

**Garlic Mustard (*Alliaria petiolata*) Management Plan\_2012 Update**  
for the  
Village of Grand Pré and Surrounding Area  
Nova Scotia, Canada



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NS Youth Conservation Corps (NSYCC), August 2009*

*Caitlin Porter and Jake Parker, NSYCC, August 2010*

*Jessica Fredericks and John Sommerville, NSYCC, August 2011*

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The logo for the Government of Canada, featuring the word "Canada" in a serif font with a small Canadian flag above the letter "a".

and

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<http://www.gov.ns.ca/tran/enviroservices/Mustard/Garlic%20Mustard%20Management%20Plan.pdf>

## Table of Contents

<b>Table of Contents</b>	<b>1</b>
<b>Acknowledgements</b>	<b>3</b>
<b>Executive Summary</b>	<b>4</b>
<b>Introduction</b>	<b>6</b>
<b>Garlic Mustard</b>	<b>7</b>
Description	7
Current North American Distribution	9
<b>Damage &amp; Threats</b>	<b>10</b>
<b>Inventory</b>	<b>11</b>
<b>Management Plans</b>	<b>13</b>
Goals	13
Objectives	14
Further research efforts	17
Materials & Methods	17
Disposal	20
Evaluation	21
Resource Requirements	23
<b>Further Recommendations</b>	<b>25</b>
1 – Lead Agency	25
2 – Plant Biology	25
3 – Community Engagement	25
4 – New Reports	26
5 – BMPs	26
6 – Project Support	26
<b>References</b>	<b>26</b>
<b>Appendix A – Background Information on Initiating Management of Garlic Mustard in Nova Scotia and Management Plan Development</b>	<b>29</b>
<b>Appendix B – Map of 2008 Known Extent of Garlic Mustard in Nova Scotia (data collected in May – June 2008)</b>	<b>32</b>
<b>Appendix C 2009 and 2010 Distribution Maps Generated by NSYCC Interns</b>	<b>33</b>
<b>Appendix D Outlier Population UTM Locations</b>	<b>37</b>
<b>Appendix E – 2010/11 Notes on Garlic Mustard (<i>Alliaria petiolata</i>) Plant Biology in Nova Scotia</b>	<b>38</b>

**Appendix F Strategic Monitoring Areas \_\_\_\_\_ 44**

**Appendix G – Notice Distributed by the E.C. Smith Herbarium (Acadia University) to Solicit New Reports of Garlic Mustard Occurrences \_\_\_\_\_ 45**

**Appendix H – Informational Flyer Distributed by Clean Annapolis River Project to Increase Awareness of Garlic Mustard Identification and Impacts \_\_\_\_\_ 46**

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Some of the text in this plan is based on a paper prepared for the Transportation Association of Canada (TAC) by Pett et al. (2008; available on-line at the NSTIR website:

[http://www.gov.ns.ca/tran/enviroservices/Mustard/TAC\\_2008%20Garlic%20Mustard%20paper.pdf](http://www.gov.ns.ca/tran/enviroservices/Mustard/TAC_2008%20Garlic%20Mustard%20paper.pdf)).

Two students in 2009, Alexandra Wade and Sondra Brehaut, two students in 2010, Caitlin Porter and Jake Parker, and two students in 2011, Jessica Fredericks and John Sommerville, were also hired through the Nova Scotia Youth Conservation Corps (NSYCC) to assist with the project implementation and updating of this plan. Special thanks to Helen Smith and her NSYCC Team at NS Environment and Clean Nova Scotia for attending to all of the administration details for the students in 2009, 2010 and 2011. Scott MacIvor at Saint Mary's University provided some assistance with the identification of insect species found browsing on Garlic Mustard in 2010.

For further information, please contact Dr. Bob Pett, Environmental Services, NSTIR Head Office, 1672 Granville Street, PO Box 186, Halifax, NS, B3J 2N2 (Tel: 902-424-4082; [pettrj@gov.ns.ca](mailto:pettrj@gov.ns.ca)).

## Executive Summary

Garlic mustard (*Alliaria petiolata*) is a shade-tolerant, invasive alien, biennial plant from Europe. In 2002, a roadside population of garlic mustard was reported in the community of Grand Pré, Nova Scotia, the only known occurrence of this plant in the province. The population has subsequently spread along roadsides, infested the Grand Pré National Historic Site and 3 core areas, crossed a major watershed divide and formed a colony in Hantsport, approximately 10km east of the original infestation. Garlic mustard becomes established in disturbed areas, such as ditches, and spreads into undisturbed areas, including closed-canopy forests.

In the summer of 2007, Clean Annapolis River Project (CARP) organized a meeting of managers from key government agencies to initiate discussion about management of this isolated population. Given the limited size of the infestation, and based on professional experience and scientific research, numerous experts felt that immediate action to eradicate the existing garlic mustard population would be the best course of action. As a result of that meeting, Parks Canada and the Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) both expressed a keen interest in working towards the long-term management of this species.

This document is the management plan that was developed jointly by NSTIR, Parks Canada, and CARP. The long-term management goals identified for garlic mustard are:

- Prevent further spread and new introductions of garlic mustard in NS.
- Conduct a case study of best management practices (BMPs) applicable to managing roadside populations of garlic mustard in NS.
- Increase public awareness of invasive alien species.
- Engage other agencies in the management of garlic mustard in NS, and solicit additional project support.
- Establish a management committee to oversee the management plan implementation and annual revisions.

The original 2008 Management plan is annually updated based on notes, observations and findings. Management practices are updated in subsequent years

The Year 1 (2008 – 2009) management objectives were:

- Accurately inventory/map all known populations of garlic mustard in NS.
- Prevent seed production in all known outlier/satellite populations of garlic mustard in NS.
- Implement BMP along roadsides in the Grand Pré area.
- Increase public awareness about garlic mustard, and invasive alien plants in general.
- Engage the communities of Grand Pré and surrounding areas in taking an active role in the management of garlic mustard.

The Year 2 (2009-2010), 3 (2010-2011) and 4 (2011-2012) management objectives were updated to include:

- Further inventory and mapping of garlic mustard populations in NS.
- Removal of all adult plants in outlying populations in order to prevent seed production.
- Increase public awareness about garlic mustard and invasive plants in general through posters, an information session and personal communications.
- Observe biological traits and evaluate control measures through use of permanent sample plots.

Further key management considerations are detailed for 6 topics as summarized below.

**Lead Agency** – In 2009, 2010, and 2011, Dr. Bob Pett, NSTIR Environmental Services, took the initiative to hire students through the NS Youth Conservation Corps (NSYCC) to further this project.

**Plant Biology** – It is recommended that a number of permanent sample plots be established in the Grand Pré area to make local observations about the biological traits of garlic mustard. Preliminary sample plots were established in the summer of 2010. In 2011, these sample plots were revisited and two more sample plots were established. However, continued investigations into plant biology and potential for garlic mustard to become established in the Acadian Forest will require engagement of one or more university researchers. High-level expertise is required for advanced research as well as negotiations with private landowners for various study sites.

**New Occurrences** – It is recommended that project partners continue to contact staff at the E.C. Smith Herbarium at Acadia University to see if any new reports of garlic mustard have been received. New sites in Port Williams and Truro were verified in 2011, and further surveys should expand in surrounding areas for other occurrences.

**BMPs** – The roadside BMPs drafted for NSTIR (Godwin and Stewart 2007), and described in Pett et al. (2008) should be revised based on findings from each year of the project.

**Project Support** – It is recommended that partners remain involved in the *Invasive Species Alliance of Nova Scotia*, and the *Invasive Alien Species Atlantic Network*. Membership in these groups will enable partners to stay connected with other groups involved in invasive plant management, and may result in access to other funding or project support.

In 2012 and beyond, NSTIR will be drastically changing its approach to garlic mustard control. Discussions in 2010 with the US experts in garlic mustard, Victoria Nuzzo and Bernd Blossey, indicate that established garlic mustard infestations should be left alone and time will eventually solve the problem. Populations should gradually subside over a period of 6 to 10 years. Based on more than 10 years of monitoring, the US experts have found that continued active control, by pulling, cutting, spraying, burning, etc., actually promotes garlic mustard growth and spread. Interestingly, the underlying cause relates to two other invading species, earthworms and whitetail deer. Glaciation killed off all of the native earthworms in Canada and today's worms originally came with European colonists in ship ballast, potted plants, and packing materials. Deer were introduced to NS in the 1890s and are now very common in most of Nova Scotia. Earthworms are essential for garlic mustard to spread and deer aid the process by indirect means – heavy grazing of forest understory vegetation. Further information on this topic is given in Nuzzo et al. (2009) and Knight et al. (2009).

The Year 5 (2012-2013) management objectives are therefore updated to include:

- Continued surveillance of garlic mustard populations in NS.
- Removal of adult plants limited to new outlier populations (e.g., Kentville and Hantsport).
- Maintain communication with ISANS and staff at E.C. Smith Herbarium, Acadia University.

*NOTE: This document is loosely formatted after The Nature Conservancy's (TNC) "Site Weed Management Plan" template (Tu and Meyers-Rice 2001). Though the template is designed for use in protected areas, its format can be applied to any management area.*

## Introduction

Grand Pré is a rural community of fewer than 1,000 inhabitants in Kings County, western Nova Scotia (Figure 1). The populations of garlic mustard (*Alliaria petiolata*) in Grand Pré, and surrounding area, are the only documented populations in the province of Nova Scotia. The populations are located on federal, provincial, and private lands. Federal property belongs to the Grand Pré National Historic Site of Canada. Provincial property is comprised of road right-of-ways (ROW) belonging to the Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR). Private lands include residential and agricultural properties in the community of Grand Pré, and surrounding area. All area types are “disturbed”, and include ditches, pathways, lawns, gardens, etc. As such, there are no conservation targets or goals for these locations. Plants have not been reported in any areas of high natural value, but are present in hedgerows, wooded areas on residential properties, and along streambanks. The management concern is that this plant becomes established in disturbed areas, such as ditches, and subsequently spreads into undisturbed areas (e.g., Kaufman and Kaufman 2007).

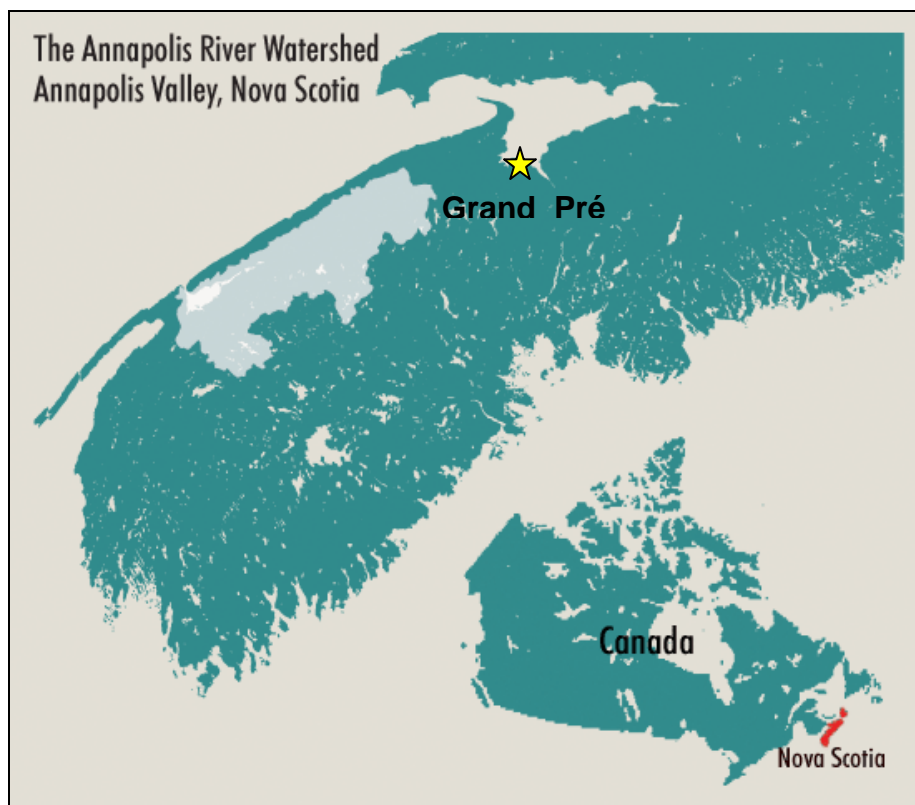


Figure 1. Map of Nova Scotia, depicting the village of Grand Pré, Nova Scotia. The light blue area on the map represents the Annapolis River Watershed, within the Annapolis Valley. This is the geographic area in which the Clean Annapolis River Project (CARP) typically conducts its project work.

Given that there are no conservation goals for these sites due to lack of high-value natural areas, and mixed land ownership, garlic mustard is not interfering with any specific targets. Currently, there is no way of knowing the extent to which forests in Nova Scotia might be affected by this plant.



Threats posed to natural areas by garlic mustard are documented in the “Garlic Mustard” section of this document, under the heading “Damage & Threats.” Due to its documented ability to invade and impact undisturbed closed-canopy forested systems (e.g., Stinson et al. 2006, Meekins and McCarthy 2001, Munger 2001, Nuzzo 2000), project partners and supporters feel that developing a management plan would be a proactive measure. Though one management goal cannot be specified for the entire infested area, all project partners have the collective goal of preventing further spread and/or new introductions of garlic mustard in Nova Scotia. After the initial management year (2008), partners have chosen to pursue management actions again in 2009, 2010 and 2011. Background information on how this management initiative came to be is detailed in Appendix A.

