Terrestrial Invasive Plant Management

ESPM 4041W-Problem Solving for Environmental Change

University of Minnesota-
College of Food,
Agricultural and Natural
Resource Sciences

Report One of Five

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# Table of Contents

List of Figures ........................................................................................................................................ ii
List of Tables .......................................................................................................................................... ii
Acknowledgments ........................................................................................................................... iii
Executive Summary .......................................................................................................................... iv
Introduction .......................................................................................................................................... 1
  Visions, Goals and Objectives .......................................................................................................... 2
  Site Description .............................................................................................................................. 3
  Research Techniques .................................................................................................................... 4
  Inventory ........................................................................................................................................ 5
Invasives Background .......................................................................................................................... 6
Findings ................................................................................................................................................ 10
Recommendations .............................................................................................................................. 11
  Recommendation 1. Work with Volunteers to Identify and Prevent the Spread of Invasive Species ............................................................... 12
  Recommendation 2. - Design and Implement Plan for Active Management of Invasive Species ................................................................................. 13
  Recommendation 3. - Monitor Parks Periodically for Presence of Invasive Species to Maintain the Parks Free of New Invasive Plants ............................................................................................ 15
Conclusion ......................................................................................................................................... 16
References .......................................................................................................................................... 17
Appendices ......................................................................................................................................... 19
  Appendix B: Vegetation Survey Record Sheet ........................................................................... 27
  Appendix C: Example brochure for volunteer training .............................................................. 28
  Appendix D: Timetable for invasive management ........................................................................ 30
List of Figures

Figure 1. Minnesota county map with the City of Plymouth (blue) identified in the Minneapolis-St. Paul metropolitan area………………………………………………………3

Figure 2. Percentage of surveyed plots with the garlic mustard (*Alliaria petiolata*) present at each open space and natural area observed in Plymouth, Minnesota…..11

List of Tables

Table 1. Researcher and manager interviewees, regarding terrestrial invasive species monitoring and management, Plymouth, Minnesota, 2016……………………………………..5
Acknowledgments

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Executive Summary

Communities across Minnesota are increasingly focused on the risk invasive plant species pose to their native vegetation, parks, and natural spaces. Most local land management organizations have programs in place to manage buckthorn, but other common plant invasives are present throughout the state including garlic mustard (*Alliaria petiolata*), wild parsnip (*Pastinaca sativa*), oriental bittersweet (*Celastrus orbiculatus*), and grecian foxglove (*Digitalis lanata*). These invasives outcompete native plants, especially in environments already affected by invasive earthworms and abundant deer populations.

Students from the University of Minnesota’s Environmental Sciences, Policy and Management program were tasked with working with the City of Plymouth to develop a management plan for the aforementioned invasive plants, including development of a plant monitoring methodology to prevent the spread of the invasives. In line with Plymouth’s most recent comprehensive plan, the recommended management plans will “continue to maintain and renovate existing parks, open space and trails” in order to “provide a high-quality park and open space system”. (Comprehensive Plan, 2016) Seven natural areas were surveyed to assess the current presence of four invasive plant species in Plymouth: Elm Creek Woods, Ferndale, French Ridge, Nature Canyon, Shadyview, Hartenburg, and County Road 73 park. Of the seven parks considered in the study, five contained garlic mustard, and two were free of four invasive species assessed in this study. However, buckthorn was detected in varying density in every park surveyed.

The recommendations to protect Plymouth’s parks from invasive species include:

1. Work with volunteers to identify and prevent the spread of invasive species.
   a. Implement a neighborhood training program focused on identification and safe removal of plant invasives.
   b. Trained volunteers can be equipped with brochures (see Appendix D) detailing how to spot plant invasives, how to remove them, and how to prevent their spread.
   c. Create a partnership with property owners and the City of Plymouth to ensure the sustainability of the training program.
2. Design and implement a plan for active management of invasive species.
a. Implement mechanical control measures carried out by volunteers, where possible.
b. Plant native competitors that inhibit the spread and growth of invasive plants.
c. Where necessary, use herbicides to remove already established invasive populations.

