Conservation of forest plant communities: A potential solution to the threat from Garlic Mustard (*Alliaria petiolata)*

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Introduction

The understory herb Garlic Mustard (*Alliaria petiolata*) is an invasive herbaceous biennial plant species that was introduced to North America in the mid-1800s (Rodgers *et al*. 2008). It is present in many deciduous, coniferous, and mixed forests. The herb is of concern to many conservation biologists in North America because of its ability to rapidly colonize and outcompete most of the native understory plants (Callaway *et al.* 2008), dramatically changing the forest understory. Most plant species present in the forest understory are restricted by various herbivores in the area; however, Garlic Mustard produces toxins as a herbivore defence mechanism preventing natural management of the plant (Rodgers *et al*. 2008). The ability to produce these toxins, as well as its rapid growth and earlier growth period, make Garlic Mustard a very successful competitor. Furthermore, Garlic Mustard inhibits a mutualistic mycorrhizal fungus that is needed by tree seedlings and other native plants (Rodgers *et al.* 2008).

In the spring, Garlic Mustard emerges earlier than other understory plant species which may allow it to acquire nutrients while the rest of the vegetation is still inactive (Rodgers *et al*. 2008). Additionally, the plant has demonstrated remarkable plasticity in its response to habitat heterogeneity and therefore is found in a variety of ecological conditions (Byers *et al.* 1998). After germination, each Garlic Mustard plant produces a rosette of dark green leaves by the end of the first summer. In the winter, this species demonstrates the rare trait of retaining their green colour under the snow (Rodgers *et al*. 2008). In the following spring, the one year old plants start to bloom in April and usually continue through until July. These plants will produce fruit from June until

September and senesce soon after the fruit is dropped (Rodgers *et al.* 2008). One of the main restrictions for many seed producing plants is pollination; Garlic Mustard like many weeds is self-pollinating (Susko *et al*. 1999) which allows its populations to grow particularly rapidly.

There are a variety of reasons why this species thrives in North America. Growth and survival of Garlic mustard is restricted in its native habitat of Europe, because it is frequently and intensively attacked by a common weevil species (*Ceutorhynchus scrobicollis*) (Greber *et al*. 2007). Therefore, in Europe the combination of a common natural herbivore and the resistance of the mycorrhizae to Garlic Mustard's toxins *(*Callaway *et al*. 2008*)* allow tree seedlings and other plant species to coexist. This is not the case in North America however consequently, this plant is a cause for concern in conservation areas as well as many other natural woodlands. Thus, we must take steps to manage this invasive species.

Current Garlic Mustard Management Practices

One of the main problems with Garlic Mustard management is its seedbank. When seeds are released from the mature adult some of the seeds will not germinate in the following spring; in fact many can remain dormant for up to five years in the soil (Slaughter *et al*. 2007). Therefore, the management and possible eradication of Garlic Mustard must be a long term process. One method that is commonly employed for Garlic Mustard management is the act of weeding, which is simply pulling the one year

old plants out of the ground in the early spring before seeds are produced. While this may give the appearance of immediate progress the long term effect of this method is not as successful and can even promote Garlic Mustard population growth because the disturbed soil may facilitate germination. The soil is disturbed when the herb is pulled from the ground thereby opening up the ground and presenting a favourable environment for germination and emergence from the seedbank. Previous studies have shown that populations of Garlic Mustard tend to increase rapidly in areas of high disturbance (floods, fires ect) and decrease when disturbance is infrequent (Nuzzo 1999).

Other Management Practices to Control Garlic Mustard Expansion

Other possible control methods include appropriately timed clipping at the base of the shoot, and herbicide use. Garlic Mustard plants with damage to the flower-shoot have increased mortality along with reduced seed production (Rebek *et al.* 2005). Clipping at the base of the plant effectively kills it because its capacity to resprout is apparently very limited (Pardini *et al.* 2008). Furthermore, unlike weeding, germination from the seedbank is not stimulated since the soil is not disturbed. Note that although the seeds in the seedbank are viable for up to 5 years only a very small percentage of seeds will germinate after 2 years dormancy (Slaughter *et al.* 2007). Table 1 (part of Table 2 in Rebek *et al*. 2005) demonstrates that certain traits are affected by the clipping method. Clipping at the base shows a significant decrease in seed production, seed

weight, vegetative biomass, and shoot height indicating that it is an effective treatment method.

