Population dynamics of garlic mustard (*Alliaria petiolata*):

A new invader to Alberta's central parkland subregion

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Abstract

Garlic mustard (*Alliaria petiolata*), a highly invasive biennial plant species, was first discovered in Alberta in 2010. It is present in two urban ravines in Edmonton and one in St. Albert. Introduced from Europe, this invasive species can be found in 37 US states and 7 Canadian provinces. This species rapidly invades forest ecosystems by dominating native vegetation. Garlic mustard is a threat to Edmonton's River Valley due to its highly interconnected nature and the many native flora and fauna that inhabit this area. Understanding the population dynamics of an invasive species is critical to making informed management decisions. Previous research on the population dynamics of garlic mustard in other regions has reported high mortality in the first year and low second year mortality. The goal of our project was to assess garlic mustard mortality in its first and second year of growth within Edmonton's central parkland subregion. To assess first year mortality fifteen 0.5 m^2 quadrats were established in spring and monitored with biweekly counts over the first growing season in 2014 and 2015. To assess second year mortality fifteen 0.5 m^2 quadrats were established in fall and then relocated in spring and monitored with biweekly counts over the second growing season in 2013-2014 and 2014-2015. Overall, first year mortality was 27% in 2014 and 2015 and second year mortality was 31% and 47%, respectively. This research will contribute to a broader understanding of the population dynamics of this species and may inform management decisions.

Introduction

Garlic mustard (*Alliaria petiolata*) is highly invasive of forest ecosystems where it quickly dominates and displaces native vegetation[1]. Named after its distinct garlic scent and taste, garlic mustard was brought over by early European settlers as a garden herb[1]. Now, garlic mustard can be found in 37 US states as well as in British Columbia, Quebec, Ontario, Nova Scotia, Prince Edward Island, New Brunswick[2,3] and as of 2010, Alberta. Garlic mustard is located in the Forest Lawn Ravine in St. Albert and the Westmount Ravine and Mill Creek Ravine in Edmonton[4]. These garlic mustard populations fall within the central parkland subregion of Alberta's natural parkland region[6]. The largest population is found in Mill Creek Ravine, Edmonton, which is a tributary ravine connected to the larger North Saskatchewan River Valley. This park system forms one of the largest expanses of urban parkland in North America[5] and is home to an array of native plant and animal species, which may be impacted by the spread of garlic mustard. The Alberta Weed Control Act has classified garlic mustard as prohibited noxious meaning municipalities as well as homeowners have a legal obligation to destroy this species on any property in which it is present[12]. Hand pulling of second year plants during the early flowering stage prior to seed set is the most common control strategy for garlic mustard.

Garlic mustard is a biennial plant; requiring two growing seasons to complete its life cycle[2,7,8]. Two paddle-shaped cotyledons emerge in early spring and plants complete the first year of their growing season as a rosette[1,2]. After overwintering, second year plants bolt and flower in early spring[1,7]. Small white flowers are primarily self-fertilized to form silique seed pods that release between 200-1000 seeds per plant in summer[1,7,8,9]. The seeds are dropped 1-2 m from the parent plant and can remain dormant in the soil for up to 10 years[1,8]. Environmental or anthropogenic disturbances seem to dramatically increase garlic mustard germination and population spread[8].

Population dynamics of garlic mustard have not been examined in this region. We assessed first and second year mortality of plants in the Mill Creek Ravine by conducting bi-weekly counts of fifteen 0.5 m^2 first year quadrats and fifteen 0.5 m^2 second year quadrats and this has been replicated in two growing seasons (2014 and 2015). Garlic mustard exhibits complex population dynamics, which can complicate control[10]. An understanding of the population dynamics of invasive species can inform management decisions. Furthermore, the results from this project may also support predictions about the relative potential for garlic mustard to spread in this region.

Methods

Site description and quadrat set up

First year and second year quadrats were located in the Mill Creek Ravine in Edmonton (53° 31'12.6", 113° 28'25.6"). Mill Creek Ravine is a forested urban natural area that sees heavy recreational use. There are extensive dirt and paved trails used by mountain bikers, joggers and walkers. Additionally, a section of the infested area of the ravine is an off-leash dog walking area and homeless populations often camp in the area during summer months. The garlic mustard infestation in this area extends from municipal property onto private residential properties that border the ravine. The vegetation within Mill Creek consists primarily of native ground cover, deciduous trees and shrubs, as well as some coniferous trees.

Voluntary annual garlic mustard pulls are organized by the City of Edmonton within this area. Quadrats were located north and south of 76 Avenue (Figure 1). All quadrats had to meet the following criteria: i. Be at least 5 m from a right of way (path); ii. Be at least 5 m away from another quadrat; iii. Contain at least 10 garlic mustard plants. Quadrats were marked with metal spikes at each corner as well as coloured flagging tape around the perimeter. Labelled flagging tape was tied to a nearby tree branch for detection and sometimes spray paint was used to highlight the location. Each quadrat was given a unique identifier. For each quadrat, leaf litter, slope direction, GPS coordinates, potential disturbances, non garlic mustard species, number of garlic mustard plants and their stage of growth were recorded on both the first and last day of data collection. Photos of each quadrat were taken using a Canon PowerShot camera or iPhone 5C camera.