Given new research information (Nuzzo et al., 2009, and personal communication with the lead researchers, Victoria Nuzzo and Bernd Blossey), our control actions in 2012 will be drastically reduced. Changes in forest communities and plant invasions are now believed to be driven by the invasion of another alien species – earthworms. Glaciation killed all of the native worms in Canada and earthworm species that are now present arrived with the Europeans centuries ago as part of ship ballast, potted plants and other packing materials. Earthworm invasions from the cities to rural agricultural and forested areas markedly alters soil chemistry and physical structure and inhibits seed germination and growth of soil fungi (mycorrhizae) that assist the growth of many of our native plants. These changes in turn enable the growth and spread of invasive alien plants (IAPs) like garlic mustard. Also, intense grazing of forest understorey plants by whitetail deer indirectly aids the spread of IAPs (Knight et al., 2009; Nuzzo et al. 2009). Unless, one is prepared to control the growth and spread of earthworms (and deer), the current recommendation is to leave garlic mustard infestations alone. In time, the alien and natural plants species will come to a new equilibrium.

## Garlic Mustard

**Note:** Unless otherwise cited, information on plant biology, life history, threats, and distribution, is drawn from Nuzzo (2000), which is an “Element Stewardship Abstract” (ESA) prepared for The Nature Conservancy (TNC). ESAs are summaries of available information on invasive species, compiled from literature, researchers, and managers. Similar information is also widely available in less detail on numerous invasive species factsheets.

### Description

Native to Europe, garlic mustard is a biennial herb reproducing solely by seed. The first-year plants are basal rosettes with kidney-shaped leaves with scalloped edges (Figure 2a). In early spring of the second year, the plant produces a single or few-branched ~1m tall flowering stalk (in NS, June 2008, flowering stalks ranged from 8cm to almost 2m tall). Alternate leaves on the flowering stem are triangular in shape, and sharply toothed (Figure 2b). Garlic mustard, as the name implies, has a strong garlic odor in spring and fall, which differentiates it from all similar native species. Interestingly, some people who have a garlic-rich diet have difficulty recognizing the garlic mustard odour (Bob Pett, Jocelyne Marchand, personal communication 2008). Small flowers have four white petals arranged in a cross shape. First flowers were noted in NS on 10 May 2008 and 18 April 2009 (Sam Vander Kloet, personal communication 2008, 2009). Seeds are borne in linear siliquae, and a single plant can disperse up to 8,000 seeds before dying in mid-late summer. The seeds are spread primarily by anthropogenic disturbance. Garlic mustard seed can

remain viable in the soil for up to five years, and some sources claim up to seven years (Johnson 2001).



Figure 2a. Handful of first-year garlic mustard (*Alliaria petiolata*). These rosettes are quite large, but size is highly variable.



Figure 2b. Top of a second-year garlic mustard (*Alliaria petiolata*) displaying small white cross-shaped flowers, and triangular toothed leaves.

## Current North American Distribution

Nuzzo (1992, 1993, cited in Nuzzo 2000) noted that garlic mustard has demonstrated exponential spread since its introduction. Within Canada, garlic mustard occurs in British Columbia, Ontario, Quebec, New Brunswick, Nova Scotia, and Prince Edward Island. In the United States, the plant is most common in the Northeast and Midwest, but also occurs as far west as Oregon and Washington, as far south as Georgia and has also been found in Alaska. North American distribution maps are available from United States Department of Agriculture (USDA) Plants Database website; and more recently updated Natureserve explorer online.

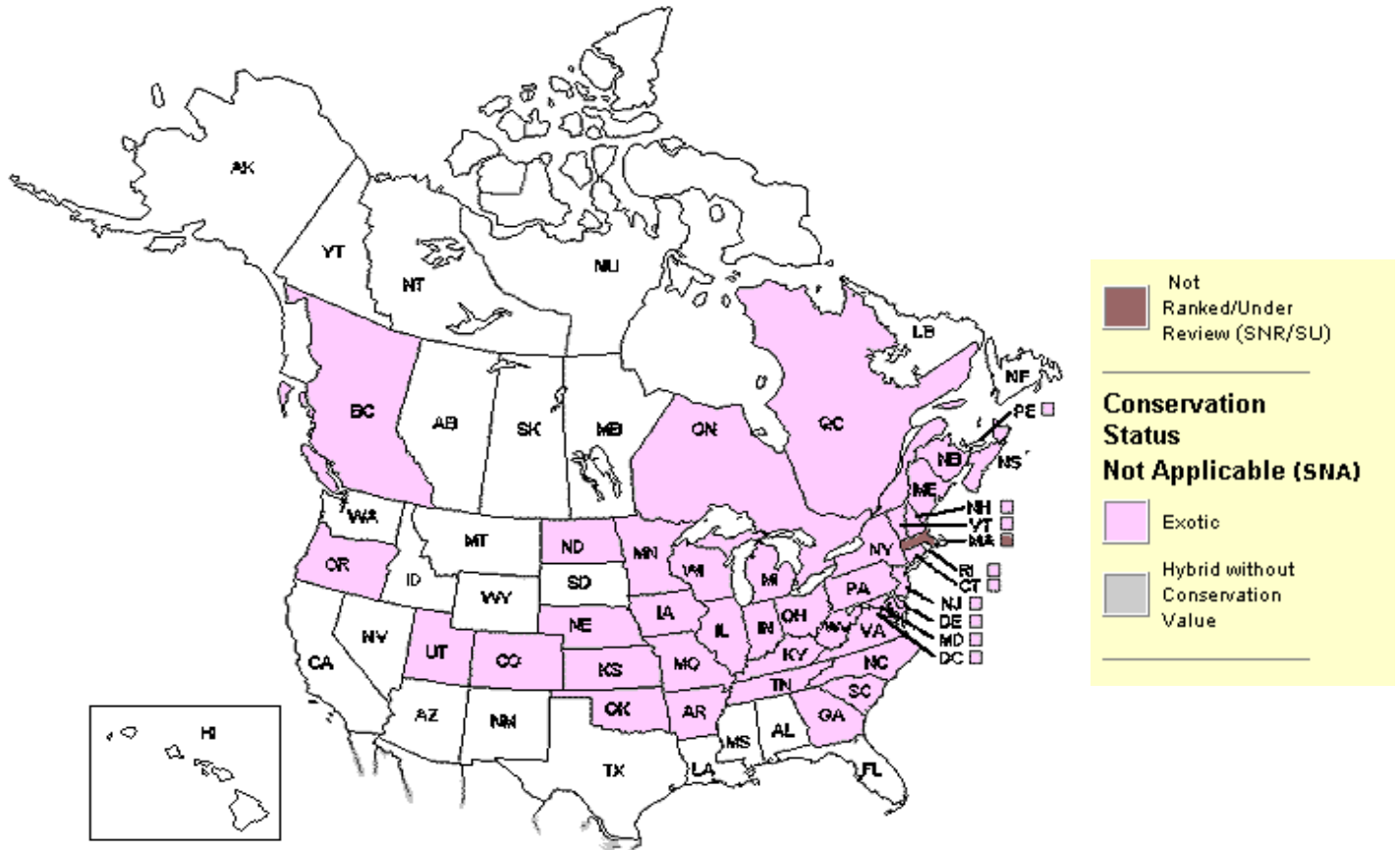


Figure 3. North American distribution of garlic mustard (*Alliaria petiolata*). (Natureserve Explorer 2010)

The USDA site does not list PEI as having any occurrences, but garlic mustard has been present in Prince Edward Island National Park for several years (Kirby Tulk, Jackie Waddell, personal communication 2007). A distribution map of garlic mustard in North America created by Natureserve includes PEI.

Garlic mustard has persisted in the Saint John River Valley of New Brunswick for several decades, and was cited in the *Flora of New Brunswick* (Hinds, 2000). Much of the Saint John River Valley is a distinct ecoregion in the Atlantic provinces, with unique species such as silver maple (*Acer saccharinum*). The distribution of native Acadian Forest is inclusive of New Brunswick and Nova

Scotia. Understanding the spread of invasive garlic mustard in New Brunswick could provide insight into its behavior in Nova Scotia.

The current known distribution for garlic mustard in Nova Scotia is described in the “Inventory” section of this document, with further notes in Appendices B to F. The E.C. Smith Herbarium at Acadia University is soliciting additional reports of this species through the distribution of notices and flyers (Appendix G and H). Yearly spread of garlic mustard along roadsides, from the point of origin in Grand Pré, has been observed by Dr. Sam Vander Kloet (personal communication 2008), and others.

## Damage & Threats

Many invasive plants remain weeds of disturbed landscapes, and do not pose a real threat to native ecosystems. Garlic mustard is one of the few species that has the ability to invade and dominate closed-canopy forest understories (see Figure 4). The Canadian Council of Forest Ministers (2006) describes garlic mustard as “highly invasive” in reference to Canadian forests. This may be of particular concern in Atlantic Canada, where the remaining Acadian Forest is considered an endangered ecosystem type (Ricketts et al. 1999). Recent research has indicated that garlic mustard invasion in forest understories may suppress the regeneration of native tree seedlings, including sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), and white ash (*Fraxinus americana*), and in turn alter the overall community composition (Stinson et al. 2006).



Figure 4. Garlic mustard infestation at Core 3 on Ridge Road near the Grand Pre Road, June 2009.

Havinga et al. (2000) list garlic mustard as a Category 1 invasive plant in southern Ontario, defined as “species that exclude all other species and dominate sites indefinitely.” They note that garlic mustard “dominates forest herb layer”. Blaney (2001) and Blaney and Hill (2006) identified garlic mustard as one of the most important invasive alien plants in the Maritimes, and noted that it may

have the potential to impact native species. More recently, Blaney, a botanist with the Atlantic Canada Conservation Data Centre (ACDC), stated that "...there is high potential for local impacts that would be significant to biodiversity conservation", in reference to garlic mustard in NS (personal communication 2007).

In addition, garlic mustard may impact diversity and cover of native plant species, threaten several species of butterfly, and render habitat less suitable for native animals. There are conflicting observations on the use of garlic mustard as food by whitetail deer (Cavers et al., 1979, cited in Nuzzo 2000).

In 2006, garlic mustard was given a High/Medium I – Rank (Invasive Species Impact Rank; US National Park Service, Nature Conservancy and NatureServe) in the United States. As described by NatureServe 2010, several factors contribute to the assignment of this rank (below). These factors summarize the threat posed by garlic mustard ranked in relative importance to other invasive species in the United States, where garlic mustard has become more established.

*Low significance for impact on ecosystem processes and system-wide parameters and accessibility of invaded areas.*

*Medium/Low significance for:* Impact on ecological community structure (measured only by species richness, not composition), proportion of potential range currently occupied (with comment that it is expanding into new habitats), impact of management of native species with note that there may be non-target damage to native look-alikes associated with herbicide use.

*High/Moderate significance for:* Diversity of habitats or ecological systems invaded in the United States, current trend in total range within the United States, long distance dispersal potential within the United States, reproductive characteristics, general management difficulty, minimum time commitment for effective management.

*High Significance for:* Impact on ecological community composition, impact on individual plant or animal species, conservation significant of communities and native species threatened, current range size in the united states, proportion of current range where the species is negatively impacting biodiversity in the united states, proportion of US biogeographic units invaded, local range expansion or change in abundance (on average doubling every 4 years; Nuzzo 2000), inherent ability to invade conservation areas and other native species habitats.

## **Inventory**

**Note:** An accurate inventory of garlic mustard in Nova Scotia was one of the management objectives identified for Years 1 to 4 (2008 – 2011). Methods for describing density are derived from Atkinson (2008) and the Aldo Leopold Foundation (2007).

The only known population of garlic mustard in Nova Scotia was discovered in 2002 along a roadside adjacent to private property in the village of Grand Pré (Ruth Newell, Jim Wolford, personal communication 2007). After its establishment, botanists at Acadia University and local community members recorded the spread of this population along roadside ditches west to Lower Wolfville, and east to Hantsport. Figure 5 illustrates the spread of garlic mustard in the Grand Pré area between 2005 and 2007.

