appeared to be quite effective. When looking at the area in the summer of 2019, the stalks were quite short and sparse. Many of the stalks that did come up also had many shoots, indicating that there was significant die off, allowing the survivors to use up more energy and resources (see photo, below). In July 2019, Public Stewardship volunteers (approximately 30 attendees) worked hard to spade the area surrounding this management area, and to remove thatch. This was important as it allowed for better regeneration of native and naturalized vegetation in the area.

Multiple stalks emerging out of a single shoot in the 2nd study area at Brick Works.

BRICK WORKS RESULTS: PHRAGMITES SPADING PROTOCOL

It is difficult to draw accurate conclusions from the Brick Works site because of the need to switch study areas halfway through. The second area we used as a study site also has a markedly different management history from other sites, in that it was very recently (summer 2018) flattened using plywood and sprayed with herbicide. With that in mind, in the first study area, it does appear as though spading may have allowed for further growth of stinging nettle and Canada thistle. In the second study area, initial results appear to indicate that spading twice was the most effective in preventing phragmites re-growth. Another season of data collection and treatment would be needed, however, to draw more concrete conclusions.

BRICK WORKS RESULTS: BIODIVERSITY

TRANSECT	AUGUST 27 2018	JULY 22 2019	JULY 26 2019*	SEPTEMBER 16 2019*
1	Only phragmites present	Stinging nettle 50% coverage	Slender rush - 1 Purple loosestrife - 2	Slender rush - 2 Dandelion - 2 Purple loosestrife - 1 Willowherb - 3 American aster - 4
2	Only phragmites present	Canada goldenrod - 1 Stinging nettle - 40% coverage	Slender rush - 2 Purple loosestrife - 3	Willowherb - 2 Slender rush - 2 Carrot sp. - 1 Aster sp. - 8
3	Vetch sp. - 2 Stinging nettle - 50% coverage	Canada thistle - 5 Stinging nettle - 25% coverage	Slender rush - 3 Canada goldenrod - 5 Purple loosestrife - 8	American aster - 4 Slender rush - 3 Dandelion - 1 Aster sp. - 13 Purple loosestrife - 2 Willowherb - 1
4	Stinging nettle - 50% coverage	Canada goldenrod - 3 Stinging nettle - 30% coverage	Canada thistle - 1 Dandelion - 1 Purple loosestrife - 5 Canada goldenrod - 2	Evening primrose - 4 American aster - 2 Willowherb - 1 Purple loosestrife - 1 Aster sp. - 10 Colt's foot - 1

*At new study site

While biodiversity was not very high in 2018, volunteers did note that within 10 meters of the transects there were Canada goldenrod, wetland goldenrod, walnut, ash, common buckthorn, red osier dogwood, and hawthorn plants growing. At the second site we saw an increase in biodiversity and abundance just within a single growing season. Having nearly 30 volunteers assist in thatch removal and spading during the public stewardship event was very helpful in that regard.

Photo: Ian Darragh Photography

EVERGREEN BRICK WORKS RESULTS: CITIZEN SCIENCE STEWARDSHIP METRICS

DATE	NUMBER OF VOLUNTEERS AND STAFF	AMOUNT REMOVED IN 2 HOURS	AMOUNT REMOVED PER PERSON
August 27 2018	15	8.5 bags (85 lbs)	5.7 lbs
October 1 2018	16	9 bags (90 lbs)	5.6 lbs
July 22 2019*	2	1 bag (10 lbs)	5 lbs
August 20 2019 CSP Public stewardship event	33	23 bags (230 lbs)	6.9 lbs
September 16 2019*	2	0.5 bags (5 lbs)	2.5 lbs

*Because the 2019 site was decided upon at a later date, we weren't able to do the data collection and treatments such that they coincided with CSP days at Brick Works. As a result, only a small amount of phragmites was removed on these days (just the amount to complete the treatment).

CSP volunteer spade phragmites outside of the immediate study area. Queen Anne's Lace and other naturalized vegetation lined the trail in addition to the phragmites.