Table 1
A portion of the mean (±SE) *A. petiolata* reproduction and size measurments by cutting treatment for 2002 and 2003 (N=20 except basal-cut: 2002, N=10 and 2003, N=17)

Variable	Treatment	2002	2003
Seed production	Control	791.78±77.05[a]	88.14±14.28[a]
	Tip-cut	674.99±91.52[a]	83.74±15.38[a]
	Basal-cut	144.01±54.34[b]	20.99±8.88[b]
Seed weight (mg)	Control	1.452±0.0062[a]	1.711±.107[a]
	Tip-cut	1.003±0.0053[b]	1.697±0.118[a]
	Basal-cut	0.526±0.113[c]	0.763±0.224[b]
Vegetative biomass (g)	Control	3.761±0.394[a]	0.416±0.0076[a,b]
	Tip-cut	4.150±0.563[a]	0.580±0.103[a]
	Basal-cut	0.994±0.293[b]	0.189±0.048[b]
Shoot height (cm)	Control	238.39±28.55[a]	51.63±3.22[a]
	Tip-cut	174.63±24.01[b]	49.20±3.41[a]
	Basal-cut	96.75±15.41[c]	28.58±5.31[b]

Variable means within columns with the same letter are not significantly different using pairwise difference tests (P>0.05)

The use of herbicide has been successful in containing Garlic Mustard populations. Glyphosphate spraying(1-2% concentration) on the adult rosettes reduces the adult population of Garlic Mustard effectively (Slaughter *et al*. 2007) resulting in increased cover of spring perennials and graminoids in the following season (Hochstedler *et al*. 2007). Figure 1 (figure 2 from Hochstedler *et al*. 2007) shows that plots treated with herbicide have a higher percentage of spring perennials than plots that are not treated with herbicide. In addition, figure 2 (part of figure 1 from Slaughter *et al*. 2007) indicates that the herbicide application reduced the adult and rosette cover to less than 1% throughout the years.