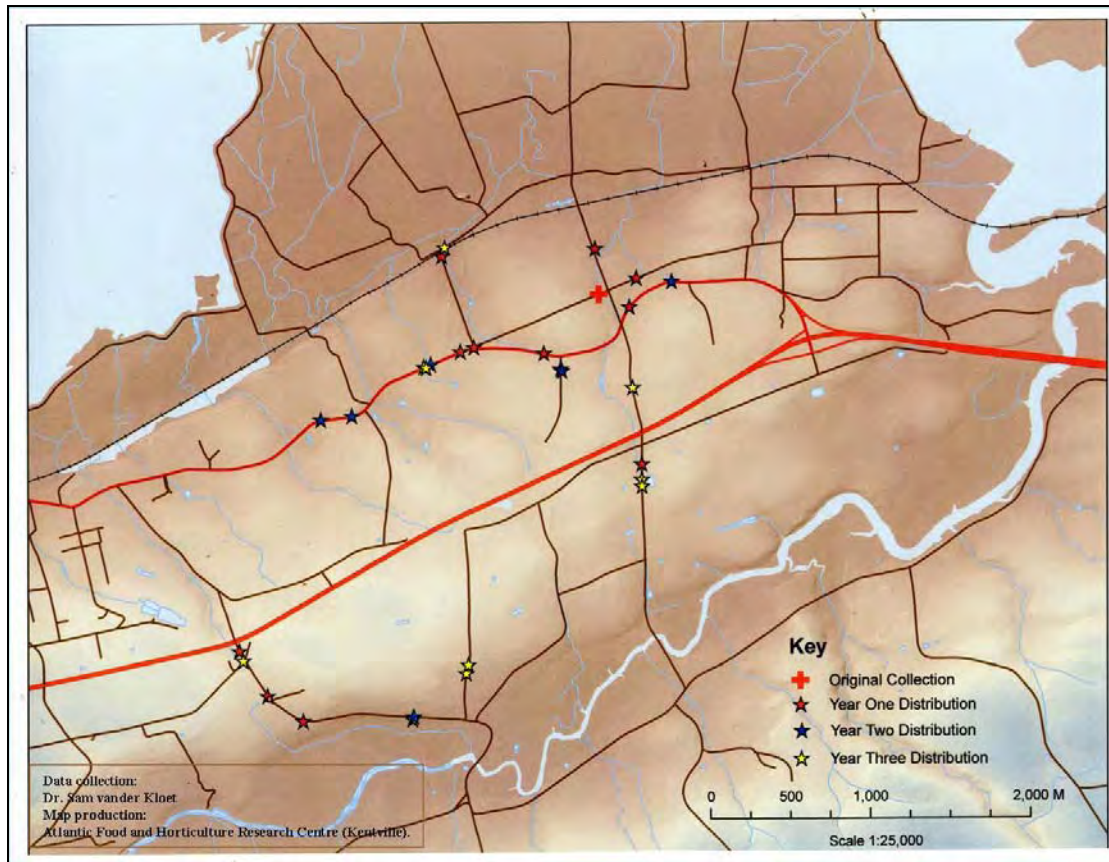


Figure 5. Spread of garlic mustard (*Alliaria petiolata*) from the point of original collection in Grand Pré, NS. On this map, Year one was 2005, year two was 2006, and year three was 2007. Data collected by Dr. Sam Vander Kloet, and map produced by the Atlantic Food and Horticulture Research Centre.

In May of 2009, 2010 and 2011, the extent of garlic mustard in NS was revisited and re-mapped when necessary by NSTIR-NSYCC staff. Known populations from the previous year were re-examined. Several new populations discovered in Kentville and Canning in 2009 were re-investigated in 2010. A similar mustard species was observed at the Kentville (Sesame Street), but there was no evidence of garlic mustard. However, garlic mustard was present in 2011. No plants were seen in Canning in either 2010 or 2011, although there was no GPS coordinates for the original 2009 report. Continued monitoring in these outlier areas is recommended.

In 2010, the Core 1 population was considerably expanded from the formerly understood southern boundary at old Post Road – at least to properties on the South side of Highway 1, and at least twice as far to the East. The 2010 extent of garlic mustard is mapped in Appendix C. Several residents noted that garlic mustard in this area has existed over the past 3 years and the extent is likely to be even larger on private lands located between and near Core 1 and Core 2.

The extent of Core 2 also appears to have increased in 2010 and 2011. Ditches on the western corner of Martin Cross road and Melanson Road were densely filled with garlic mustard. A stream directly across from Martin Cross road which was previously considered to be an outlier should now be considered as part of Core 2. The northern extent has also expanded to the top of the hill along the edge of agricultural fields and a new vineyard. Based on 2009 descriptions, garlic

mustard and another invasive plant, wild chervil (*Anthriscus sylvestris*), have moved along the small stream through a small wooded area to a cow pasture on the Gaspereau River dykelands. During a QA/QC visit, a neighbouring home owner informed us of dense wild chervil in their backyard which they have been managing for the past 3 years by pulling (and burning old plants) and by mowing, with little success.

The outlier in Hantsport appears to have been reduced in 2010 and again in 2011 due to management efforts. Other outliers described in 2008 and 2009 persisted in 2010 and in 2011.

In 2011, populations were confirmed in Truro's Victoria Park by contacts at the Nova Scotia Agricultural College (NSAC). Other possible outliers in Truro could be further investigated.

A Port Williams population of garlic mustard was reported in 2010 and in 2011 this location was visited and coordinates were taken at the roadside bank invasion. This site can be found on High Street near residence 945. Dense populations were observed along the roadside banks down to a small tributary of the Cornwallis River. There is some speculation that the plant may have come from wild birdseed mixture used in feeders along the edge of the bank.

It is possible that garlic mustard is present in other areas of Nova Scotia but that occurrences have not been reported or recorded. Ruth Newell at the E.C. Smith Herbarium at Acadia University continues to solicit additional reports through the distribution of notices and community meetings. In June 2010, Dr. Bob Pett investigated a reported sighting of garlic mustard at a residence in Halifax only to find it was a false claim.

## **Management Plans**

### **Goals**

At a March 2008 planning meeting, project partners (NSTIR, Parks Canada, and CARP) identified four long-term goals for the management of garlic mustard in NS (as per meeting minutes taken on 19 March 2008): (1) eradicate all known garlic mustard populations in NS; (2) prevent further spread and new introductions of garlic mustard in NS; (3) conduct a case study of the best management practices (BMP) that could be applied to managing NS roadside populations; and (4) increase public awareness of garlic mustard and other invasive alien plants.

When mapping the known garlic mustard populations in May and June 2008, it was discovered that the extent of the infestation was much larger than originally thought, making the goal of eradication an unlikely prospect. As such, long-term management goals were revised as follows (as per meeting minutes taken on 27 August 2008):

- Prevent further spread and new introductions of garlic mustard in NS.
- Conduct a case study of BMPs that could be applied to managing roadside populations of garlic mustard in NS.
- Increase public awareness of invasive alien species.
- Engage other agencies in the management of garlic mustard in NS, and solicit additional project support.
- Establish a management committee to oversee the management plan implementation and annual revisions.

Project partners agreed that recommended long-term goals be revisited on an annual basis to determine whether or not they are still realistic. Re-evaluation of goals must consider the following factors: distribution and extent of garlic mustard, resources of the management committee or project partners, community involvement, and monitoring and evaluation of previous management efforts.

## Objectives

Year 1 (2008-2009) management objectives for garlic mustard were identified as follows:

- Accurately inventory/map all known populations of garlic mustard in NS.
- Prevent seed production in all known outlier/satellite populations of garlic mustard in NS.
- Implement BMPs along roadsides in the Grand Pré area.
- Increase public awareness about garlic mustard, and invasive alien plants in general.
- Engage the communities of Grand Pré and surrounding areas in taking an active role in the management of garlic mustard.

The Year 2 (2009-2010) and 3 (2010-2011) management objectives were updated to include:

- Further inventory and mapping of garlic mustard populations in NS.
- Removal of all adult plants in outlying populations in order to prevent seed production.
- Engage community and increase public awareness about garlic mustard and invasive plants in general through posters, an information session and personal communications.
- Observe biological traits and evaluate control measures through use of permanent sample plots.

The management objectives for Year 4 (2011-2012) were scaled back on the basis of discussions between Marika Godwin, ISANS coordinator, and two US experts in garlic mustard, Victoria Nuzzo and Bernd Blossey (emails in August 2010). Based on more than 10 years of monitoring, the US experts recommended that established garlic mustard infestations should be left alone.

Populations should gradually subside over a period of approximately 6 to 10 years. Continued active control, by pulling, cutting, spraying, burning, etc., actually promotes garlic mustard growth and spread. Interestingly, the underlying cause relates to two other invading species, earthworms and whitetail deer. As noted earlier, glaciation killed off all of the native earthworms in Canada and today's worms originally came with European colonists in ship ballast, potted plants, and packing materials. Deer were introduced to NS in the 1890s and are now very common in most of Nova Scotia. Earthworms are essential for garlic mustard to spread and deer aid the process by indirect means – heavy grazing of forest understory vegetation. Further information on this topic is given in a paper by Nuzzo et al. (2009) and Knight et al. (2009).

In summary, the Year 4 (2011-12) management objectives included:

- Further inventory and mapping of garlic mustard populations in NS.
- Removal of adult (second-year) plants limited to the newer outlying populations only (e.g., Hantsport, Wolfville, Greenwich, Kentville).
- Engage community and increase public awareness about garlic mustard and invasive plants in general through posters, an information session and personal communications.
- Observe biological traits and evaluate control measures through use of permanent sample plots.



Given the new advice from the US experts, the observations and results of 4 years of BMP application, the Year 5 (2012-2013) management objectives will be revised again to include:

- Continued surveillance of garlic mustard populations in NS.
- Removal of adult plants limited to the newer outlying populations only (Kentville, Greenwich, Wolfville, and Hantsport).
- Maintain communication with ISANS and staff at E.C. Smith Herbarium, Acadia University.

## **Summary of Management Objectives:**

### Inventory/Map

See the “Inventory” section for a description of the known extent of garlic mustard in Nova Scotia. Maps are provided in Appendices B and C.

### Prevent Seed Production in Outlier Populations

Adult (second-year) garlic mustard plants in outlier populations were hand-pulled in 2008 through 2011, as described in the “Management” section of this document, under the heading “Materials & Methods”.

### Implement Roadside BMPs

BMPs for working in ditches containing garlic mustard were researched, written, and forwarded to NSTIR for their consideration (Godwin and Stewart 2007). After circulating the BMP document to their Operations staff, the Environmental Services Section of NSTIR committed to implementing the recommendations in 2008 through 2011. Control and prevention of further spread of this invasive plant relies on the following practices: (1) proper identification of garlic mustard plants in all life history stages (*i.e.*, training), (2) mechanical removal of the plants during the flowering stage and prior to seed production (*limited to hand pulling only*), (3) proper disposal of cut plant material to reduce the risk of spread, (4) quality control surveys to inspect cut areas and the entire infested area for missed or late-blooming plants, (5) cleaning of equipment before it leaves the affected area (*none required as mowers not used*), and (6) long-term commitment by NSTIR, Parks Canada, and the local community to implement the BMPs until the seedbank is depleted. The BMPs are described in greater detail in Pett et al. (2008).

### Increase Public Awareness

In 2008, CARP organized and led a community information session for the residents of Grand Pré and surrounding area, held on 14 August 2007. The goals were to increase public awareness about garlic mustard, and engage community members to take action. A good turnout of 20 local residents and ensuing lively discussion were encouraging. A second community information session 27 March 2008 was attended by only 8 people. It was later discovered that another community meeting was scheduled for the same date. In March and April 2008, CARP delivered presentations about garlic mustard to 10 Women’s Institutes of Nova Scotia (WINS) groups (more than 60 people), including as an invited guest at the Eastern Kings District WINS annual meeting. Eastern Kings is the geographic area in which garlic mustard is known to occur, and therefore comprises an important audience. On 19 May 2008, CARP was invited by the Grand Pré Community Association to set up a display at the Horton Community Hall Plant Sale, an annual fundraiser in support of the hall. Garlic mustard identification, impacts, and management were discussed with approximately 30 local residents. In early June 2008, CARP staff conducted door-to-door community outreach in Grand Pré and surrounding area. A flyer with information about garlic mustard (Appendix D) was delivered to 119 households. Staff also collected contact

information for residents that they spoke with, and documented their willingness to participate in future community management initiatives.

A spreadsheet of this contact information is archived at CARP. In addition, CARP contacted David Morse (MLA, Kings South, and Minister, NS Natural Resources), Mark Parent (MLA, Kings North, and Minister, NS Environment), Fred Whalen (Warden, Municipality of the County of Kings), and John Fuller (Councillor, Municipality of Kings) in an effort to solicit municipal support for the project. Though we were commended for our efforts, there was no offer of support, and no political presence at any public garlic mustard event.

In 2009, an information session was held for the community of Grand Pré on June 4, 2009 at the Grand Pré National Historic Site. This presentation had very low attendance. However, it was noted by the two NSYCC students that most of the community was already very informed about and interested in the Garlic Mustard problem. They noticed that, while working in the field, residents that passed-by would comment on the work being done and were already aware of the issue. Residents were also very receptive to any new information on the project and any ideas regarding how they could get rid of garlic mustard on their own properties. This is evidence that the community involvement campaign of 2008 was very successful.

Another information session was held for the community of Grand Pré on June 3, 2010. Attendance was again low, but like 2009, and participants were all aware of the issue. Verbal contact with local residents also led to the discovery of new garlic mustard populations that were not previously known therefore leading to a better understanding of the problem areas within the Grand Pré area. Although attendance was low at the information session the mayor of Wolfville was present and mentioned that the next year he would look into distributing garlic mustard fact sheets using the postal service in order to increase public awareness. It was also mentioned that a column would be published in the Chronicle Herald on invasive species and that garlic mustard would be included to further educate people on the problems certain invasive species pose. Informative posters were also put up around the community.

On June 7, 2011, a third information session was held in Grand Pré and attendance was again low despite branching out to new advertising for the meeting. Posters were placed in town centres, tourist bureaus, local gathering spots, and given to those interested at Acadia University.

### Engage Communities

Project partners discussed volunteer training, and community work days or pulling events, but none were coordinated for 2008, 2009, 2010 or 2011 because of unknowns related to peak flowering (spring weather-dependent) and best means to dispose of pulled plants. Despite numerous requests for leadership from within the Grand Pré and communities, no volunteers came forward. However, during the implementation of control efforts, numerous local residents came and talked with CARP and NSTIR staff about garlic mustard, and several people arranged for NSTIR staff to collect garbage bags of pulled plant material from their properties. In 2010, black garbage bags were dropped at a collection site on Miner Lane that were not from NSTIR which shows that local residents are still active in attempting to control further spread of garlic mustard. Parks Canada and the E.C. Smith Herbarium at Acadia University received more than 10 phone calls after CARP's public outreach campaign (Wayne Kelley, Ruth Newell, personal communication 2008), demonstrating public interest in the issue. One possible explanation for the lack of leadership at the community level may be that Grand Pré has submitted a bid to the United

Nations Educational, Scientific and Cultural Organization (UNESCO) for consideration as a “World Heritage Site”. The bid is a very involved process, and numerous residents were previously committed to this effort (see [www.nominationgrandpre.ca](http://www.nominationgrandpre.ca)).