Photo: Ian Darragh Photography

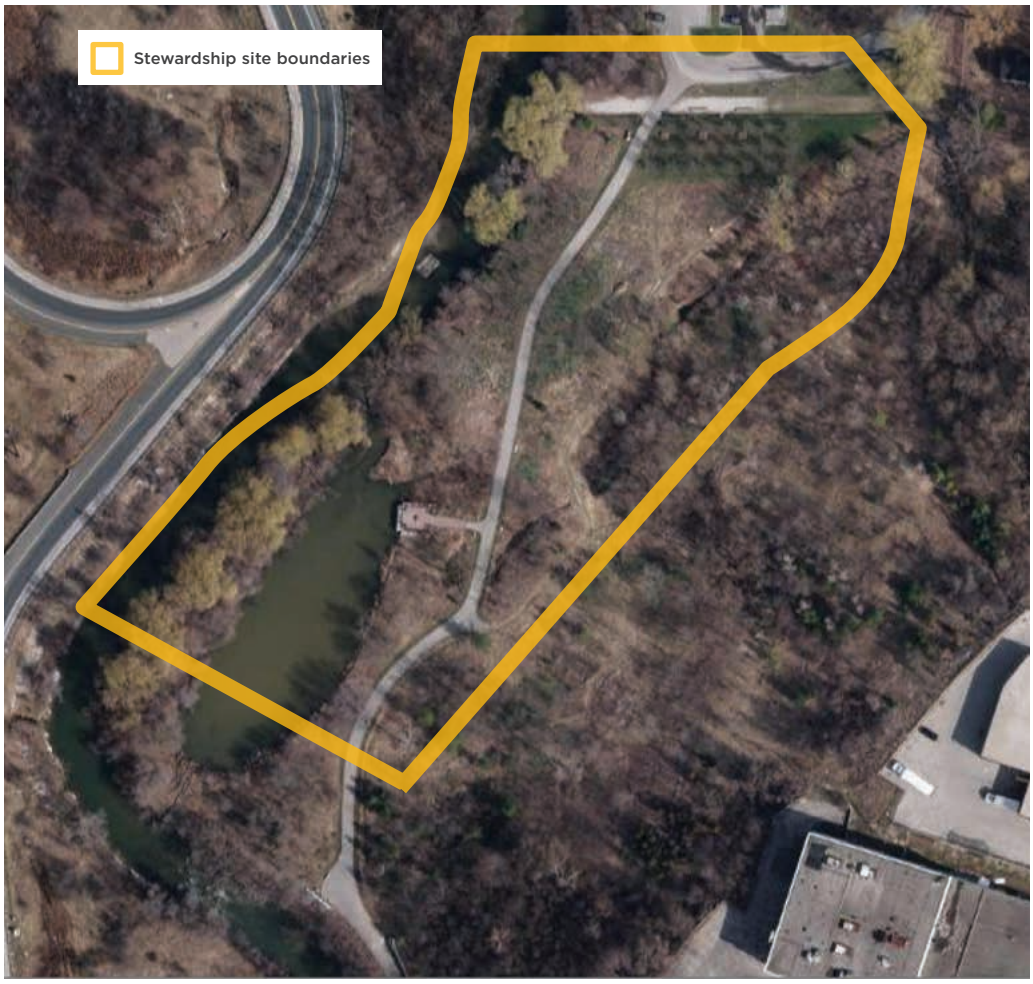
MILNE HOLLOW

Bird's-eye-view of the Milne Hollow study site.

Site Details

This site is located at Charles Sauriol Conservation Area, at 1191 Lawrence Avenue East, North York. The GPS coordinates of the study area are: 43.738317, -79.328916. The EDDMapS Record ID is 8020346. The approximate size of the stand is 252 square meters. This site differs from the other sites in that it is more shaded than the others. It is also competing with another invasive species - Dog Strangling Vine (DSV), which was often found climbing up the phragmites stalks. For the 2019 study season, we arrived on site for the first round of data collection and treatment to find the study area, including our transects had been brush cut by City staff, except for the control and "cut once" plots. We removed the thatch and plant debris to allow for better regrowth of native and naturalized vegetation. We also spaded some of the surrounding phragmites stalk, and pulled some DSV.