3. Monitor parks periodically for presence of invasive species.
   a. Ensure continued participation in proposed neighborhood watch program.
   b. Provide structure for training and education programs managed by the city.
Introduction

Invasive plant species have documented debilitating effects on native forest ecosystems (Invasive Species, MnDNR). The Minnesota Department of Natural Resources describe invasives as “species that are not native to Minnesota and cause economic or environmental harm or harm to human health”. A common invasive plant present across Minnesota for many years is buckthorn. The City of Plymouth currently employs an effective buckthorn management plan, utilizing staff management and volunteer help. Volunteers are provided with a pamphlet describing buckthorn identification, removal, and prevention.

Terrestrial invasive species are nonnative plants that did not evolve with the natural community but were introduced and now threaten the native ecosystems (Invasive Species, MnDNR). These invasives outcompete native vegetation for light, water, and nutrients. They lack native controls such as disease and insects, which restrict their growth. Plymouth currently has a buckthorn management plan, but is yet to evaluate the presence or absence of other common invasive species (Rippe & Northway, 2016). These species of concern include garlic mustard (*Alliaria petiolata*), wild parsnip (*Pastinaca sativa*), oriental bittersweet (*Celastrus orbiculatus*), and grecian foxglove (*Digitalis lanata*). Wild parsnip and grecian foxglove can cause skin damage, and oriental bittersweet and garlic mustard can inhibit the growth of native plants (Invasive Species, MnDNR). Once established in an ecosystem, these species are difficult to remove.

Most of the species of concern do not proliferate in well-mowed lawn areas (Invasive Species, MnDNR). However, the city owns a number of natural areas and opens spaces that are not intensively managed, but still need to be maintained. The focus of this study is seven of these areas and open spaces susceptible to plant invasives because of their lack of visitors and maintenance, including Elm Creek Woods, Ferndale, French Ridge, Nature Canyon, Shadyview, Hartenburg, and County Road 73 park. (Plymouth Parks & Recreation Listing). These areas will be surveyed for the presence, absence, and density of the aforementioned plant invasives. Based off of this information, a management plan will dictate further steps to prevent the establishment or spread of specific invasive plant species.
Visions, Goals and Objectives

The vision statement for the class as a whole, guides five project groups focused on stormwater management, park use, park safety, volunteer programs, and this report on terrestrial invasive species management. Specifically, the vision is to:

To collaborate with the City of Plymouth to create a cohesive, comprehensible set of recommendations to improve the safety and vitality of the community, while also preserving the city’s natural resources and improving community engagement.

The vision statement for this specific project group as it relates to invasive species management is as follows:

To provide the City of Plymouth with the tools they need to create an effective, sustainable invasive plant management plan to prevent the growth of current invasives, stop the infiltration of new invasive plants, and provide a framework to quickly and efficiently detect and remove any new invasive plants.

The report goals are to provide the City of Plymouth with knowledge of four invasive plant species within the open space municipal parks, based on data collected in Fall 2016 using an efficient sampling method. By providing maps of known invasive plant locations and areas at risk for the invasion of these plant species, we aim to empower the city to manage and remove these plant pests before they can cause serious damage to the park ecosystems and park users.

The goals can be achieved with the following objectives:

- Identify four invasive plants of most concern (grecian foxglove, wild parsnip, garlic mustard, and oriental bittersweet) in seven natural areas and park open spaces,
- Map areas with invasive plants using GIS Software,
- Provide information on invasive plants of concern in the parks, so these species can be identified and managed by city officials, volunteers, and other community members, and
- Provide recommendations for future terrestrial invasive species monitoring in parks and open spaces.
Methods

Site Description

This project was conducted in cooperation with the City of Plymouth which is located in Hennepin County, and is part of the Minneapolis-St. Paul metropolitan area of Minnesota (Figure 1). Located 12 miles northwest of downtown Minneapolis, Plymouth is easily accessible using major transportation routes in the metro area. Interstate 494 and Highway 55 run directly through Plymouth. Highway 169 is located on the city’s eastern border and Interstate 394 is within four miles of the center of Plymouth. The city is home to approximately 74,594 residents and covers 35.3 square miles. The majority of residents are between the ages of 25 and 59 (Our Community, City of Plymouth, 2016).