### Further research efforts

In 2010, permanent sample plots were created and effort was made to make observations on the biology of garlic mustard. In 2011 these sample plots were revisited and two more were established. In future years, more ecological and biological research effort led my university researchers could expand our knowledge of the biology of Nova Scotian populations and potentially provide a better understanding of the behaviour and threat of garlic mustard in the Acadian Forest community.

Garlic mustard has been known in the Saint John River valley possibly for a longer period of time based on its presence in the *Flora of New Brunswick*, 2000 second edition. In 2010, UNBSJ plant biology lab was informally asked about the species but there was no knowledge in their study areas. The Acadian Forest in New Brunswick is likely more comparable to Nova Scotia than other regions to the west where garlic mustard has previously been documented (see Figure 3).

### **Materials & Methods**

Note: Unless otherwise cited, information on management options is drawn from Nuzzo (2000).

Control techniques for garlic mustard are well documented by Nuzzo (2000). Given that garlic mustard reproduces solely by seed, the key to control and eventual eradication is reducing or eliminating seed production. Control methods for garlic mustard include burning, herbicide, cutting, pulling, and mowing. While no control method has proven to be 100% effective, cutting plants at ground level during peak flowering has resulted in 99% mortality. Mowing may have a similar impact, but the use of mowing equipment presents additional risks for soil disturbance, damage to native vegetation, and further spread of seed. Plants cut, pulled or mowed prior to full flowering may have enough resources to send up additional stems and hence a second mowing may be required together with comprehensive quality assurance surveys. Depending upon the type of mower used, the flowers on cut flowering stems may also have sufficient resources to sustain seed production (Solis 1998, cited in Nuzzo 2000; pulled flowering plants were still able to produce seed when laid in piles on the ground). It is unknown whether this latter risk could be minimized by the use of a “Brush-Hog” mower that effectively mulches the plants and may eliminate the need to collect and dispose of cut materials. Upon assessing available options and resources for control, project partners decided to implement a combination of mowing, cutting, and pulling in 2008, while only pulling was used in 2009 through 2011.

As previously stated, when conducting inventory and mapping activities it was discovered that the extent of the infestation was beyond the scope of the project’s management resources. The many occurrences on private lands also made it difficult to both map and control the infestation. It was therefore decided that efforts would be concentrated on controlling satellite (outlier) populations, and reducing the risk of spread along major transportation corridors away from the three Core populations (see Appendices B to E and the Excel Master Spreadsheet for further information; the satellite/outlier populations were assigned names based on their geographic locations).

## Materials Required

The following materials are required for control of garlic mustard:

- Gloves
- Closed-toe footwear
- Health and safety equipment (appropriate first aid kit, water, sunscreen, insect repellent)
- Black garbage bags (regular and 3mm contractor grade)
- Camera
- GPS unit
- Datasheets
- Clipboards
- Pencils
- Flagging tape
- Gas-powered trimmer (whipper-snipper) – optional
- Painted stakes and tool for driving these in order to create permanent sample plots.

## Methods for Outlier/Satellite Populations

Outlier populations were treated by staff and volunteers. In previous years, at all outlier populations, identified above, all second-year (flowering) plants were counted, hand-pulled, and bagged. Teams of two people recorded the following information at each outlier site: date, name(s), start time, site name, GPS coordinates, location description (with sketch), number of plants pulled, number of garbage bags, end time, total time, and comments/observations. Upon completion of treatment, garbage bags were double-bagged in 3mm contractor-grade black plastic bags, and placed on the roadside for same-day collection by NSTIR trucks.

Second-year (flowering plants) were hand pulled, GPS coordinates were taken of new locations, and sample plots were setup in certain areas to determine how effective hand pulling was in controlling the spread of seeds in future years. The project leader was informed of areas covered as each of the previously identified outliers was completed and QA/QC efforts took place.

## 2008 Methods for Roadsides in Core 1 Population

Roadsides in the Core 1 population were treated by NSTIR staff, NSYCC students and various volunteers. The project leader provided “in the field” training to NSTIR employees. This included site visits to ditches infested with garlic mustard, instruction in first and second-year plant identification, demonstration of hand-pulling and plant bagging procedures, as well as delineation of areas to be treated (maps provided). All roadside (ditch) populations within Core 1 were hand-pulled and bagged. No data sheets were completed by NSTIR staff, but they kept the project leader informed of areas treated. The number of plants pulled was not recorded in the Core 1 population, as tallying pulled plants significantly increases treatment time (Brendan MacNeill, personal communication 2008). Again, upon completion of treatment, garbage bags were double-bagged in 3mm contractor grade black plastic bags, and placed on the roadside for collection by NSTIR trucks.

## Methods for Parks Canada Properties

All second-year (flowering) plants on the small federal property (Grand Pré National Historic Site) were hand-pulled and bagged by Parks Canada staff throughout the growing season.

Outcomes for Year 1: Over a 2 week period between June 9 and June 20, 2008, NSTIR, CARP staff, and community volunteers hand-pulled 106 extra large garbage bags full of garlic mustard

plants from the core infestation area and six outlier populations. Parks Canada staff pulled three garbage bags full of garlic mustard plants from their properties. For several reasons, no mowing was conducted in the Grand Pré area specifically for the purpose of garlic mustard control. The primary factor in this decision was that no pressure washing equipment was available for on-site cleaning of the mower, which, if not cleaned, would pose a risk for dispersal. The second factor was that most of the garlic mustard plants are located beyond the reach of the mower blade (i.e., upper side of ditches, and low lying areas). Other roadside vegetation, particularly grasses, was very tall at the proposed mowing time, and would have constituted the bulk of cut plant material that then would have had to be collected and bagged.

Outcomes for Year 2: Over a four week period between May 19 to June 12, 2009, NSTIR staff and some community volunteers hand-pulled 36 extra large garbage bags full of garlic mustard plants from core infestation areas and 10 outlier populations. Parks Canada staff also pulled several garbage bags full of garlic mustard plants from their property. Planned changes for Year 2 proposed that NSTIR would either mow or whipper-snip some of the garlic mustard populations prior to peak flowering in order to minimize the risk of seed dispersal. This was not implemented due to time restrictions as well as an unanticipated early flowering of the garlic mustard (April 18, 2009 whereas in the previous year the first flower was noted on May 10, 2008). Another reason mowing was not used was the necessary cleaning of the machines required to reduce the spread and the danger of using heavy machinery in ditches. It was also planned to engage Grand Pré community members in a “community work day” during Environment Week (the first week of June). This objective was also not achieved due to time constraints associated with the late (mid-May) start of picking.

Outcomes for Year 3: Over a four week period between May 19 to June 11, 2010, NSTIR staff and some community volunteers hand-pulled an undetermined number of garbage bags because they were not counted before pick up. These bags were filled with garlic mustard from core infestation areas and the 10 outlier populations along with newly discovered populations. Parks Canada staff also pulled a couple bags full of garlic mustard plants from their property. Through direct verbal communication with Parks Canada staff, they believe of all the methods practiced for controlling the spread of garlic mustard hand pulling the plants and ensuring the roots are uprooted is the most effective method. As stated above planned changes for year 3 proposed the NSTIR would either mow or whipper-snip some of the garlic mustard populations prior to peak flowering in order to minimize the risk of seed dispersal, but this method again was not practiced due to the same reasons as the previous year. Another similarity to year 2 was that a “community work day” was not organized, again for similar reasons as the previous year.

Outcomes for Year 4: In 2011, some outlier populations were hand pulled as the primary form of control on seed dispersal in late May and early June. All outlier sites were visited and re-mapped if necessary, but hand-pulling occurred at only the outlier sites with small infestations – Kentville, Greenwich, Wolfville, and Hantsport. The 3 years of active control at Hantsport seemed to be paying-off; very few second-year plants were observed (and pulled).

#### Schedule

It was anticipated that peak flowering would occur around mid-June (Kirby Tulk, personal communication 2008), and control activities for Year 1 were planned to start on June 9, 2008, and continue until the project objectives were met. Based on the outcomes of the first (trial) year, and considering plant biology, project resources, community involvement, and annual objectives,

partners should strive to establish a management schedule for 2009 and beyond. Approximate dates include the following:

- April-May – conduct monitoring surveys to assess effectiveness of previous control efforts and search for new occurrences;
- May – engage “Invasive Plants Team” (NSYCC and NSTIR staff) and make plans for community/volunteer training and management activities;
- Early June – implement volunteer training and management activities;
- Early June – implement all project management activities (Note: this is dependent on the type of actions planned for the next control year);
- Late June – Quality Assessment/Quality Control (QA/QC) surveys;
- July, August, September – monitoring activities;
- September and beyond – evaluate and revise management plan.

In order to maximize use of resources, mechanical control of garlic mustard plants should be conducted at peak flowering (Nuzzo 2000). The logic behind this is that by waiting until peak flowering (full bloom and/or siliques developing), the plants will have used up too many resources producing flowers to send up a second flowering stalk in the event that the entire root system is not pulled. In other words, you get the most “bang for your buck” for control. Unfortunately, because cut/pulled flowering plants may still produce viable seed, plants must be collected for disposal, as opposed to left on site to decompose. In 2010, plants that were mowed or cut on the edges of private land were observed flowering a second time though the plants were weakened and flowers not as robust, suggesting less seeds were produced. We observed plants which were chemically treated on private land were completely killed.

## **Disposal**

Because pulled and cut material can still generate viable seed (Solis 1998, cited in Nuzzo 2000), harvested plant material must be collected for proper disposal. Composting is generally not recommended for highly invasive plants as it typically requires off-site transport and there are no guarantees that the process is hot enough and lengthy enough to kill all seed (e.g., Ward 2003). Based on literature review, and expert recommendations (e.g., Heather Stewart, Julia Reekie, Kirby Tulk, personal communication 2007), the ideal disposal method for cut or pulled flowering garlic mustard, and other invasive plants, is on-site incineration. Unfortunately, a portable incinerator was not available during 2008, and purchasing one was not an option.

A viable alternative to incineration is the “cooking” of plant material in black plastic, followed by disposal in a landfill (Adirondack Park Agency 2006, and Diane LaRue, personal communication 2007). Sealing harvested plant material in thick black plastic (3mm thickness minimum) and leaving it in the sun to liquefy is an effective method that eliminates the risk of seed dispersal (Adirondack Park Agency 2006). Though very rapid decomposition has been recorded using clear bags (Kirby Tulk, personal communication 2008), literature suggests leaving black bags in the sun for a minimum of three weeks to allow plant material to decompose (Hamilton County Soil and Water Conservation District, date unknown).

Outcomes for Year 1: This year, all cut/pulled plant material was double bagged in black plastic (regular garbage bag first, then 3mm contractor-quality bags). Each large 3mm bag holds two to three smaller bags, depending on how full they are. At the end of each day, NSTIR Operations staff collected the bags and transported them to the NSTIR base in New Minas, NS, approximately

12 km away from the infestation. This included a number of bags that were placed roadside by private landowners who had pulled plants on their own properties. Bags were laid out (not piled) on gravel, in a slight depression to prevent movement, and left to decompose. Six marked bags of the 106 large bags are checked weekly to assess the state of decomposition. The following information was recorded on a datasheet: bag number, colour of plants, state of decomposition, odour, and presence of mould. At the time of printing of the 2008 programme, project partners were looking at a variety of options for disposal of the decomposed plant material. The province of Nova Scotia does not permit landfilling of organic material, and as described above, composting is generally not recommended for invasive plant material. In the Spring of 2009, bags were transported to the incineration facility at the Nova Scotia Agriculture College in Truro, and burned.

Outcomes for Year 2: Similar to Year 1, all cut/pulled plant material was double bagged in black plastic contractor-quality bags. The bags were collected and stored near a core area. Bags placed roadside by community members were also picked up and placed with the NSTIR collection. The bags were laid out on gravel roadside, which prevented movement, and later transported to the NSTIR Base in New Minas for further decomposition.

Outcomes for Year 3: Similar to previous years, all cut/pulled plant material was double bagged in black plastic contractor-quality bags. The bags were collected and stored on Old Post Road within the boundary of Core 1. Bags were subsequently picked up for storage at the NSTIR base at New Minas. Some community members complained about an inability to properly dispose of the material once managed on their own properties and asked for a designated pick up day. Confusion about proper disposal methods could result in viable seed accidentally ending up in landfills and municipal compost sites, contributing further to spread.

Several sample plots were established to test the viability of seeds “cooked” in plastic bags between 2009 and 2010. If seeds are destroyed by this method, it would be cheaper than incineration.

Outcomes for Year 4 (2011): As in previous years any plants that had been pulled were disposed of by double bagging in black plastic bags and brought to NSTIR base in New Minas. A few residents did provide their own bags. Also, new sample plots were established in “clean sites” located near the Greenwich outlier site in order to check for seed viability after “cooking” in plastic bags. Unfortunately, the previous year’s plots in what we thought were weed-free “clean sites”, had second year flowering plants (see Appendix E; small rosettes must have been missed during the 2010 surveys and plot establishment).

## **Evaluation**

Two types of monitoring are required for this program. The first is to determine that short-term objectives are being met, and that the process is being carried out correctly and at the right time. The second is to determine that over the long-term, the management program is effective for the ultimate goal of prevention of further spread and new introductions. The short-term monitoring is a quality assessment/quality control (QA/QC) mechanism to determine if the management actions are being applied at the correct time, and if they are effective. This will include monitoring for presence/absence of new or remnant flowers and seed material after the management actions have been implemented.