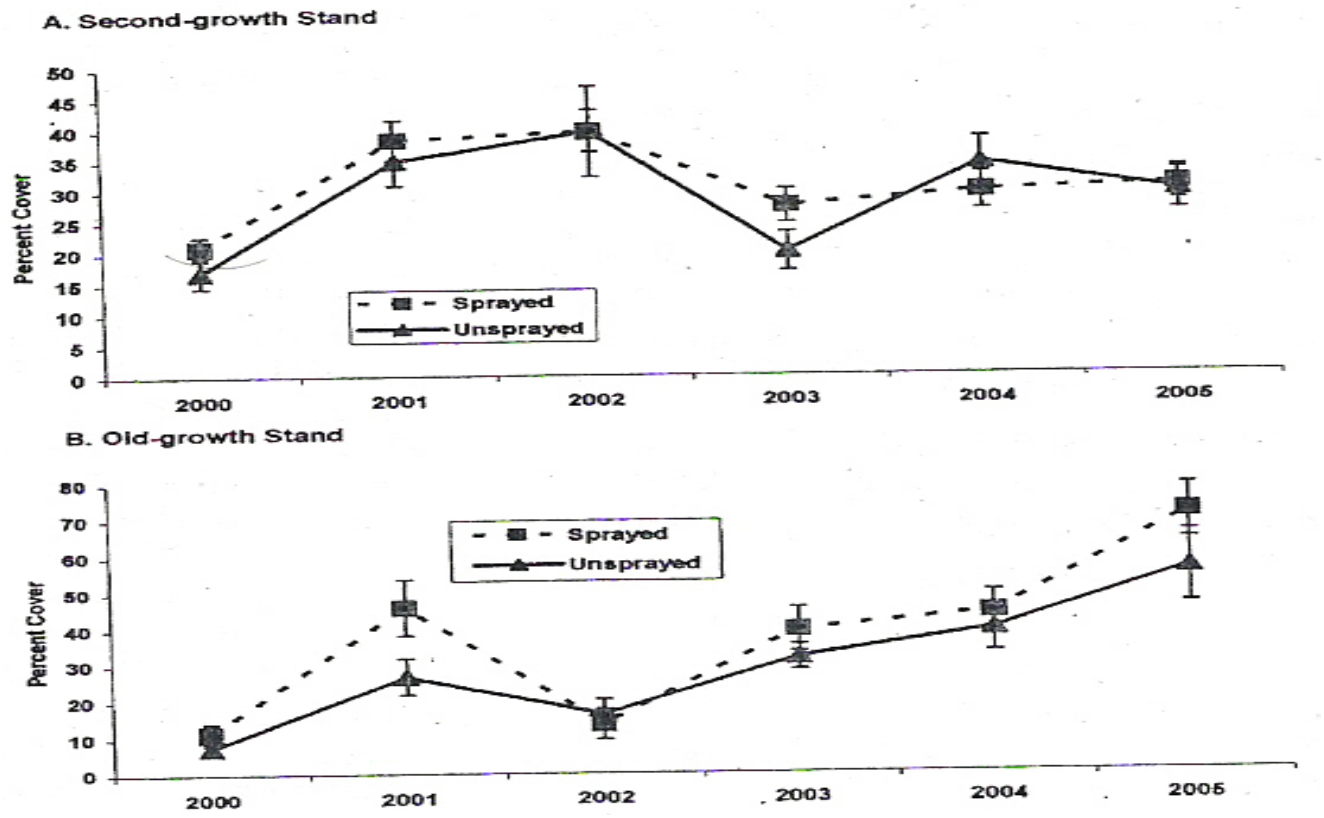

Figure 1 Spring perennial percent cover (mean ± SE), (a) second-growth and (b) old-growth stands, 2000-2005. Means based on 1 x 1 m plots.