Figure 1. Minnesota county map with the City of Plymouth (blue) identified in the Minneapolis-St. Paul metropolitan area. (Source: Developed and distributed by the City of Plymouth.)
Plymouth has an expansive park system consisting of 54 parks that cover 1,671.9 acres (2.6 square miles). The 54 parks have been classified into six categories: community park, natural areas and open space, neighborhood and mini park, the northwest greenway, playfield, school park and special use and city recreation facility. The City of Plymouth’s Parks and Recreation Department is in charge of managing the municipal parks. More specific information regarding the individual parks and contact information for the parks and recreation department is available on the city’s website (Our Community, City of Plymouth).

The entirety of Hennepin County is within the Deciduous Forest-Woodland Zone, which is composed primarily of oak, maple and ash. Other native plants that make up the understory of the deciduous forest are Wild Geranium, Jack in the Pulpit, Bloodroot, as well as various ferns or sedges. Plymouth has a humid continental climate with very cold winters and hot, humid summers. This type of climate is common for the Midwest.

Research Techniques

Literature Review
Vegetation surveys conducted were based on a literature review and standard Minnesota Department of Natural Resources (Minnesota DNR) survey techniques (Brauer, 2016). Using online databases from the MNDNR and the Minnesota Department of Agriculture, a pamphlet was constructed for each surveyor with images and descriptions identifying the species. Proper safety protocol for coming near or into contact with these plants was also described. The Plymouth Parks & Recreation Department provided information detailing park locations, aerial photographs, and general descriptions of the prioritized parks. These descriptions were used to determine accessible entrance points into the parks.

Interviews
Adequate background information about ecosystem effects, removal and preventative management of invasive species were necessary to propose useful recommendations. Multiple experts were interviewed and answered questions based on their expertise and professional background (Table 1). There was regular communication with the Project Coordinators and instructors throughout the project development.
Table 1. Researcher and manager interviewees, regarding terrestrial invasive species monitoring and management, Plymouth, Minnesota, 2016.

<table>
<thead>
<tr>
<th>Name</th>
<th>Employer</th>
<th>Field of Study</th>
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<tbody>
<tr>
<td>Paul Buck</td>
<td>City of Plymouth</td>
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<tr>
<td>Rebecca Montgomery</td>
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<td>Gary Johnson</td>
<td>University of Minnesota Forest Resources Department</td>
<td>Extension Professor, specialization in Urban Forestry and Community Outreach, Class Instructor</td>
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Inventory

Invasive plant density was collected using vegetation surveys to provide an accurate assessment of garlic mustard (*Alliaria petiolata*), wild parsnip (*Pastinaca sativa*), oriental bittersweet (*Celastrus orbiculatus*), grecian foxglove (*Digitalis lanata*) in the city. Maps of each natural area were generated using ArcGIS (Appendix A). Depending on the landscape and acreage of each natural area, maps were either overlaid with a one acre by one acre square, or 100 to 200 meter transects. In areas greater than 10 acres, a grid was used. In areas less than 10 acres, transects were used. In each square acre, a randomly generated one by one-meter square of vegetation was sampled. Along each transect, a sample was taken every 10 or 20 meters, respectively.
The visual analysis was conducted in one meter by one meter squares, placed in the specified locations described above. The one by one-meter square was analyzed for the presence or absence of the four plant invasives in question. If present, a species density was recorded as high, medium or low, based on coverage of the square. If 25% of the square was occupied by the invasive, it was marked low, if 50% it was marked medium, and 75%+ was marked as high (Appendix B).

Data was displayed using GIS map figures, first indicating presence absence, then plant density (high/medium/low). In addition, a new GIS layer was being created for the presence or absence of the four species of concern, so that it can be added to the current buckthorn assessment maps developed by Plymouth staff. In addition, this layer was used in the Park and Trail Safety Report (#5). The goals of the board of Parks & Recreation are to take this layer and make it available to volunteers to identify and remove invasive species. A brochure (Appendix C) will be provided with pictures of the species, any danger to people and animals, and what is the best way to remove the species. (Our Community, City of Plymouth)

Invasives Background

Garlic mustard (Alliaria petiolata) was first introduced to the United States from Europe in the 1860’s, for culinary and medicinal reasons. Because of a lack of predators, garlic mustard is able to grow and spread largely unrestricted. Since being introduced, garlic mustard has spread through the East to the Midwest states in the U.S., in addition to portions of Canada. (Minnesota Department of Agriculture (MDA), 2016).