We were able to collect data and employ the treatments for the second date, which was September 12th. This will be treated as the "first round", given the complication from earlier in the season. Because the phragmites growing season can go into November, having a second round of data collection in mid October is still appropriate.



The Milne Hollow stewardship site boundaries.

Management History

Phragmites management in the northern patch has been very successful, with almost complete eradication of the plant over the course of a 5 year period. The volunteers also successfully planted native vegetation, and removed other invasive species, such as motherwort and DSV. The southern patch has been met with less marked success than the northern patch, as the stand there is large and extends into the water where it is difficult to access. Overall, Milne Hollow is one of the most efficient sites for invasive species management, thanks to the large number of volunteers who work with this site.

MILNE HOLLOW RESULTS: PHRAGMITES SPADING PROTOCOL

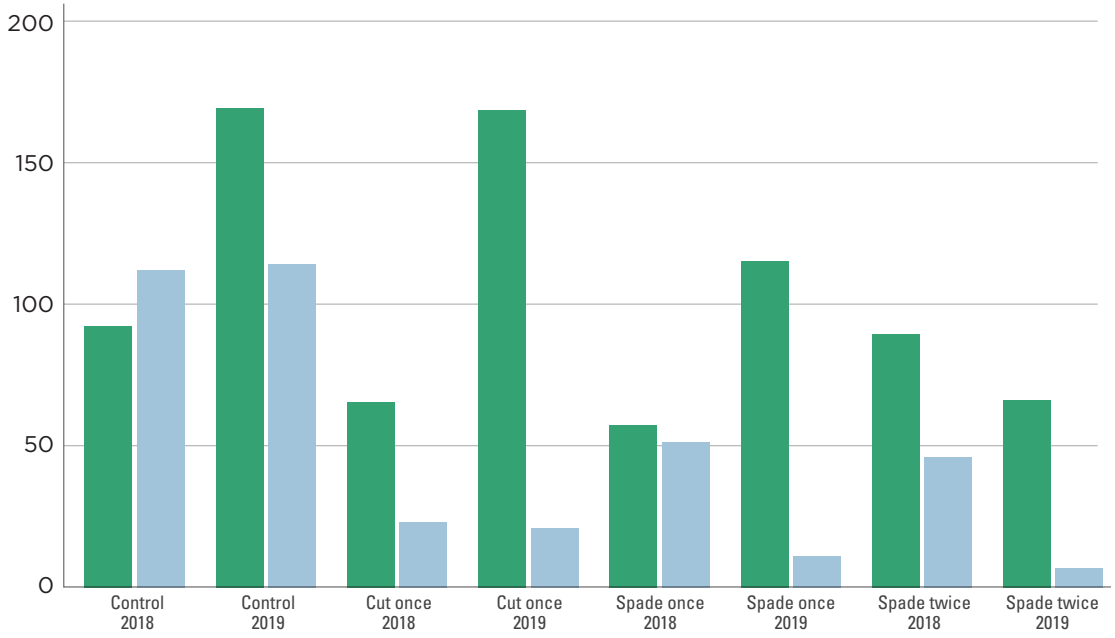
The graphs and charts below show the impacts of the spading protocol on stalk density, height, and diameter. The other metric used included the percent of stalks that were flowering and seeding. Milne hollow consistently had shorter stalk heights than the other study sites, and also flowered considerably less (in 2019 only one single stalk in the control transect had produced a flower head). This could be due to a few major factors. The first is that before EcoSpark's engagement in the area, volunteers worked hard to spade and cut the area for several years. The second being the level of overhead shading produced by the deciduous forest surrounding our study site.

The photosynthetic rate of the phragmites at the Milne Hollow site would have been considerably less than the other sites, where in most cases there was negligible overhead cover. Finally, the other possible reason was the significant presence of dog strangling vine in the area, which was often found using the phragmites stalks to climb, and could have been directly competing with the phragmites.