Long-term monitoring is required to determine the success of the management program. This management effectiveness monitoring is required for assessment of overall success balanced with costs. To adequately carry out this type of monitoring, population density or biomass needs to be measured at the outset, and annually at the same time of year to determine if the plant density/biomass is actually decreasing. Recommendations by Nuzzo (2000) are to monitor annually for presence/absence, frequency, cover, density, and seed production using a meter square (m<sup>2</sup>) plot.

Outcomes for Year 1: While mapping garlic mustard plants using GPS, the team discovered that the area of infestation was much larger than originally known. Given the resources allocated to the project for 2008, it was determined that control efforts would be focused on isolated, outlier populations. Six populations (the only known outliers in 2008) were mapped and targeted for control. All adult garlic mustard plants were counted and hand-pulled from every site. These sites will be the focus of short-term and long-term monitoring efforts. Immediately following treatment, all sites were surveyed for missed plants, as part of the QA/QC plan. In the short term, July – September 2008, all outlier sites were to be surveyed once a month for new plants or new shoots coming off plants that were broken (as opposed to completely pulled) during the control effort. All outlier sites were surveyed in mid-late August, and no adult plants were found at any site. Some sites had been mowed through NSTIR's right-of-way maintenance practices.

Outcomes for Year 2: Outlier sites were surveyed in May to observe the changes in the density of plants and roadsides were surveyed for new populations as per the planned changes for Year 2. Roadside surveys were done on foot and by car with numerous locations found by Sam Vander Kloet. The Team discovered four new outlier populations that greatly expanded the total area of infestation, from Kentville to Hantsport and the Gaspereau River to Canning (efforts were again focused on isolated outlier populations for control). This large increase in area could be a result of further spread by garlic mustard but is more likely due to previous education, better identification by local community members, and disposal of "contaminated" soil (the Greenwich site is situated at a waste disposal site). All flowering garlic mustard plants were pulled by hand in the 10 outlier sites. Following treatment, sites were surveyed throughout the summer for any reoccurring flowering plants. In a large patch of garlic mustard found on Miner Lane in Grand Pré, a few large plants were also tagged. This was done in order to monitor the growth in following years and to see if the plant came back the following year.

Planned changes for Year 3: For the long term, outlier sites will be surveyed at the same time (April/May) every year for changes in the density of plants. Surveying of roadsides will take place yearly for new populations. For efficiency, roadside surveys must be done on foot or by bicycle as small plants are easily missed when traveling by car. Sam Vander Kloet has noted that small populations can appear and disappear from one year to the next, and these changes in frequency and cover should be noted. Some permanent 1m<sup>2</sup> plots should be established in the core population to monitor biological traits. This would best be done on property of private ownership, with landowner permission. The tagged plants should be examined and their status recorded to better understand the life cycle of the garlic mustard.

Outcomes for Year 3: Known satellite populations were observed still existing but managed areas appear to have demonstrated a decrease in the adult plants and rosettes present based on personal observations. Outlier sites were surveyed in May to observe the changes in the density of pants and roadsides were surveyed for new populations as per the planned changes for year 2.



Roadside surveys were done on foot and by car with a number of new populations found. New populations were found on Simpson bridge road, outside of core 1 which increased its size and on private land within Grand Pre area. This new large increase in area could be a result in the spread of the garlic mustard through the years but for the most part it could probably be attributed to the fact that people are becoming more educated about the plant and are able to identify it in new areas.

Upon further investigation of the Kentville site it was determined that garlic mustard in fact was not present but the area should continue to be monitored in case a reoccurrence occurs and the same can be said for the Canning population.

As was done in the previous year all flower plants in the outlier populations were pulled by hand and the areas were surveyed throughout the summer for any reoccurring flowering plants. When it came to locating tagged plants on Miner Lane the plants could not be found. Permanent 1m<sup>2</sup> plots were set up in areas of the Core 1 population as well as an outlier population on Melanson road and GPS coordinates were recorded so that biological traits can be monitored in subsequent years. Within these sample plots stems were counted and then pulled for a more quantitative comparison in Year 4.

Year 4 – Plans and Outcomes: For the long term, outlier sites will be surveyed at the same time (May-June) every year for changes in the density of plants. Surveying of roadsides will take place yearly for new populations. For efficiency, roadside surveys must be done on foot as small plants are easily missed when traveling by car. Sam Vander Kloet has noted that small populations can appear and disappear from one year to the next, and these changes in frequency and cover should be noted. The permanent 1m<sup>2</sup> plots and the areas where the “cooked” plants were placed should continue to be monitored in the following years to gain a better understanding of the biological traits. As noted above, areas where “cooked plant materials” were spread in 2010 (in supposedly weed-free clean plots) had second-year flowering plants. Obviously, we had missed the presence of the small first-year rosettes in the plots.

## **Resource Requirements**

Prior to the initiation of control activities, NSTIR did not specify how many resources would be allocated to the garlic mustard project. One crew of two people worked for a total of 7 days (4 days for one, 3 days for the other) at a rate of \$127/day = \$889. The use of the NSTIR half-ton truck is valued at \$136/day for 4 days = \$544. In reality, the cost for the truck would be slightly more, as it came to the control sites every treatment day to collect bags for disposal. The total known costs incurred by NSTIR are \$1,671. Costs do not take into account the project planning time for NSTIR Environmental Services staff, NSTIR Operations Supervisors time, use of the NSTIR base for temporary storage, or costs to dispose of the 100+ bags of plant material.

The costs for CARP's involvement in the planning, outreach, control, and monitoring portions of the project were relatively high, attributed mostly to travel expenses. Staff wages spent on outreach and control activities were \$4,095, travel costs were in excess of \$1,500, and approximately \$200 was spent on field supplies, for a total cost of \$5,795. This does not take into account supervisor's time, prior research on garlic mustard control, or time spent preparing this management plan.

Parks Canada had their summer staff spend approximately three hours hand pulling plants on Parks property. No estimates of costs incurred by Parks Canada (including planning and hosting of meetings and public outreach events) was available at the time of report writing.

PEI National Park gives the following resource estimates for garlic mustard monitoring and control (Atkinson 2008): two technicians for one week for field work (monitoring and control) at a rate of \$158/technician/day = \$1,580; and, one person for three days for data entry and report preparation at a rate of \$158/day = \$475. The total annual Park budget for garlic mustard control on 2.7ha is \$2,055. No costs are cited for equipment, transportation, or disposal, though they would not be expected to be significant given the Park's ownership of vehicles and equipment.

It is important to note that hand pulling garlic mustard plants is not difficult. The number of plants that can be pulled by one person in a given amount of time varies widely depending on the site, soil type and moisture, competing vegetation, and size of the plants. CARP counted all of the plants at each outlier site, so that long-term monitoring would indicate changes in abundance over time. While it is possible to determine a rate using this data, it is not felt that it would be relevant. Counting plants as they are being pulled significantly impacts the amount of time it takes to pull them (Brendan MacNeill, personal communication 2008). When not counting, it is possible to pull garlic mustard plants in big handfuls, as opposed to one at a time.

Outcomes for Year 1: No resource planning was conducted prior to implementing management actions in 2008. There are several reasons for this: no existing management plan or template to use as a reference, unknown density and distribution of garlic mustard plants, multiple project partners, little knowledge of time required to implement desired management actions, and lack of resource planning meetings. We therefore view 2008 as a trial year.

Outcomes for Year 2: NSTIR created a partnership with the NS Youth Conservation Corps (NSYCC) and Clean Nova Scotia to help alleviate some of the cost and resource availability associated with use of NSTIR District Operations staff. NSYCC summer students were hired from the Grand Pré area and were required to have their own transportation (local mileage was covered by NSTIR).

Planned changes for Year 3: A continued partnership between NSTIR and NSYCC is recommended for 2010, along with hiring of local students. The summer students should be encouraged to organize a "community work day" and work towards transferring this responsibility to an committed community member. A large group of volunteers could potentially have a significant impact on garlic mustard populations, in addition to making access to private property less difficult. NSTIR will continue to examine the option of mowing/cutting prior to flowering, provided the cut material does not contribute to the seedbank (some test-plots should be developed to re-examine this possibility). At some point in the future, NSTIR and its partners will have to determine if they should continue to spend public dollars (and community efforts) to continue the control program. Decisions will be based on success of the control efforts (trends in plant abundance and distribution) and government funding priorities, and perhaps public will and/or government regulations.

Outcomes for Year 3: Weed pulling and community awareness and education efforts were continued as in other years. Some permanent sample plots were created.

Outcomes for Year 4: Less weed pulling occurred, but awareness efforts were continued and education expanded by sharing new research with the community. Sample plots were re-visited and new plots were created. Future control efforts will be put on hold based on the recommendations of US experts. The only control efforts will focus on three small outliers in Kentville, Greenwich and Hantsport.

The Year 5 (2012-2013) management objectives will be limited to three components:

- Continued surveillance of garlic mustard populations in NS.
- Removal of adult plants in three small populations (Kentville, Greenwich and Hantsport).
- Maintain communication with ISANS and staff at the E.C. Smith Herbarium at Acadia U.

## **Further Recommendations**

Project partners will continue to consider the following six items in coming years.

### **1 – Lead Agency**

Given the scope of the garlic mustard infestation in Grand Pré, potential impacts of further spread of garlic mustard into undisturbed forests of Nova Scotia, and the limited resources of all partners, there is a need for one or more government departments to take the initiative with the garlic mustard management plan. NSTIR took on this role for 2008-2011 and engaged two students through the NS Youth Conservation Corps (NSYCC) to assist with a control program and ongoing development of this Management Plan. NSTIR will continue as the lead in 2012, however, it is now acknowledged that long-term control activities will be sharply curtailed. Communication with both ISANS and staff at the E.C. Smith Herbarium at Acadia University will continue and any changes to management plans and leadership will follow advice and recommendations of a larger body of experts.

### **2 – Plant Biology**

Literature states that adult garlic mustard plants can be variable in size, ranging from short, single-stemmed plants, to tall multi-stemmed plants (e.g., Nuzzo 2000 and 2010 pers. communications). In June and July 2008, some plants were noted with especially vigorous growth, having upwards of 15 stems on a single plant. In addition, these large plants had substantially larger tap roots than their smaller companions (hence the possibility of more than two-year old plants). In 2009, it was recommended that some permanent sample plots be established to observe biological traits of garlic mustard. Baseline plant biology information was collected in 2010 and 2011 and is included in Appendix F. Further research will require engagement of one or more university researchers.

### **3 – Community Engagement**

Though numerous landowners expressed interest in garlic mustard management and volunteered their personal contact information over the past four years, no clear community leaders have come forward. Given the recommendations by US experts concerning garlic mustard, further direct engagement activities are not planned for 2012. This decision may be re-visited in the future depending upon discussion amongst ISANS members and a new champion taking on the role.

## 4 – New Reports

Given the distinct possibility of undocumented occurrences of garlic mustard in Nova Scotia, it is important to continue to increase awareness, and solicit and document new reports. This is best accomplished by postings to the ISANS website and contacts with local botanists at universities and, or local naturalist groups. New reports by partners or others should be directed to staff at the E.C. Smith Herbarium at Acadia University and [info@invasivespeciesns.ca](mailto:info@invasivespeciesns.ca).

## 5 – BMPs

The roadside BMPs drafted for NSTIR (Godwin and Stewart 2007), and described in Pett et. al (2008) are no longer relevant based on evidence and recommendations of US researchers. Active control is only recommended for very new populations that have not yet established a significant seed bank. NSTIR's Environmental Services staff will continue to survey the populations in the Grand Pré area to monitor any substantial change. As noted above, weed pulling in 2012 will only occur at the three small outlier sites in Hantsport, Greenwich and Kentville. This management plan will also be updated to maintain an on-going record of activities and posted on the NSTIR website (<http://www.gov.ns.ca/tran/works/enviroservices/>). Appropriate weblinks will also be established to the ISANS website.

## 6 – Project Support

Project partners should continue to pursue additional support for management of the only known occurrences of garlic mustard in Nova Scotia. It is recommended that partners remain involved in the *Invasive Species Alliance of Nova Scotia (ISANS)*, and the *Invasive Alien Species Atlantic Network*. Membership in these groups will enable partners to stay connected with other groups involved in invasive plant management, and may result in access to funding or other project support opportunities.

**NOTE:** All GPS data and raw data collected in 2008, 2009, 2010 and 2011 are provided in an Excel Master Spreadsheet. A copy of this file will be available at the CARP office in Annapolis Royal, the E.C. Smith Herbarium at Acadia University in Wolfville (Ruth Newell), the Grand Pré National Historic Site (Wayne Kelley) and the NSTIR Head Office in Halifax (Dr. Bob Pett). All inquiries about the data or this management plan should be directed to Dr. Bob Pett (1672 Granville Street, PO Box 186, Halifax, NS, B3J 2N2; Tel: 902-424-4082; [pettrj@gov.ns.ca](mailto:pettrj@gov.ns.ca)).

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## **Appendix A – Background Information on Initiating Management of Garlic Mustard in Nova Scotia and Management Plan Development**

Responsibility for invasive plants, at present, does not fall under any Nova Scotia provincial government agency (with the exception of noxious weeds, Nova Scotia Department of Agriculture, and potentially Giant Hogweed management activities, Nova Scotia Department of Natural Resources). As such, no geographically relevant template for management of invasive plants is readily available for reference.