Garlic mustard
(Alliaria petiolate)
Photo credit: Illinois Wild Flowers
Garlic mustard is a biennial plant, in its first year it grows as a rosette of green, heart shaped leaves with scalloped margins that persists through the winter. In its second year, garlic mustard grows stalks between 1-4 feet tall with triangular, toothy leaves along the stalk and small, white flowers at the end of the stalk. Crushed leaves tend to smell of garlic, especially in the spring. Flowers and seeds develop in early summer, with each plant capable of producing hundreds of seeds that can remain viable in the soil for five to eight years. Streams, rainwater runoff, and seed ‘hitch hiking’ by attaching to humans and animals that pass close to the plant, all spread the seeds to new locations. Garlic mustard grows well in upland and floodplain forests, urban areas, and along roadsides, and while it thrives in shady conditions, it is capable of growing in sunny environments (MDA, 2016).

Removal of small clusters of garlic mustard is not very difficult. It can be removed from the ground by hand, so long as care is taken to ensure that the root system is taken up with it. While mowing/trimming regiments can be done, and is very useful for large-scale infestations, garlic mustard grows well in forest environments where this approach isn’t always practical. The biggest problem in removing garlic mustard is the longevity of the seeds in the soil and the late-spring early-summer blooms. Areas that have had garlic mustard removed need to be monitored for years afterwards to control any resurgence of garlic mustard (MDA, 2016).

Oriental bittersweet (Celastrus orbiculatus) was introduced to the United States in the 1860s as an ornamental plant, due to its distinctive bright red berries. Oriental bittersweet grows rapidly, and can shade out the vegetation it grows on. The additional weight from oriental bittersweet can also cause damage to trees and shrubs, especially when snow and ice accumulate. Oriental bittersweet’s success has led to a decline of American bittersweet, a native species, through both competition and hybridization. Since introduced, oriental bittersweet has spread through most states in the Northeast and the Midwest (MDA, 2016).
Oriental bittersweet is a deciduous woody perennial plant that grows as vines to approximately 60 feet long, although they may reach up to 100 feet long. The plant has an extensive root system. Oriental bittersweet has separate male and female plants, with fruit only growing on the female plants. The leaves are alternate, glossy, and round with finely toothed margins. The leaves turn yellow in fall and stay on the plant until late in the season. Small, greenish yellow five petal flowers grow on both sexes of the plants, with blooming occurring in May and June. Oriental bittersweet berries are scarlet red with orange capsules, with the berries persisting into winter. The plants spread by the fruit being eaten by birds and mammals, with the seeds being dispersed. Studies have found that the seeds can last in the guts of birds for 2-6 weeks. The plants also spread by being used as ornamentals, usually mistakenly labeled as American bittersweet. Oriental bittersweet grows in grasslands, woods, and roadsides, and while it grows best in sunny environments, the seedlings are very shade tolerant (MDA, 2016).

Removal of oriental bittersweet is dependent on the extent of the infestation. While it can be removed by hand, removal of the root system makes it difficult to do. Hand removal is useful for removing seedlings, and is a good solution for monitoring areas that have had initial removal conducted. Cutting and mowing of oriental bittersweet should be avoided, as it stimulates regrowth. Chemical herbicides work best for removal, as it eliminates both the plant and the root system (MDA, 2016).

**Wild parsnip** (*Pastinaca sativa*) was introduced to the United States by European settlers. Over time, the plant escaped cultivation and became wild, spreading to many areas in the US (MDA, 2016). While wild parsnip does displace native wildlife, the larger concern is the chemicals in its sap that makes the skin vulnerable to sunlight, causing burns and blisters (Southeastern Wisconsin Invasive Species Consortium (SEWISC) 2016).
Wild parsnip is a biennial that spends its first year as a rosette that has several sprouts with 6 inch leaves. In its second year, wild parsnip grows a 4-6-foot-tall stem, with alternating leaf compounds made of smaller leaflets, with fewer leaflets as the leaves ascend the stem. The top of the stem branches out with yellow, 5 petalled flowers at the end of the branches. Wild parsnip blooms during the summer. In addition, it has a long, thick taproot that is edible. The plant juices and sap of wild parsnip can cause Phytophotodermatitis to the skin. When the juices come in contact with skin in sunlight, rash and/or blistering can occur, and skin discoloration can last for several months (MDA, 2016).