The chart below shows that spading, in particular spading twice, is the most effective in reducing stalk density, which is one of the most important indicators of management efficacy. Percent difference indicates difference between the 2019 count and the 2018 count, and is calculated separately for both before the first treatment, and before the second treatment.

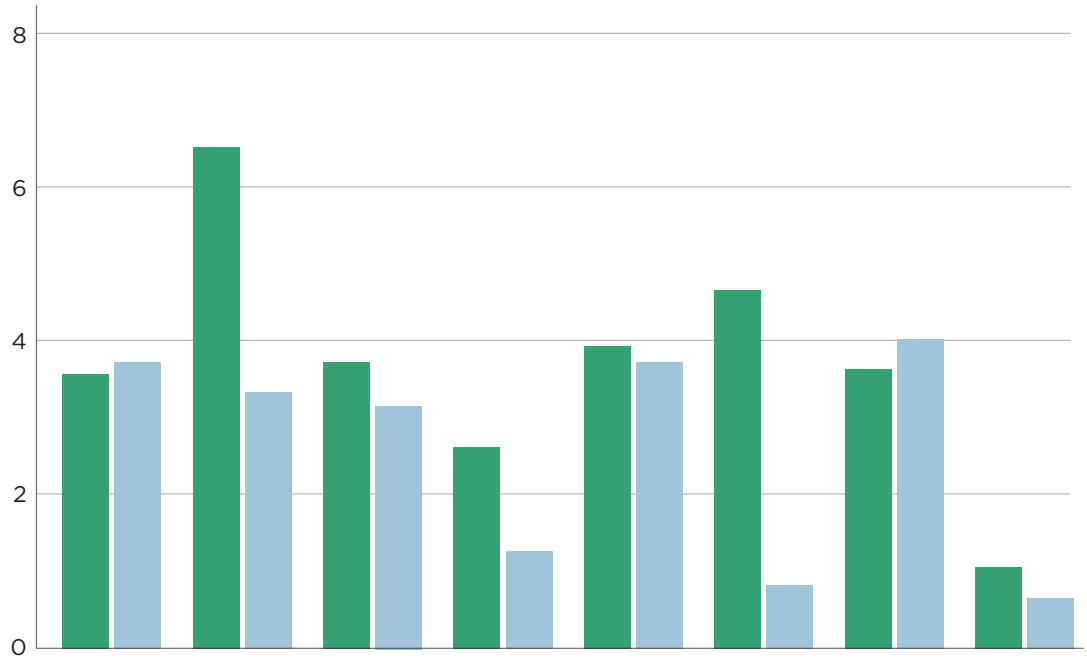
AVERAGE STALK DENSITY				
Control 2018	**Control 2019**	**Difference**	**% Difference**	
31.6	43.6	12	**37.97%**	Before 1st Treatment
32	45.3	13.3	**41.56%**	Before 2nd Treatment
Cut once 2018	**Cut once 2019**	**Difference**	**% Difference**	
6	9.3	3.3	**55.00%**	Before 1st Treatment
8.67	23	14.33	**165.28%**	Before 2nd Treatment
Spade once 2018	**Spade once 2019**	**Difference**	**% Difference**	
35.3	21.67	-13.63	**-38.61%**	Before 1st Treatment
16.6	4	-12.6	**-75.90%**	Before 2nd Treatment
Spade twice 2018	**Spade twice 2019**	**Difference**	**% Difference**	
9.67	4.5	-5.17	**-53.46%**	Before 1st Treatment
12	0.67	-11.33	**-94.42%**	Before 2nd Treatment