In an effort to initiate some discussion about the management of this isolated population of garlic mustard, CARP organized a meeting of managers from key government agencies. Based on professional experience and scientific research, numerous experts feel that immediate eradication of the existing garlic mustard population would be the best course of action (e.g., Heather Stewart, Sean Blaney, personal communication 2007). The meeting was held in the multi-purpose room at the Grand Pré National Historic Site, Grand Pré, NS. Attendees at the 23 July 2007 meeting included representatives from Parks Canada, NSTIR, the NS Department of Natural Resources, Wildlife and Forestry Divisions (NSDNR), the Acadia University E.C. Smith Herbarium, a volunteer with the Nova Scotia Nature Trust (NSNT) experienced in the control of invasive plants, and a Research Scientist/Botanist with the Applied Geomatics Research Group (AGRG), Nova Scotia Community College. Several others, including the NS provincial Weed Inspector (Department of Agriculture) were also invited, but unable to attend. The objectives of this meeting were as follows:

- Raise awareness about garlic mustard.
- Identify partners who will collaborate to create and implement a management plan for garlic mustard.
- Develop components of a management strategy to deal with current outbreak of garlic mustard in Grand Pré, NS, and beyond.
- Establish a timeline for management.
- Identify management milestones (within accepted timeline).

Unfortunately, no agency was able to take leadership on this initiative, but Parks Canada (Grand Pré National Historic Site) and NSTIR both expressed a keen interest in working towards the long-term management of this species. It was decided that further public outreach and spatial data collection should be the next steps taken towards management of the garlic mustard population (as per meeting minutes 31 July 2007). NSTIR requested that some better management practices (BMPs) for working in garlic mustard infested ditches be developed for operational consideration.

Parks Canada Agency is developing an ecological integrity (EI) program for all national parks (Atkinson 2008). At this time, it does not appear as though the EI program will apply to Historic Sites (Wayne Kelley, personal communication 2008). However, in practicing due diligence, the Grand Pré National Historic Site will conduct monitoring and management activities for garlic mustard.

NSTIR has an important role in preventing further spread of this plant by adjusting ROW maintenance practices in areas infested with garlic mustard. In addition, the Transportation Association of Canada (TAC) included a session on the “management of the spread of invasive plants” at their 2008 annual conference. The session received entries from 4 provinces (Bob Pett,

personal communication 2008), including Nova Scotia's garlic mustard submission, highlighting the role of provincial transportation agencies in the management of invasive plants. NSTIR describes the goals of their Integrated Roadside Vegetation Management (IRVM) program as follows: erosion control, slope stability, clear sight lines, drainage of roadways, biofiltration of roadway pollutants, promotion of species diversity, habitat creation, and control of undesirable vegetation, which includes noxious weeds, sweet clover, and trees and large shrubs (LaRue 2004, and Bob Pett, personal communication 2008). The author of the NSTIR Roadside Vegetation Field Manual is a vegetation consultant who feels that the agency has a key role in dealing with the problems associated with invasive alien plants (Diane LaRue, personal communication 2007).

CARP has been involved in numerous local, regional, national, and international initiatives to support community environmental management. Though the community of Grand Pré is located outside of the Annapolis River watershed, CARP became involved in the initial 2007 efforts to solicit support for management of this isolated population of garlic mustard. Given their extensive experience with public outreach, and their more recent experience with invasive terrestrial plants, garlic mustard management seemed a natural extension of the work CARP was doing. In addition, CARP feels that public education is an important means of preventing future introductions, and receiving early reports of detection of new invasive alien species (IAS).

Because no locally relevant management plan for invasive alien plants exists, the components of the garlic mustard management plan were derived from The Nature Conservancy's (TNC) *Site Weed Management Template* (Tu and Meyers-Rice 2001).

It is widely accepted that an adaptive management approach (AMA) is the only way to effectively mitigate the impacts of invasive alien species (Smith 2008). AMA has been used for garlic mustard control in Ontario (Silvia Strobl, personal communication 2007), and Prince Edward Island (Kirby Tulk, personal communication 2007). The concept of AMA is especially important in this case, given that this will be the first time a management plan has been implemented for garlic mustard in Nova Scotia. The U.S. Nature Conservancy (TNC) has modified the original concept of adaptive management to apply to invasive species (Smith 2008). AMA begins with establishing goals for the site. After goal-setting, management follows a cyclical pattern of steps, as follows: (1) establish targets and goals, (2) identify and prioritize species that threaten targets and goals, (3) assess control techniques, (4) develop and implement management plan, (5) monitor and assess impact of management actions, and (6) review and modify plan. At the end of each cycle (one management year), goals are modified to reflect outcomes of management actions. Though the TNC AMA template is designed to apply to geographic areas with conservation targets (e.g., parks, preserves), its basic components are applicable to any location, provided there are management goals.

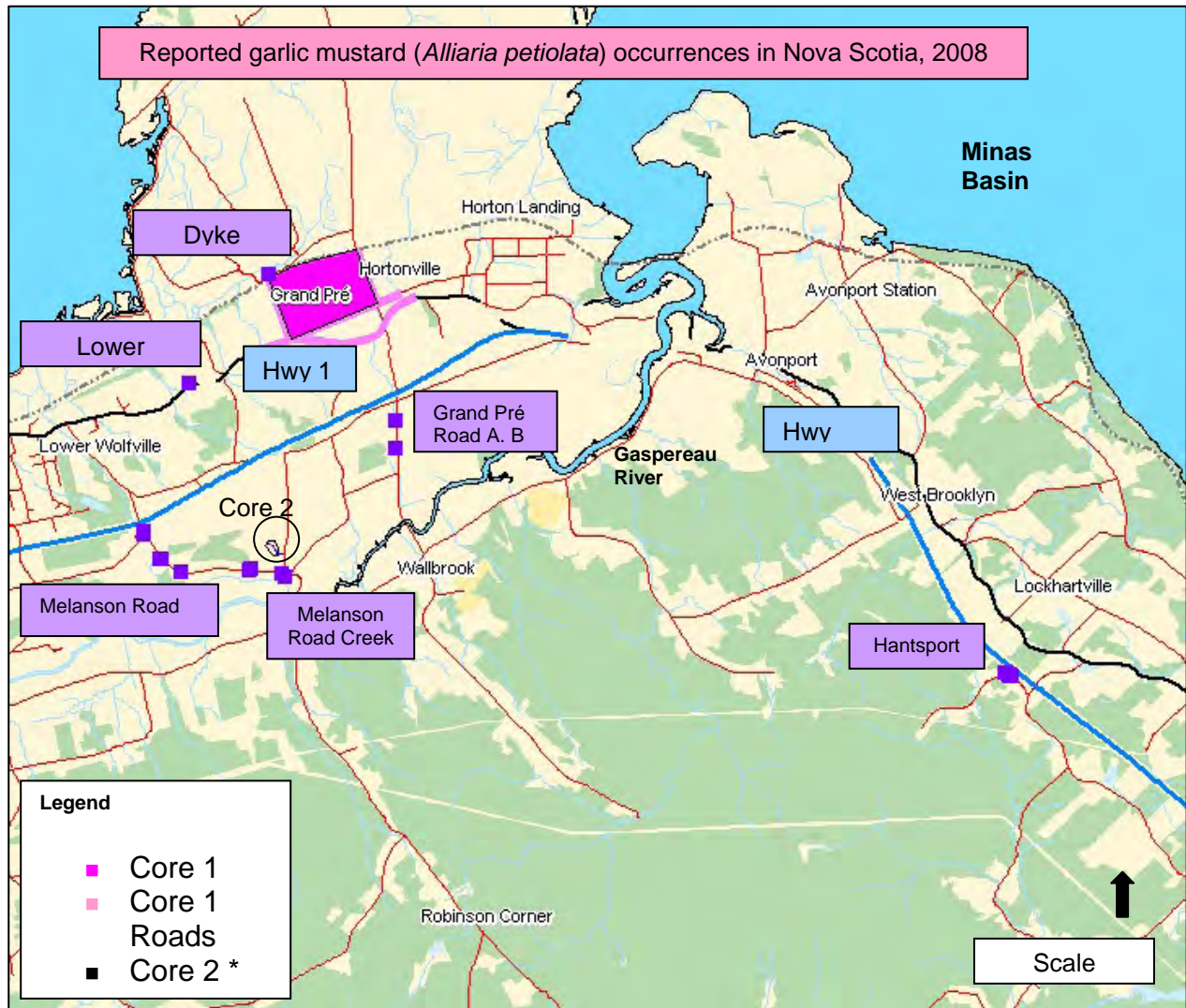
When dealing with numerous species on one site, management priorities must be determined based on priority. This "Priority Setting" section of the plan is used to rank invasive species using four categories: (1) current extent of the species, (2) current and potential impacts of the species, (3) value of habitats/areas infested or potentially infested, and (4) difficulty of control. Based on the ranking, management priorities are established. TNC emphasizes the importance of category (1), and suggests that resources are best allocated to prevention of new problems and addressing newly developing infestations.



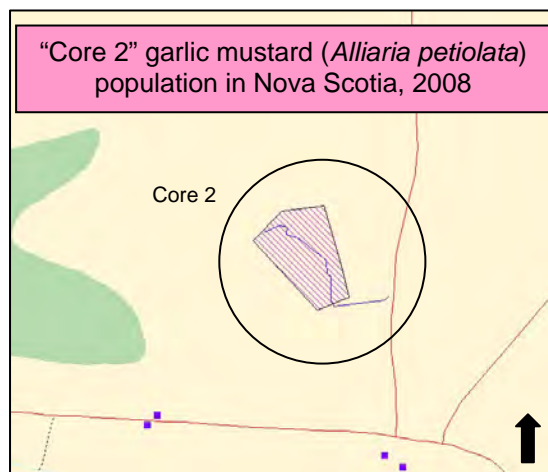
In the case of this weed management plan, garlic mustard is the only species being addressed. As such, prioritization of species is not required. However, it is important to note that within category (1), “species present as new populations or outliers of larger infestations, especially if they are expanding rapidly” are considered to be second priority, after “species not yet on the site but which are present nearby”. This concept of working from the outside in (outliers towards core) is common in invasive species management (e.g., Aldo Leopold Foundation 2007).

Though it is possible in theory to control garlic mustard with available technologies (see Nuzzo 2000), a long-term commitment is required. Prince Edward Island National Park is in its fourth year of control efforts, and is still conducting experimental control trials. It is suspected that in previous years they may have been inadvertently spreading seed during control treatments (Kirby Tulk, personal communication 2007). Experienced managers in Ontario emphasize that all management efforts absolutely require provision for multi-year follow-up (Sylvia Strobl, personal communication 2007, and Jim Rockwood, personal communication 2008). Though garlic mustard seed is commonly cited as having 5-year viability (e.g., Nuzzo 2000), botanists suggest that follow-up activities should continue well beyond that timeline (Sam Vander Kloet, personal communication 2008). It may be worthwhile to consult these groups with 2011 findings and to seek input into development of BMPs based on their experiences and to consult managers in other provinces or states for input.

## Appendix B – Map of 2008 Known Extent of Garlic Mustard in Nova Scotia (data collected in May – June 2008)

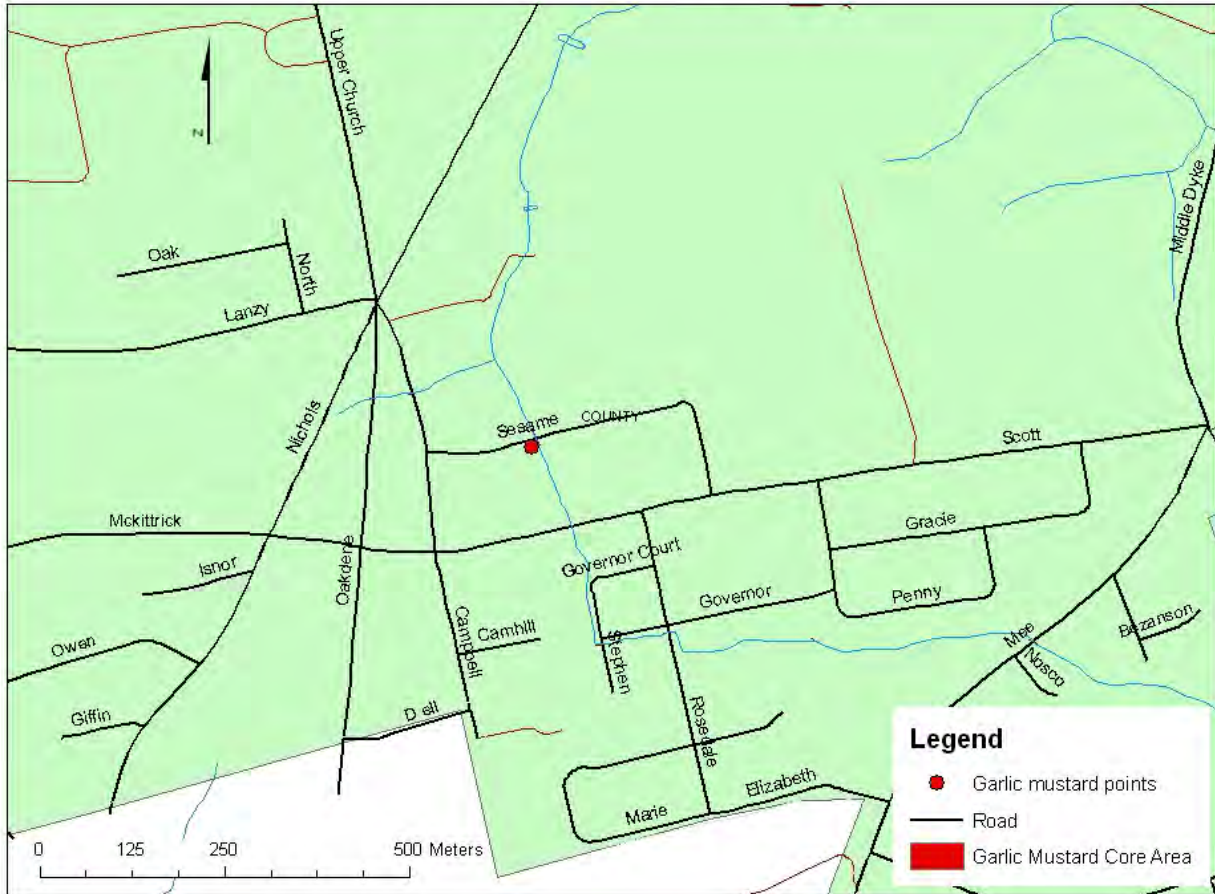


Map created by Marika Godwin, Clean Annapolis River Project (CARP), using fGIS. Data collected in May/June 2008 by Marika Godwin and Julianne Butt, CARP. “Core 1” is 57.49ha, and “Core 2” is 1.12ha. “Core 1 Roads” are 4.2km in length.