The main difficulty in managing wild parsnip is burns caused by the plant. While wild parsnip can be pulled out by hand, the risks associated with this makes it a poor choice for management beyond a few plants. In all cases rubber gloves and other safety measures need to be used when touching the plant. A shovel will cut the roots from beneath the plant, which is an effective control method. For large groups of plants, mowing shortly before flowering can eliminate most of the plants, with monitoring to remove any plants that re-sprout (MDA, 2016).

**Grecian foxglove** (*Digitalis lanata*) was introduced to the United States from Europe as an ornamental. While grecian foxglove outgrows and displaces native plants, the biggest concern is the toxicity of the plant (MDA, 2016).
Foxglove is a perennial plant that spends its first year as a rosette that is a dense clump of spear shaped leaves that round at the point. During subsequent years, grecian foxglove grows a 2-5-foot-tall flowering stem. The flowers are creamy white to pale yellow tubular flowers in elongated clusters. It is sometimes mistaken with the common garden Foxglove, which typically has a wider range of flower colors. Flowering occurs in the summer and the plant is primarily pollinated by bees. Ingestion of plant material and skin contact with grecian foxglove can be dangerous. The symptoms of foxglove poisoning include nausea, vomiting, and severe headache (MDA, 2016).

The main difficulty to managing this invasive is the toxicity of the plant. Small populations of the plants can be had pulled, but great care needs to be taken to not make skin contact with the plant. Frequent mowing during the growing season can control flowering and seeding of the plant. Herbicides can also reduce populations over time (MDA, 2016).

Findings

Park Monitoring

The Parks & Recreation Department of the City of Plymouth relies heavily on visitors and park maintenance to report sightings of terrestrial invasive plants. While the Plymouth community and its volunteers are very involved in the detection and removal of buckthorn, other less known invasives can more easily begin to spread undetected (Rippe & Northway, 2016). The City of Plymouth is home to 75 parks, nine of which are categorized as natural areas and/or open spaces. (Parks & Recreation) These areas have generally low levels of use, mainly because of their lack of accessibility and amenities that are commonly found in other types of parks. The low levels of visitation make it difficult for the Parks & Recreation Department to monitor the spread of terrestrial invasives (Rippe & Northway, 2016).

Invasives Detection

Seven natural areas and/or open spaces were chosen and given priority by the City of Plymouth to be surveyed for presence or absence of the four terrestrial invasive plant species, garlic mustard (Alliaria petiolata), wild parsnip (Pastinaca sativa), oriental
bittersweet (*Celastrus orbiculatus*), grecian foxglove (*Digitalis lanata*) (Appendix A). One of the four terrestrial invasive plant species inventoried was found and identified at five of the seven parks surveyed, including; Shadyview, County Road 73, Hartenberg, Ferndale, and French Ridge (Figure 2). All of the specified invasives were absent at Elm Creek Woods and Nature Canyon. The only invasive species from our specified list that was found within the parks was garlic mustard (*Alliaria petiolata*).

Plant survey results show that presence of garlic mustard per plots surveyed ranged from 6% to 53%, rounded to the nearest whole number where garlic mustard was present. Shadyview Park had the highest presence, with 53% of the total plots identified with the presence of garlic mustard. Garlic mustard was the only species included in the graph because it was the only specified invasive species found within the parks (Figure 2).

![Bar graph showing percentage of surveyed plots with garlic mustard present at each open space and natural area observed in Plymouth, Minnesota, Fall 2016.](image)

**Figure 2.** Percentage of surveyed plots with the garlic mustard (*Alliaria petiolata*) present at each open space and natural area observed in Plymouth, Minnesota, Fall 2016. Each observation was made at a specified point located on the maps in Appendix A.1-7. The point was marked within a 1 square meter area and each area was marked absent or present.

**Recommendations**

The most effective management strategy to prevent the spread of plant invasives is to preclude entry into any ecosystem (Sakai et al, 2001). To prevent the spread of invasive plant species in Plymouth parks and natural area, we recommend implementation of a neighborhood training and watch program. This program will rely on volunteers,
equipped with brochures (Appendix D) detailing how to identify plant invasives, how to remove them, and how to prevent their spread. We'll also provide management strategies to the city forester of Plymouth, including best management practices for infestations too large or at all dangerous for volunteers.