AVERAGE STALK HEIGHT: 2018 AND 2019



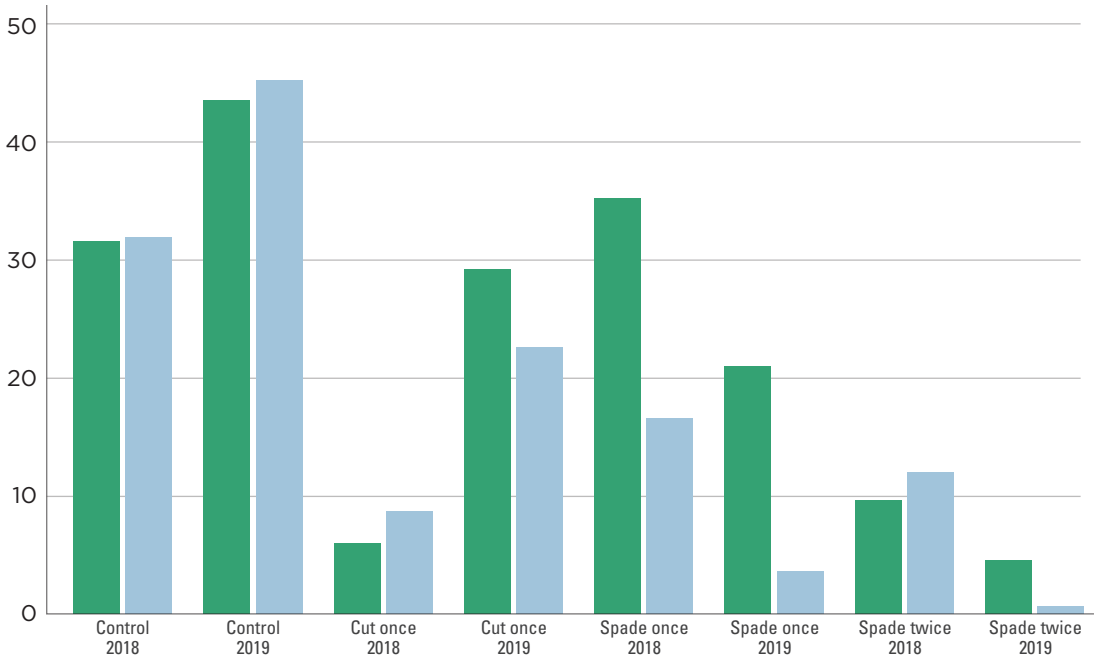
Graph representing the average stalk height in centimeters across the 2018 and 2019 seasons. Note that in 2019 transects 3 and 4 were brush cut at the beginning of the season by City staff accidentally, which means that the numbers collected from those transects could be lower than they would have been had they not been brush cut

AVERAGE STALK DIAMETER: 2018 AND 2019



Graph representing the average stalk diameter in millimeters across the 2018 and 2019 seasons. Note that in 2019 transects 3 and 4 were brush cut at the beginning of the season by City staff accidentally, which means that the numbers collected from those transects could be lower than they would have been had they not been brush cut

AVERAGE STALK DENSITY: 2018 AND 2019



Graph representing the average stalk density across the 2018 and 2019 seasons. Note that in 2019 transects 3 and 4 were brush cut at the beginning of the season by City staff accidentally, which means that the numbers collected from those transects could be lower than they would have been had they not been brush cut

Milne Hollow had one of the most impressive biodiversity rebounds, thanks to spading that took place in 2017, a year before the project officially began.