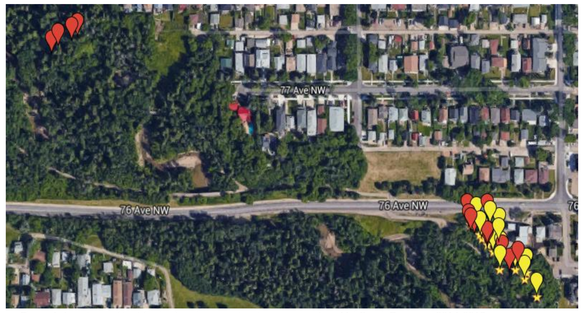

Figure 1: Locations of first (yellow) and second (red) year quadrats in Mill Creek Ravine in 2014-2015

First year mortality (2014; 2015)

Quadrats were set up when snow cover had primarily melted and the first cotyledons were observed emerging from the soil. Final counts took place immediately following the first reported overnight temperatures of below 0° C (first overnight freeze) in Edmonton. Garlic mustard plants within the first year quadrats were harvested during the final count to ensure accuracy. The 2014 quadrats were set up on May 2, 2014 and harvested September 9, 2014. The 2015 quadrats were set up on April 24, 2015 and harvested September 18, 2015.

Second year mortality (2013-2014; 2014-2015)

The 2013-2014 quadrats were set up on September 1, 2013, overwintered and the first spring count took place on May 2, 2014 and harvest and final count took place on July 10, 2014. The 2014-2015 quadrats were set up on September 11, 2014, overwintered and the first spring count took place on April 23, 2015 and harvest and final count took place on July 22, 2015. The number of siliques present on each individual plant within a quadrat was also recorded.

Statistical analysis

Descriptive statistics was used to describe the data (mean ± standard error) for the following periods at 95% confidence intervals. Mean mortality in first year plants was compared in Spring vs. Fall. Mean second year mortality was measured across three periods for each year: Fall vs. Spring, Spring vs. Summer and Fall vs. Summer. A t-test was applied in order to observe if there was a difference in mortality between the two years of data collection.

Results

Table 1: First-year Garlic Mustard Quadrat Data from Spring-Summer 2013-2015

Period	Year 1 (2013 – 2014)		Year 2 (2014 – 2015)	
	% Mortality (± SE)	95% Confidence Interval	% Mortality (± SE)	95% Confidence Interval
Spring-Fall	27.3 (± 5.59)	16.3-38.3	26.5 (± 4.91)	16.9-36.1

Table 2: Second-year Garlic Mustard Quadrat Data from Fall-Summer 2013-2015

Period	Year 1 (2013 – 2014)*		Year 2 (2014 – 2015)*	
	% Mortality (± SE)	95% Confidence Interval	% Mortality (± SE)	95% Confidence Interval
Fall-Spring	26.6 (± 6.75)	13.4-39.9	33.4 (± 10.23)	13.3-53.4
Spring-Summer	8.1 (± 4.67)	-1.04-17.26	18.4 (± 11.09)	-3.36-40.12
Fall-Summer	31.0 (± 8.81)	13.7-48.2	47.2 (± 10.75)	26.1-68.3

*A t-test assuming unequal variances determined the differences in 2014 and 2015 second year mortality was statistically insignificant (t=1.16, p=0.26, df=14).

Discussion

The objective of this project was to quantify first and second year mortality in the invasive biennial garlic mustard (*Alliaria petiolata)* plant in Edmonton's central parkland subregion. Overall, first year mortality was 27% in 2014 and 2015 and second year mortality was 31% and 47%, respectively. Studies in Illinois and in Ontario both showed high first year mortality of 91-95% and negligible second year mortality[1,7]. Compared to this published data, we observed comparatively low mean first year mortality of 27% in both 2014 and 2015; and comparatively high second year mortality of 31% and 47% in 2013-2014 and 2014-2015, respectively. While the differences in second year mortality between the two replicates was determined statistically insignificant, the summer of 2014-2015 was much drier. In Minnesota, a study on second year mortality displayed variable mortality rates, ranging between 7% to 45% over a three year period[13]; this highlights the importance in evaluating mortality over several years.

Most often, either first year or second year plants will dominate in an area in a given year[2] and it has been observed that when intraspecific competition between first and second year plants is present within the same patch it can negatively affect first year survival[11]. Because of the high natural mortality of first year plants and the importance of second year competition in further enhancing mortality during the early growing season, targeting of second year plants at the flowering stage is considered most effective for control. Research suggests that control of first year plants will only effectively reduce population density if >95% are destroyed, whereas this will be achieved if >85% of second year plants are destroyed[10]. Control strategies that do not achieve these levels should be reconsidered as they may actually exacerbate population growth through reductions in competition and increases in disturbance and spread. In St. Albert vegetation management crews have used herbicide (glyphosate) to control second year plants in early spring prior to the emergence of native species, followed by manual removal in later spring of any missed plants. They report that this has been effective in reducing the population[4]. There is consensus that invasive species, once established, are virtually impossible to eradicate, so early detection and a rapid evidence based management response to new populations is critical. Understanding the population dynamics of this species in this region is critical for supporting effective management decisions.

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