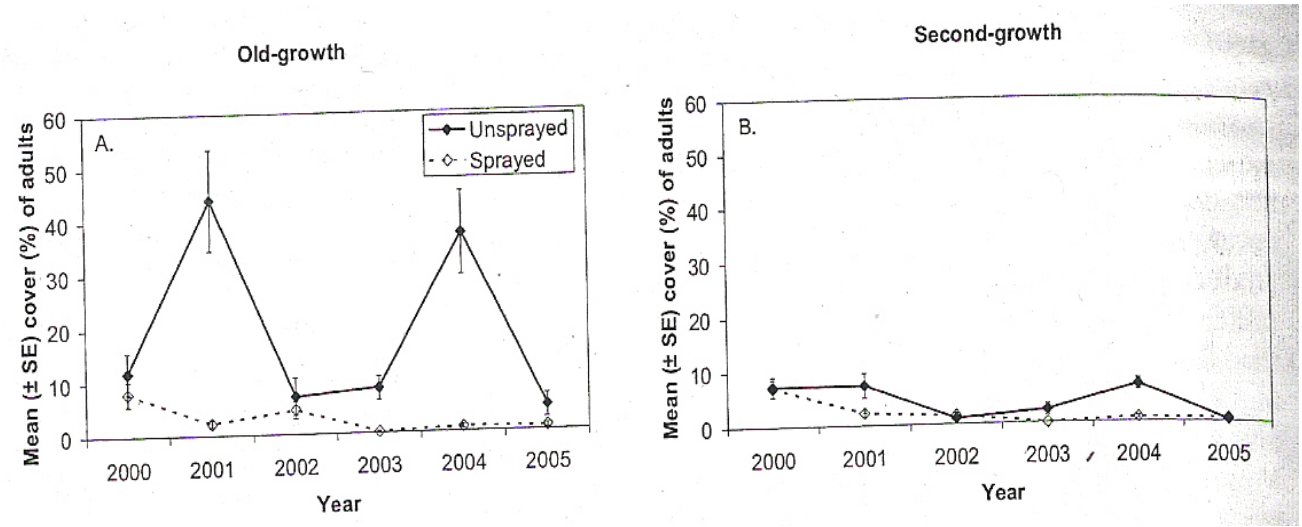

Figure 2 Mean (± SE) May *A. petiolata* adult and rosette cover in each stand (A: old-growth adult cover, B: second-growth adult cover) 2000-2005. Means based on 25 1 x 1 m plots per treatment, per stand, except as reduced by treefall in 2003-2005.

A Combined Approach to Managing Garlic Mustard Populations

Although resilience in the seedbank proves to be one of the greatest obstacles in controlling and eradicating the Garlic Mustard plant, eradication of the herb may be possible if a management plan is put in place and maintained for a minimum of 5 years. Our review of the biology and current practices for managing Garlic Mustard strongly suggests that a combination of appropriately timed clipping and herbicide use would have much greater success than the current weeding practice in controlling its distribution. Garlic Mustard is able to flower between April and May and so the first stage must be implemented in late April to early May (Pardini *et al.* 2008). A three stage process is proposed: clipping at the base in spring; trimming at mid-height in summer; and limited application of herbicide on surviving rosettes in the fall. The first stage will be to clip all Garlic Mustard plants at the base of the shoot to minimize potential resprouting. For those plants that may have resprouted and any seeds that may have germinated the second and third stages will help to ensure that they do not return the following spring. The second stage will be to trim any of the Garlic Mustard plants at mid-height to prevent seed production in the flower head. This is less time-consuming than clipping at the base and will be performed in the middle of the growing season. The third and final stage will be implemented, the application of the glyphosphate herbicide to any remaining rosettes, in the fall. This timing is in the fall to avoid damage to the spring flora which is the prevailing vegetation in most forest communities (Slaughter *et al.* 2007).

Proposed Research to Test the Combined Approach to Managing Garlic Mustard

The aim of this research is to determine if a combination of methods (clipping, trimming, herbicide) will be effective at minimizing the adult population and thus seed production in the growing season of Garlic Mustard. Quadrats will be set up to monitor the growth of the plant through the management periods. The quadrats will use blind marks, with the use of a GPS unit, to ensure that there is no bias in the treatment of the plots. One plot will not receive any treatments as a control for the natural growth of the plant. The first stage will be implemented in late April to early May when the plants are beginning to emerge from winter inactivity. This will involve clipping each plant at the base, approximately 1 – 3 cm above soil level by hand. The second stage will be in the middle of the growing season and will be less time consuming than the first stage. The second stage will be implemented in mid June when the flowers would begin to emerge on the plant. The use of weed trimmers or large shrub trimmers will be used to cut the stalks at mid-height of the surviving plants. The fallen stalks must be removed from the sites to ensure that any associated seeds do not enter the ground. The third and final stage will be implemented in early September to minimize the damage to natural flora as it is spring flora that is the prevailing vegetation in most forest communities (Slaughter *et al.* 2007). This will involve using a 1-2% concentrated glyphosphate herbicide on the Garlic Mustard, such as Roundup. The primary target of the herbicide will be the adult rosettes.

The marked quadrats will be examined every week from May until October for any growth of Garlic Mustard. The quadrat number and location in the quadrat of any stalks that resprout after any of the stages will be recorded. The purpose of recording

quadrant and location will be to note whether it is the same plants or different plants that resprout after management methods. The growth achieved by possible resprouting stalks will also be monitored and recorded between stages of the combined management approach. We will also note if any stalks manage to regenerate to the flowering stage. It is probable that the results of this management program will be visible within one growing season but in order to exhaust the seedbank this study should be carried out for a period of four additional growing seasons.

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