MILNE HOLLOW RESULTS: BIODIVERSITY

TRANSECT	AUGUST 23 2018	OCTOBER 25 2018	SEPTEMBER 12 2019	OCTOBER 15 2019
1	Small geranium - 3 DSV - 95 Bittersweet nightshade - 3 Garlic mustard - 72 Canada goldenrod - 6 European avens - 1 Willowherb - 6 Rosette – 1	DSV - 21 Garlic mustard - 46 Willowherb - 6 Bittersweet nightshade - 8 Canada goldenrod - 3 Small geranium - 2	Jewelweed - 1 Equisetum - 11 Virginia creeper - 2 American aster - 8 Canada thistle - 1 Bittersweet nightshade - 2 Garlic mustard - 19 Wintercress - 30	Equisetum - 11 Bittersweet nightshade - 3 Jewelweed - 2 American aster - 8 Garlic mustard - 12 Wintercress - 28 Canada thistle - 2
2	Only phragmites present	Only phragmites present	Canada goldenrod - 5 Purple loosestrife - 3 American aster - 1 Equisetum - 1 DSV - 3 Virginia creeper - 3 Wintercress - 20	Canada goldenrod - 7 DSV - 5 American aster -2 Equisetum - 1 Wintercress - 18 Purple loosestrife - 3
3	DSV - 8 Garlic mustard - 5 Canada goldenrod - 4 European avens - 1 Willowherb - 3 Equisetum - 5 Canada thistle - 4 Downy willowherb - 1 Tall goldenrod - 1 Wintercress - 3 Grass sp. - 8	Willowherb - 1 Cow thistle - 4 Grass sp. - 5% coverage Canada goldenrod - 4 Wintercress - 3	Swamp aster - 1 Canada goldenrod - 3 Bittersweet nightshade - 2 Canada thistle - 2 Virginia creeper - 1 Purple loosestrife - 6 Equisetum - 4 Wintercress - 15	Bittersweet nightshade - 3 Swamp aster - 2 Purple loosestrife - 5 Equisetum - 3 Wintercress -17 Canada goldenrod - 4 Canada thistle - 3
4	Only phragmites present	Only phragmites present	Canada goldenrod - 6 Cattail - 2 Swamp aster - 2 American aster - 2 Flat-topped goldenrod - 1 Devil's beggarticks - 1 Wintercress - 11	Cattail - 4 Canada goldenrod - 5 Devil's beggarticks - 1 Wintercress - 13 Swamp aster - 2 American aster -2

Photos showing vegetative diversity within the transects at Milne Hollow.

Two years before EcoSpark's engagement in this area, the biodiversity in the study area was virtually nil. The cutting and spading that took place leading up to our study was instrumental in opening the space up to native and naturalized vegetation. The level of success that the CSP were met with in this patch encouraged them to spread their efforts further across other sites in the Charles Sauriol Conservation Area. While the amount of biodiversity that came back to this area is impressive, it is important to note that there is significant encroachment of DSV and garlic mustard - both of which are very invasive species. In some cases, the DSV was using the phragmites to climb up. Further effort will be required to ensure that DSV does not get so established that other plants are pushed out again.

The images above show cattails, goldenrod, and other vegetation growing well amongst each other. You can see the dead, dried stalks of phragmites mixed in with the new growth. This was one of the areas where a significant amount of thatch was removed, which allowed for better regrowth. There was no planting that occurred here - the regrowth was entirely from the pre-existing seed bank.

MILNE HOLLOW RESULTS: CITIZEN SCIENCE STEWARDSHIP METRICS

DATE	NUMBER OF VOLUNTEERS AND STAFF	AMOUNT REMOVED IN 2 HOURS	AMOUNT REMOVED PER PERSON
August 23 2018	15	5.5 bags (55 lbs)	3.7 lbs
October 25 2018	6	4 bags (40 lbs)	6.7 lbs
July 11 2019	8	5 bags (50 lbs)	6.25 lbs
September 12 2019	1	0.5 bags (5 lbs)	5 lbs

It is important to note that the volunteers at Milne Hollow were often very involved with planting, pruning, and removing other invasive species besides phragmites. The amount removed per person at this site is slightly less than the other sites, but it is because volunteer attention was drawn to these other endeavours, which are also helpful with respect to stewarding the conservation area. Finally, it bears repeating that the volunteers worked very hard in the area that would become the study area. While there is no record of it and we can't be sure, the amount of phragmites plant material they would have removed from the area was likely comparable to the other sites.

Conclusions

This study built on previous work carried out by Lynn Short, a professor of horticulture at Humber College. It was also building on the work that the CSP volunteers were already carrying out - which is to say that they were already spading, cutting, and otherwise managing phragmites in sites across Toronto. Our aim was to quantitatively see whether or not citizen science volunteers could efficiently manage invasive species on public land. We already knew from Short's work that spading was effective, but it was still important to track those metrics to demonstrate that it works in a variety of conditions, and when employed by volunteers.

Through the surveys, we learned that approximately 1/2 of volunteers had not heard of phragmites, or did not realize its impact to the natural environment, 100% of volunteers thought that the work was effective, and 80% of respondents indicated that this was not the first time they had participated in volunteer stewardship or environmental management. Most respondents said they felt more empowered to take on this kind of work, seeing that they can have an impact.