Recommendation 1. Work with Volunteers to Identify and Prevent the Spread of Invasive Species

The first step in effective management of invasive plants is the ability to accurately identify the invasive species and their potential threats. Early detection of invasive plants followed by a rapid response increases the probability of successful eradication while simultaneously keeping costs down. Although prevention may be the most difficult aspect of managing invasives, it should be a top priority since removal and restoration will be costly once the invasive plants are established. The scientific community widely agrees that prevention is the most effective approach to managing invasives. However, due to changing climatic conditions and human interaction with the natural environment, future introductions are inevitable (Worall 2002). Therefore, early detection will be the most important part of managing invasive plants.

1 - Identification
The residents of Plymouth are essential early detection of invasive species before the plants are established. We recommend that volunteers be enlisted to go out to parks and identify and report the presence and extent of invasive species (see Methods section for a monitoring approach). The most important part of the identification process is to locate and document all infestations. Identification should be prioritized in non-infested areas and if there is sufficient time and willing volunteers the infested areas. In addition, high risk areas prone to introductions should be periodically inspected (Minnesota DNR, 2015). Surveying methods may vary based on size of park and number of volunteers. Based on the work in this study, to conduct a targeted vegetation survey on a 10-acre park will take approximately one hour with five volunteers.

2 - Materials
Plymouth’s current management program for controlling buckthorn, which engages the community to help identify and remove the invasive plant, could also be implemented to manage garlic mustard or other invasive plants. With the necessary tools, invasive plant identification and monitoring will not be a complex task. Tools such as a brochure can help with plant identification and provide the community with a simple and effective
source of information to combat invasive species (Appendix C). Maps are a very useful tool to document invasives and powerful devices such as Geographic Positioning System (GPS) exist to help this task (Appendix A). However, efforts should be made to make this process as simple as possible to ensure that invasive species management objectives will be achieved (Freligh, 2016). At the very minimum, volunteers should be equipped with plant identification materials, flagging ribbon, maps or aerial photos, and a camera.

3 - Community awareness
Community awareness and education is important for prevention and early detection of invasive species outside of city parks. Establishing resident awareness and understanding the impacts of invasive species would create a partnership between property owners, the public, local and federal government, and the city of Plymouth. Collaboration and education on how to manage and prevent invasive management spread can increase the success of management efforts.

The challenges for enlisting community volunteers to prevent and detect the spread of invasives species are misidentifying the plant, safety concerns, and overall effectiveness. Plant identification can be difficult for multiple reasons, the main difficulties being the similarities between plant species (especially seedlings), and also the limited amount of time for identification due to seasonal variation. Safety concerns include the toxicity of certain invasive species such as wild parsnip. The overall effectiveness can also be called into question as volunteers will have minimal training and supervision. Fortunately, Plymouth has a long history of working with volunteers and managing diverse programs. The buckthorn volunteer program of Plymouth could be used as a model to ensure the success of new early detection and monitoring programs for other invasive species.

Recommendation 2. - Design and Implement Plan for Active Management of Invasive Species
Implementation of effective management methods will prevent the spread of terrestrial invasive plants throughout the city of Plymouth. Active management of invasives relies primarily on the information gathered in early detection monitoring. Once the plants have been identified they must be removed from the site using plant control methods to prevent further colonization. Plant control methods can be divided into three general categories: mechanical, biological, and chemical. The effectiveness of these methods depends on the targeted species and in some cases a combination of several methods
may be necessary to completely eradicate the invasive plant. Given current conditions of the four terrestrial invasives of concern in Plymouth (Figure 2) complete removal of these invasive species is an achievable goal.