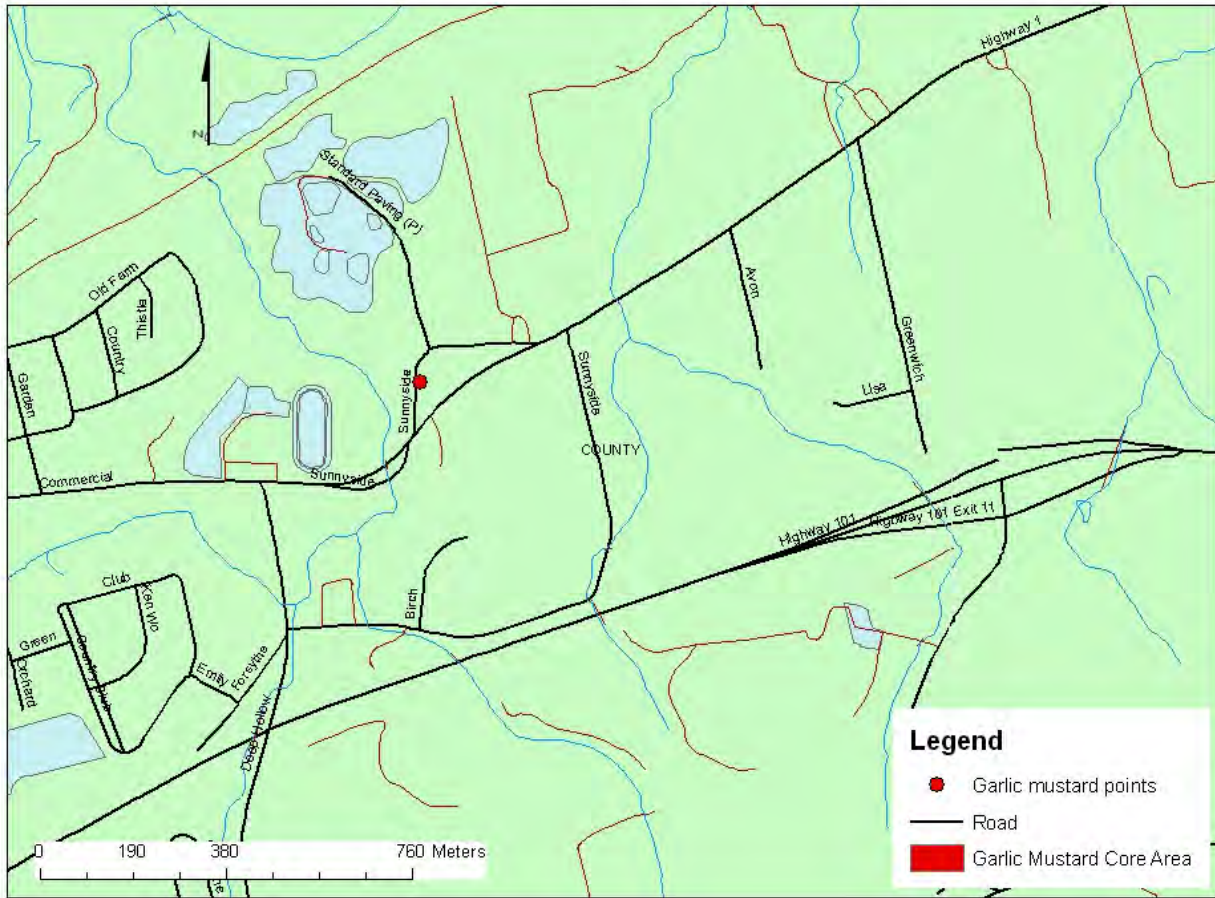


# Appendix C – 2009 and 2010 Distribution Maps Generated by NSYCC Interns

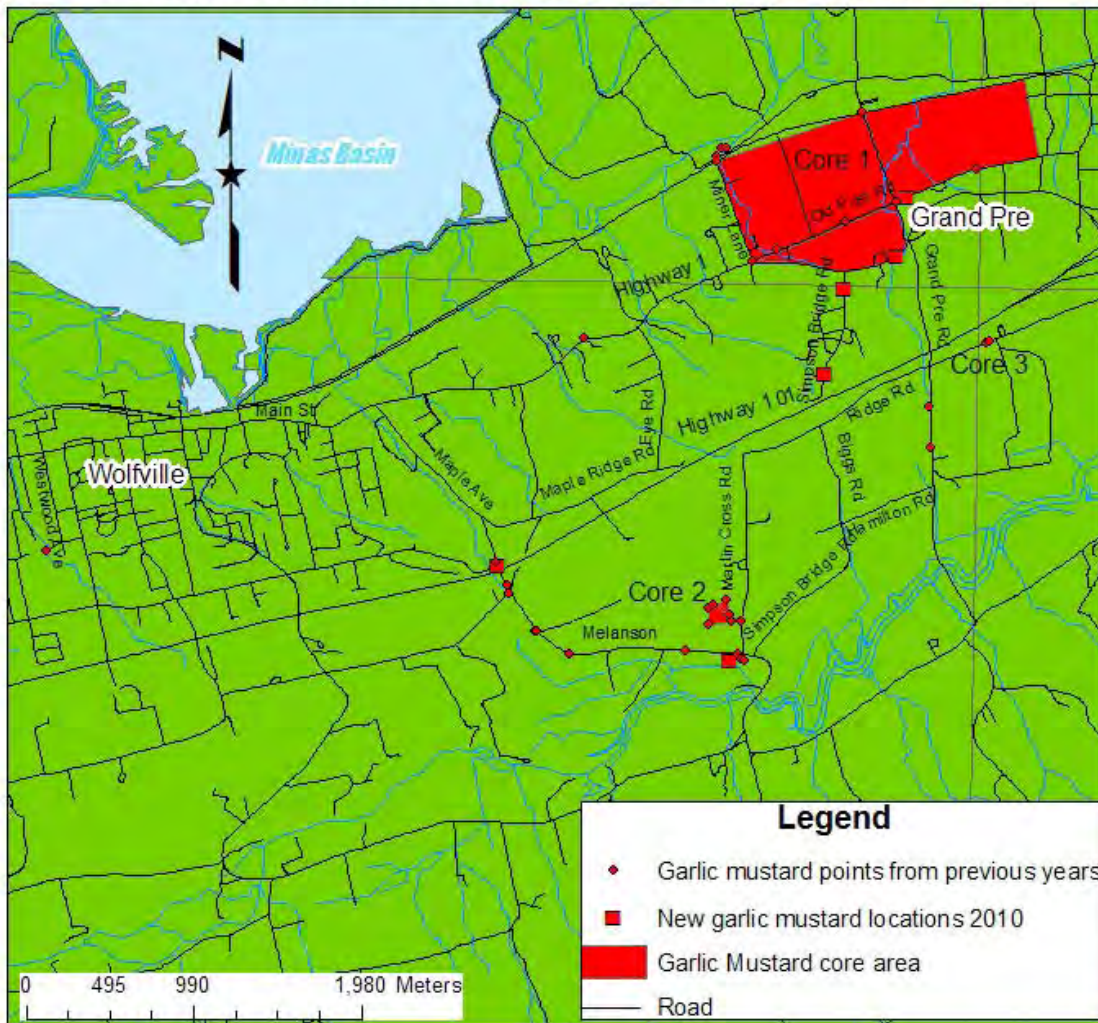
## Garlic Mustard Occurrences in Kentville



# Garlic Mustard Occurrences in Greenwich

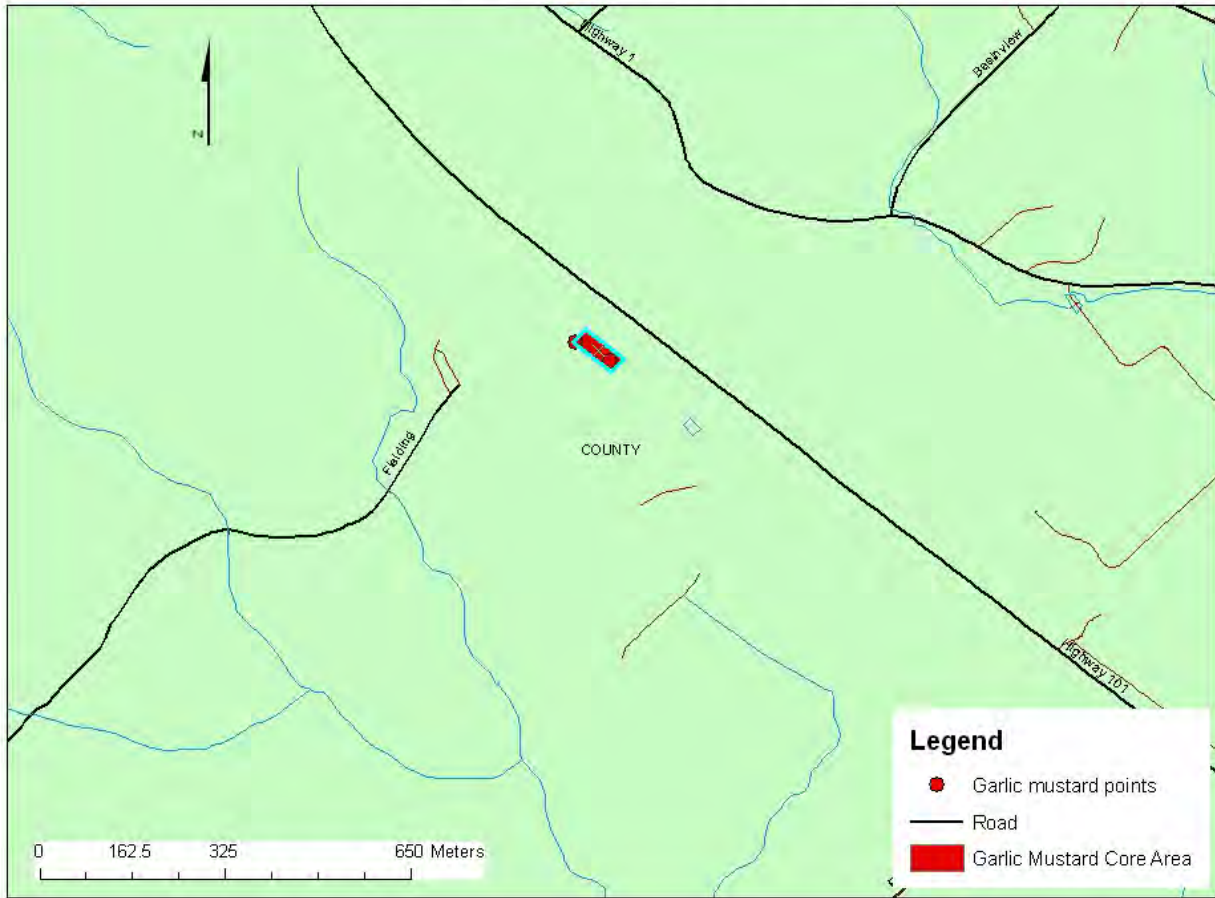


## Garlic Mustard Occurrences in Grand Pre



Note 2010 expansion of known boundaries of Core1: from Old Post road to Hwy 1 (South) and from Grand Pre Road to nearly Lower Grand Pre road (East).

## Garlic Mustard Occurrences in Hantsport



**Ben Jackson Road, near Exit 8A and Anstrum's Fruit & Vegetable Market**

## Appendix D – Outlier Population UTM Locations

SITE NAME	START UTM	START UTM	END UTM	END UTM
	E	N	E	N
Woodland Trails	392197	4993326	NA	NA
Lower Wolfville	395379	4994583	NA	NA
Lower Wolfville 2- before the cherry tree	459606	5026854	NA	NA
Melanson Road				
A	394861	4993258	NA	NA
B	394933	4993074	394928	4993117
C	395096	4992850	NA	NA
D	395104	4992850	395300	4992714
E	395978	4992731	NA	NA
F	396291	4992716	NA	NA
Melanson Road Creek	396307	4992690	396331	4992673
Martin Cross Road	396286	4992723	396349	4993264
Grand Pre Road				
A	397423	4994172	NA	NA
B	397433	4993936	397431	4993934
Hantsport	403533	4991677	403474	4991710
Dyke Road	396171	4995655	NA	NA
Miner lane- Dykes	396193	4995707	396220	4995707
Greenwich	388718	4992568	NA	NA
Kentville	382881	4994385	NA	NA
Maple Ridge Road near Hwy#1	45.08475*	64.33588*	NA	NA
Ridge Road, perpendicular to Grand Pre	397291	4995418	NA	NA
Melanson Road Creek Private Backyard	396246	4992675	NA	NA
Simpson Bridge Road			NA	NA
brookside	396804	4994366	NA	NA
brookside 2	396803	4994366	NA	NA
road start	396921	4994872	NA	NA
<b>Hwy#1 Brookside</b>	<b>397235</b>	<b>4995065</b>		

Highlighted outliers represent discovery in 2010. Details are provided in an excel spreadsheet, NSYCC database currently with Dr. Bob Pett.