Our results confirm the efficacy of spading, regardless of location. In all cases, there was a negative percent difference in the spade twice plots across both years, indicating that that was the most effective method of eradication. If the percent difference was not negative, all sites still showed that spading still produced more favourable results than cutting, or doing nothing (control).

Our citizen science metrics show that volunteers can be very efficient over a 2 hour period in removing phragmites. On average, across all sites, a single volunteer is able to remove almost 10 pounds of phragmites over a 2 hour period. If more volunteers could be recruited to targeted areas on a weekly basis over the course of the growing season, this could have a tremendous impact on managing phragmites in the city of Toronto.

There are limitations to what volunteers can do with respect to the size and location of a stand of phragmites. This is simply because a small amount of spading on a large stand won't have an appreciable impact on the resources stored in the plant's rhizomes. Volunteers are also limited by accessibility and safety when the phragmites is growing in deep water. One CSP volunteer designed an innovative tool - The Phang (pictured left) - that works around these limitations. This tool is effective in removing underwater stems, and is used extensively by some volunteers at the Milne Hollow and Beechwood Wetland sites, especially as water levels started to increase.

A photo of "The Phang", a special tool creatd by a CSP volunteer to remove phragmites in flooded areas.

Robert holding the phang

With these caveats in mind, a task force of at least 10 to 12 trained volunteers can effectively manage an emerging stand of phragmites that is 3000 square meters or less, which was the size of the largest study site (Beechwood Wetland). An emerging stand of phragmites is one that is not very dense, and that has no to very little thatch build up. There will also be very few, if any, dead stalks from previous years throughout the stand. More established stalks will be very dense and difficult to walk through, have dead stalks from previous years, and will have a thick layer of thatch

An alternative for very large stands is to directly incorporate volunteer manual spading into an integrated pest management approach taken by the municipality. Brush cutting could be employed in the centre of a stand, where biodiversity is lower, to prevent the development of seed heads and to slow photosynthesis. In the meantime, manual spading can be used around the perimeter, where native and naturalized vegetation is still growing amongst phragmites. Once the stand has been reduced to a more manageable size, manual spading can be carried out to finish off eradication, and for continued spot management.

Our spading results, citizen science metrics, and volunteer evaluations all work together to show that volunteers can effectively manage invasive phragmites using the low-cost spading technique. Thank you to the Ontario Trillium Foundation, the City of Toronto's Community Stewardship Program, and Lynn Short of the Humber Arboretum for working with EcoSpark to make this project a resounding success.

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Appendix A

2019 TREATMENT AND DATA COLLECTION SCHEDULE

LOCATION	TREATMENT AND DATE	DATA COLLECTION	NOTES
Riverdale Day 1	Control - N/A	June 26	The pin flags for the transects had been interfered with between the site visit and the first day of data collection and treatment, as a result, more time was spent organizing the placement of the pin flags. This meant that we were not able to collect the data before the end of the CSP session, and had to schedule a time the following week for the actual treatment.
	Cut once - July 5	June 26	
	Spade once - July 5	June 26	
	Spade twice - July 5	June 26	
Riverdale Day 2	Control - N/A	N/A	Upon arrival for the second round of data collection and treatment, we found that the entire study area, including our transects, had been brush cut - likely approximately 1 week prior. It was not possible to collect data as a result. Thatch was removed and bagged, totalling 12 full, extra large contractor bags.
	Cut once - N/A	N/A	
	Spade once - N/A	N/A	
	Spade twice - N/A	N/A	
Beechwood Day 1	Control - N/A	July 9	
	Cut once - July 9	July 9	
	Spade once - July 9	July 9	
	Spade twice - July 9	July 9	
Beechwood Day 2	Control - N/A	August 20	
	Cut once - N/A	August 20	
	Spade once - N/A	August 20	
	Spade twice - August 20	August 20	
Milne Hollow Day 1	Control - N/A	September 12	When we arrived on site we found that our study area, including our transects, had been brush cut accidentally. There was no data to collect. We removed the thatch, which amounted to one extra large contractor bag (full).
	Cut once - September 12	September 12	
	Spade once - September 12	September 12	
	Spade twice - September 12	Septembet 12	
Milne Hollow Day 2	Control - N/A	October 15	
	Cut once - N/A	October 15	
	Spade once - N/A	October 15	
	Spade twice - October 15	October 15	
Brick Works Day 1	Control - N/A	July 26	Initial date was July 22. After discussion with Lynn Short, we decided to abandon this site and move to a different location. One issue was that the stand extended so far beyond our study area that there was not enough volunteer power to manually remove the phragmites at a rate that would impact the overall growth of the stand (i.e. there was too much energy recruitment from the stalks and rhizomes of the surrounding stand). The other issue was that since last year there had been a significant increase in the amount of Canada thistle and stinging nettle, posing a safety risk for staff and volunteers.
	Cut once - July 29	July 26	
	Spade once - July 29	July 26	
	Spade twice - July 29	July 26	
Brick Works Day 2	Control - N/A	September 18	
	Cut once - N/A	September 18	
	Spade once - N/A	September 18	
	Spade twice - September 20	September 18	