1 - Mechanical
Mechanical control measures are the physical removal of plants from the environment. This includes: pulling, digging, cutting, chopping, girdling, mowing, tilling or hoeing the terrestrial invasive plants (Minnesota DNR, 2015). These techniques are easily applied and do not require any special licensing. Removing the entire plant from the site also ensures that future seed propagation will not continue, unless the seed are already in the ground (Ramula et al., 2008). Once removed from the site, invasive plants must be disposed appropriately since leftover plant material can cause new infestations or recolonization. The main goal is to ensure that the plant and its seeds are no longer viable; some possible options include burning, composting, and drying the plant (Frelich, 2016). (Appendix C) proposes a possible window of time for managing two invasive plant in order to maximize removal success

2 - Biological
Biological methods imply the use of native competitors, plant pathogens or insect predators to kill invasives. This can be done in a variety of ways but can only be applied to a specific target species, or species having similar characteristics. In other words, biological control will use an organism known to attack or remove a particular species. For example, one biological management technique for garlic mustard could include the introduction of native understory plants that will outcompete it by utilizing all the available resources. Native understory plants such as Wild Geranium, Jack in the Pulpit, Bloodroot, and native ferns or sedges would be ideal candidates to outcompete Garlic Mustard. This would not only remove noxious plants but also restore some of the native plant biodiversity in Plymouth.

3- Chemical
Herbicides are a very effective and resource efficient tool to manage invasive species. Many different herbicides with various functions (pre-emergent/post-emergent) are available on the market depending on the desired management goals and available resources. It is important to note that some terrestrial plant invasions would be impossible to manage without the use of herbicides (Minnesota DNR, 2015). Most common invasives can be treated with two herbicides: glyphosate (active ingredient in Roundup and Rodeo) and triclopyr (active ingredient in Brush-B-Gone and Garlon)
(Archibold et al., 1997). When choosing a pesticide always follow the labels instructions, it is important to consider the target species and its stage of growth, also be aware of the environmental conditions impacted such as nearby water resources or presence of desirable species (Minnesota DNR, 2015). Control methods can be conducted through foliar application or cut stem treatment depending on the species.

Some management techniques may have some limitations and challenges to consider when thinking of their implementations. Mechanical control is highly labor intensive and can create significant site disturbance. Biological control could potentially have negative ecological consequences without consulting prior scientific research. Correctly sourcing the plant material will be necessary to ensure you are using a native species. Chemical methods require a state-issued pesticide application license and can cause environmental and health problems. Nonetheless, the implementation of a proper management control method or a combination of several methods can ensure the removal of terrestrial invasive plants in Plymouth (Appendix D). Management of invasives with chemical control may be restricted to Plymouth staff, whereas mechanical and biological controls could be done by trained volunteers.

**Recommendation 3. - Monitor Parks Periodically for Presence of Invasive Species to Maintain the Parks Free of New Invasive Plants**

The final recommendation, and perhaps the most crucial one in ensuring the long-term ecological stability of natural areas in Plymouth, is the creation of a monitoring and education program post management. Future monitoring is a necessity to prevent the colonization of other invasive species as well as the re-establishment of removed plants. Seeds can not only stay dormant for several years before germinating, they can also spread over long distances via wind, animals and water. In addition to monitoring, education and training programs for the community of Plymouth regarding invasive plant identification and control would encourage landowners to address terrestrial plant invasions on their private lands and provide them with the tools to take the appropriate action. Resident training programs are important because the Parks and Recreation Department has no authority over private lands but these properties can serve as a source of invasive plant species that spread the plants to public lands. Continued monitoring after the invasive plants have been removed and further training in plant management will increase the chance that natural areas stay free of invasive species for decades to come.
1 - Monitoring
The monitoring program would consist of neighbors in proximity to green spaces, park users, and volunteers surveying, identifying and locating invasives. Once the removal of invasive plants is achieved, the majority of monitoring would occur primarily in the spring, which would inhibit any new plants from establishment, reaching maturity and seed production. The colonization of new invasive species remains a constant threat and could occur at any point in the future.

2 – Education and Training
A program to train not only park users but all Plymouth residents would be beneficial. It would help residents reduce propagation of invasives on public land. Informing parks users and public school students could be the first step of this program. Spreading awareness through basic plant identification, management methods, and invasive plant prevention could help reduce potential invasive colonization and spread.

Challenges associated with implementing such programs are that a long-term project may require additional staff time, intern recruitment, or volunteer coordination. Finding qualified instructors or effective educating methods could be difficult initially. Residents of Plymouth and the volunteer base that currently exists is one asset to begin with as they are ready to help improve their community. With a watch program, and tools to manage invasive plants properly, the citizens of Plymouth can help maintain the environmental health of the parks significantly.

Conclusion
Per the results of the invasive species vegetation survey, removal and biological control mechanisms will be most effective to prevent the spread of new invasive plant species. In addition to control mechanisms, a monitoring program will result in timely warning of new invasive plant outbreaks. Increased awareness about potential invasive plants and knowledge concerning how to prevent their spread will empower the residents of Plymouth to be an early-alter system and manage this problem themselves, with oversight by city staff. The management of natural areas and open spaces could prove to be a challenge, due to the lack of park users that spend time there within the natural areas. Training citizens on the importance of preventing the spread of invasive plants and empowering them to prevent the spread through observation can ensure the stability of plant biodiversity in Plymouth’s valued deciduous forests and woodlands.
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Sonya Rippe, Project Coordinator, and Barb Northway, Deputy Director of Parks & Recreations. Personal Communication September 13, 2016.


Appendices

Appendix A. GIS Survey Maps
   Elm Creek Woods Survey Map
   French Ridge Survey Map
   Hartenburg Survey Map
   County Road 73 Map
   Ferndale Survey Map
   Nature Canyon Survey Map
   Shadyview Survey Map

Appendix B: Vegetation Survey Record Sheet
Appendix C: Time windows for invasive plant management
Appendix D Example brochure for invasive removal
Appendix A: GIS Survey Maps

Figure 1. Vegetation survey grid map for Elm Creek Woods Park, open space and natural area, Plymouth, MN. Used to inventory four terrestrial invasive species Garlic mustard (Alliaria petiolata), Wild parsnip (Pastinaca sativa), Greater foxglove (Digitalis londronia) and Oriental bittersweet (Celastrus orbiculatus), Fall 2016.
Table 1. Example of spreadsheet used to keep record of what is seen in the open space and natural areas surveyed in Plymouth, MN. Fall 2016
Appendix C: Example brochure for volunteer training

Garlic Mustard

What is it and why it is an issue?

Garlic mustard is a biennial plant brought to the United States from Europe in the mid 1800s. It is an edible plant, with the leaves used in salads to provide a garlic and mustard flavor. The leaves taste best before summer.

Garlic mustard is kept in check in Europe by over 60 kinds of insects that eat it. Because none of these insects are native to the United States, garlic mustard grows and spreads rapidly. Garlic mustard pushes out native plants, grasses, and soil fertilizer for a forest’s health.

Garlic Mustard Removal

Managing garlic mustard supports the health of the natural areas in Plymouth. Forests with garlic mustard infestations have very little else, decreasing the plant diversity of the native forests, reducing what is capable of living in Plymouth forests.

City of Plymouth
3000 Plymouth Boulevard
Plymouth, MN 55446-4085
www.plymouth.gov
**Garlic Mustard**

Garlic mustard spreads to new locations by seed. A garlic mustard plant in bloom can produce up to 1000 seeds, and these seeds are spread by wind, water, and animals carrying them to new places. The seeds can stay fertile in soil for up to five years. Garlic mustard can also grow from its own taproot.

**Identification And Removal**

**First Year**
In the first year, garlic mustard grows as a circular group of green, heart shaped leaves with scalloped margins called a rosette. First year garlic mustard grows into the fall and remains green during winter. It is best to remove the plant in this stage, as it doesn’t flower or produce seeds until its second year.

**Second Year**
In the early spring of the second year, garlic mustard sprouts stalks between 1 to 4 feet tall from the rosette. Triangular, toothy leaves grow along the stalk and small, white flowers at the end of the stalk. Garlic mustard begins flowering in early summer, and will release seeds shortly after. It is best to remove second year garlic mustard before it begins flowering.

**Removal**
Garlic mustard can be safely removed by hand, although mowing is effective for second year growth prior to flowering. When pulling garlic mustard, it is important to remove the roots as best as you can, otherwise the plant may regrow from its taproot. Non-flowering garlic mustard plants that have been removed can be left where they were pulled to decompose, but flowering plants should be bagged, as they may be able to produce seeds still.

Volunteers searching parks for invasive species like garlic mustard.
Appendix D: Timetable for invasive management

Time windows for invasive plant management. Planning site preparation actions to avoid spreading invasive seeds and plants (Minnesota DNR, 2015).