2018 TREATMENT AND DATA COLLECTION SCHEDULE

LOCATION	TREATMENT AND DATE	DATA COLLECTION	NOTES
Riverdale Day 1	Control - N/A	August 22	
	Cut once - August 22	August 22	
	Spade once - August 22	August 22	
	Spade twice - August 22	August 22	
Riverdale Day 2	Control - N/A	October 3	
	Cut once - N/A	October 3	
	Spade once - N/A	October 3	
	Spade twice - October 3	October 3	
Beechwood Day 1	Control - N/A	August 27	
	Cut once - August 27	August 27	
	Spade once - August 27	August 27	
	Spade twice - August 27	August 27	
Beechwood Day 2	Control - N/A	October 1	
	Cut once - N/A	October 1	
	Spade once - N/A	October 1	
	Spade twice - October 1	October 1	
Milne Hollow Day 1	Control - N/A	August 23	
	Cut once - August 23	August 23	
	Spade once - August 23	August 23	
	Spade twice - August 23	August 23	
Milne Hollow Day 2	Control - N/A	October 25	
	Cut once - N/A	October 25	
	Spade once - N/A	October 25	
	Spade twice - October 25	October 25	
Brick Works Day 1	Control - N/A	August 27	Due to time constraints, transect 2 was not cut during the first round of data collection and treatment. It was cut October 1st, which was the same day as the second round of data collection and treatment. Data collection was incomplete across transects 3 and 4 due to time constraints as well. However, treatment was applied.
	Cut once - N/A	August 27	
	Spade once - August 27	August 27	
	Spade twice - August 27	August 27	
Brick Works Day 2	Control - N/A	October 1	
	Cut once - October 1	October 1	
	Spade once - N/A	October 1	
	Spade twice - October 1	October 1	

EcoSpark is an environmental charity whose mission is to empower communities to take an active role in protecting and sustaining their local environment. We do this by giving people the tools for education, monitoring and influencing positive change. Since 1996, EcoSpark has connected people to their local environment through education, monitoring and stewardship. We have a strong reputation in the areas of community engagement, education, citizen science, facilitation and collaboration. To date, we have directly worked with over 80,000 people from across Southern Ontario in over 20 watersheds.Our long term goal is to spark life-long environmental action in our volunteers and participants through our local, outdoor, experiential programs that inspire people to learn and to take action to benefit their local environment.

This report was developed as part of a partnership between the City of Toronto, Humber College (Lynn Short), and EcoSpark. This report explores the importance of citizen science, the value of volunteer work for environmental stewardship, and the results of a study that assessed how effectively Community Stewardship Program volunteers could remove the invasive reed: Phragmites australis subspecies australis. The goal of this report is to help the City of Toronto and other municipalities make informed decisions about the use of volunteers for environmental stewardship. For more information, visit **www.ecospark.ca/phragmites-report.**