Notes: Martin Cross Road - Sam Vander Kloet (personal communication 2008) noticed an “explosion” in the number of plants in this population from the previous year. When implementing control measures on this outlier, a large population was discovered on the adjacent property. Note: Unless otherwise cited, information on management options are drawn from Nuzzo (2000). Melanson Road Creek – When implementing control measures, another satellite population was discovered in the riparian area along a creek at the intersection of Melanson Road and Martin Cross Road. The unnamed creek was surveyed downstream to where it flows out into the Gaspereau River, and the population was named Melanson Road Creek.

## Appendix E – 2010/11 Notes on Garlic Mustard (*Allaria petiolata*) Plant Biology in Nova Scotia

In its native European habitat and occasionally in the United States, Garlic Mustard is known to be rarely used for browse by wildlife (Natureserve 2009). Herbivory by native insect species and potential management implications have however been recently documented in Ontario (Yates and Murphy 2008). Due to the relative recentness of Garlic Mustard occurrence in Nova Scotia, incidence of herbivory has not before been previously documented and its IPM (Integrated Pest Management) relevance has not been evaluated.

### A.1 Incidental Observations

#### **A.1.1 Use of GM as browse by cattle and native wildlife**

In Hantsport Deer tracks were observed in the general area of the Garlic Mustard population, though there was no evidence of browse. Natureserve explorer (2009) note seeds may be dispersed directly or indirectly by wildlife, including white tailed deer. This is not a primary mechanism for distribution and browse is reportedly (Natureserve 2009) very rare.

Local residents near Core 2 informed us they had never seen cattle browsing on garlic mustard, and intact garlic mustard plants were found in areas where cattle browse on grasses. It is unknown whether sheep would use garlic mustard for browse but in an area near Core 2 where sheep were kept (sample plot 1), the roadside extent of garlic mustard did not extend into the pasture/lawn area on neighboring private land.

#### **A.1.2 Use of GM by invertebrates**

Several invertebrates were found on or browsing on Garlic Mustard adults and rosettes including different life stages of snails, spittle bugs and stink bugs. Other invertebrate groups incidentally observed in association with garlic mustard include stink bug in the nodes of leaves, lady bug and butterflies.

Slugs and snails (2 species of snail) were observed on leaves of garlic mustard at most locations. At several locations, particularly near Core 1 and 2, one snail species was observed on leaves with signs of browse (i.e. holes). Browse by snails appeared to have no significant impact.

On the corner of Melanson and Martin Cross Road, southwest of Core 2, an infection of the garlic mustard was observed which appeared to be killing adult plants. Leaves of these plants appeared shriveled in size, curled inward and on edges. On most of these plants we found no insects. We noted stink bugs, spittle bugs, ants, and lady bugs without prevalence of one type.

Near Core 1, and several outliers near HWY 1, spittle bugs were frequently sporadically observed in association with shriveled leaves of adult plants and rosettes. It was also noted that siliques appeared shorter and dehydrated on infected adult plants when spittle bugs were present.



Photos were taken of insects feeding on the plants through a hand lens and brought to Scott MacIvor, a Masters Student in Dr. Jeremy Lundholms lab at SMU with knowledge of insects and plant ecology. He was able to identify the stink bug as two-spotted stinkbug (*Cosmopela bimacculata*), which is common in Nova Scotia and he thinks not likely as a potential candidate species for IPM.

The other species he was able to provide input on was the spittlebug, a species of *Cercopidae*. Because the insects we observed were in their nymph life stage, identification was not conclusive but suggested that the species could possibly be *Philaenus spumarius*.

Observation of herbivore attack in garlic mustard (*Alliaria petiolata*) in Southwestern Ontario was observed by Yates and Murphy, 2008. These authors recognize the significant effect this species has had on garlic mustard in the area and recommend it may be a good candidate for Garlic Mustard management. The authors recommend planning if this IPM was to be used intentionally as the pest could also host feed on other species of Brassicaceae (mustard family), or agricultural crops such as Canola. In the Annapolis Valley, agricultural implications of IPM are an important consideration before this method should be considered for use. Assessing the feasibility of using this native species for IPM may be a useful consideration.

At this point we should note also that these insects we observed in the field appear to be having a significant effect on the health of individual plants, but not on patches or populations of plants.

#### **A.1.2. Association of GM with other species**

A female ring-necked pheasant or grouse (most likely to be pheasant) was observed nesting (at least 4 eggs) in a field windbreak with understory dominated by garlic mustard, in a garlic mustard thicket at Core 2, May 19, 2010. GM at this location was healthy.

(For more information on these observations made in 2010 on browse of garlic mustard, contact previous NSYCC intern Caitlin Porter: [caitlinporter@hotmail.com](mailto:caitlinporter@hotmail.com), [Caitlin.porter@smu.ca](mailto:Caitlin.porter@smu.ca) )



## A.2 Permanent Sample Plots

An objective of previous management plans was the establishment of permanent sample plots. Six (6) sample plots were established in 2010 and two (2) in 2011. Each was flagged in the field, and GPS coordinates were taken. Sample plots 1 to 6, established in 2010, were revisited in June of 2011 to conduct observations of adult and rosette plants.

### **A.2.1 Sample Plot 1 – Hop Yard**

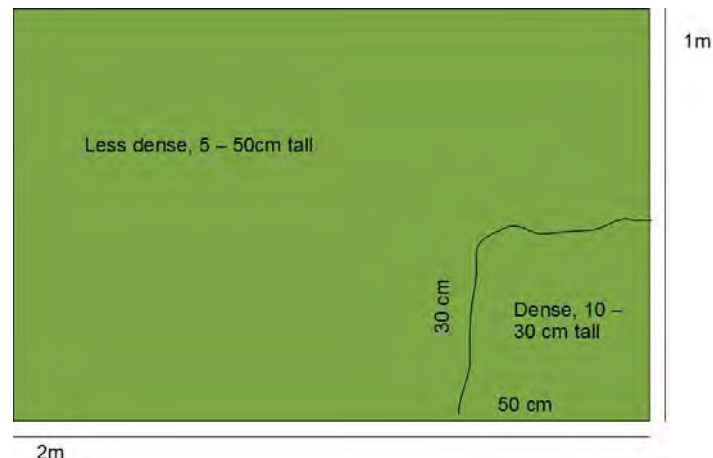
To quantitatively monitor success of pulling GM, one 1.17 x 2.34 m sample plot was established in 2010 in front of the hopyard on Melanson Road at UTM coordinates: 0395304, 4492713. The plot was selected to be representative of variability in plant growth and density characteristics (Fig. 1 & 2).

**Description of sample plot:** In front yard near roadside, full sun, some young Hawthorne trees and a telephone pole within area. Other species identified within the quadrat included: Tansy sp., *Solidago* sp., *Rosa* sp., dandelion, Chickweed sp., Timothy grass, Grey Birch seedling, Curled Dock, Vetch sp., Hawkweed sp., and one unidentified herbaceous weedy plant.

**Fig 1. Photos of Hop Yard monitoring sample plot 1.**



**Fig 2. Schematic of Hop yard sample plot 1 and approximate measurements.**



**Stem count data (sample plot 1) :**

Within the sample plot in 2010, the majority of the area was composed of less dense, tall stems. The area with the densest GM contained 98 stems. The area with least dense GM contained 101 stems. 199 adult GM stems were counted in total.

No rosettes were present in 2010 within the sample plot, suggesting removal methods from the previous year may have been successful.

In 2011, sample plot 1 was re-visited and another stem count conducted to evaluate success of pulling GM. Differentiation between the dense and less dense areas in the plot was not visible. In the 2 m by 1 m plot 22 adult stems were counted. This suggests that possible under developed rosettes were present in the sample plot the previous year and went undetected. This data does show a considerable decline in adult population size compared to previous years suggesting success when pulling GM. As in the 2010, no rosettes were visible at the time of counting.

It is recommended that this plot be revisited in 2012 for adults and rosettes to be counted to look for further decline in this area.

### **A.2.2 Sample Plot 2 – Grey house rosettes, Hwy 1**

To monitor the regeneration of rosettes and plants, one sample plot was established in 2010, opposite the grey house on Hwy 1 at UTM coordinates: 0396481, 4995026. The area was flagged on the roadside of Hwy 1, corners marked with pink flagging tape. Adult plants were removed (4 stems) and rosettes comprised 100% ground cover in this area. Rosettes were removed from the bottom right 25% of the sample plot and counted. 386 rosettes were counted in this corner and represent approximate average density. Four adults were also removed from the quadrat so that only rosettes remain. Objective of this plot can be to determine success rate of rosettes from year to year, and possibly evaluating seed bank. Other species in the quadrat include: a raspberry, alder, and an ash or serviceberry(?) sapling encroaching on the quadrat, small patch of sedge and an unidentified herbaceous species.

In 2011, adult stems were counted to help determine success rate of rosettes and seed bank regeneration potential. In 2010 a 95% failure rate was expected of rosettes due to dehydration, although rosettes can be more successful over warm winters (Natureserve 2009). In the corner of this quadrat where all rosettes had been removed in 2010, 15 adult stems were counted in 2011. This suggests that some rosettes may have been too underdeveloped to be visible during the removal of the rosettes in this corner in 2010, or that regeneration is occurring. 379 adult stems were counted in the remaining area of the quadrat. If we assume the 386 rosettes counted the previous year in one quarter of this plot is the average density then we can calculate the failure rate of last year's rosettes in this plot to be approximately 67%, lower than the expected 95%.

If this experiment is repeated in following years in various GM populations it could result in a more accurate approximation of rosette failure rate and help to learn more about GM regeneration.

### **A.2.3 Sample Plots 3-6 – Miner Road, experimental Garlic Mustard seed persistence and viability after solar cooking**

In 2010, 4 sample plots were set along on Miner Road within 3 metres of the roadside. The area is surrounded by other occurrences of GM, therefore if germination were to occur it would not contribute to spread in distribution. The following are descriptions of each of these sample plots in 2010:

*Sample Plot 3.* UTM location: 396201, 4995511. Description: Dyke end of Miner Road under willow and cherry canopy with partial shade. Flagged willow tree and cherry tree. ½ garbage bag of garlic mustard from 2009 was distributed over soil. Herby parts entirely decomposed, skeletal straw-like stems remaining. Little existing ground cover, aside from some bryophytes, due to stick and leaf litter, roadside disturbance and shade. Sticks were removed from area.

*Sample Plot 4.* UTM location: 396269, 4995350. Description: East side of Miner Road by MTT sign, flagged cherry trees on either side. Ground cover of grasses and sedges. Soil was slightly gravelly, so GM was dispersed to cover ground.

*Sample Plot 5.* UTM location : 396287, 4995308. To the north (left) of telephone pole and grey birch about 3m to achieve distance from existing GM patch. Spread widely under cherry trees approximately 2.5m from the road.

*Sample Plot 6.* UTM location same as 5, but occurs 2-3 meters north of 5 south (right) of a bayberry bush . At this sample plot, fresh GM from an adjacent location were pulled and distributed. This plot was established as a control comparison with sample plots 3-5 and to assert seed viability/success after pulling weeds and not removing the plants.

In 2011, sample plots 3-6 were revisited. Results of GM seed persistence and viability after solar cooking were inconclusive as there appeared to be both rosettes and adults within and surrounding the sample plots. This suggests GM had been missed in previous surveys and likely germination of seeds within the seedbank.

#### **A.2.4 Sample Plots 7 and 8 – Sunnyside Road, Greenwich, experimental Garlic Mustard seed persistence and viability after solar cooking.**

#### **A. 2. 3. Future Work**

In the future, if possible, permanent sample plots should be established using marked stakes, aligned on a compass bearing (for consistency of quadrat or pole placement) on 4 corners and with a standardized area at several locations.

If determined valuable to funding potential and general information about GM, a research-based sampling program could be established.

Objectives:

- If solar cooking GM in garbage bags after picking destroys viable seeds, an experiment could study if GM patches covered with torn garbage bags or black tarp are killed.
- Determine the effects of GM allelopathy on native Acadian Forest diversity by collecting species inventories and abundances from various field sites, and experimentally by growing various native seeds in soil from GM sites versus a reference site.

- Quantify distribution and spread of GM by delineating boundaries at a finer scale. Also, measuring occurrence of rosettes and adult plants adjacent to the boundary. Assessing rate of spread through point-intercept monitoring of occurrence (and stem counts) along roadsides.
- Study the effect of insect predators on populations or patches of GM with identified infestation by conducting stem counts at this site and measuring plant growth traits. Sample plots should be established where insect predation occurs and a control. Leaf and silique health can be monitored by measuring siliques and leaves and counting seeds. Biomass likely not a good indicator since it seems to be dependent on microhabitat conditions.
- Continue to sample to determine the success of treatment practices using removal and control methods and comparing with reference sites.

## References for Appendix E

NatureServe. 2009. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available <http://www.natureserve.org/explorer> (Accessed: June 11, 2010).

Yates, C. and Murphy, S. 2008. Observations of herbivore attack on garlic mustard (*Alliaria petiolata*) in Southwestern Ontario, Canada. *Biological Invasions*. 10: 757- 760.

## Appendix F – Strategic Monitoring Areas

Because the main concern with garlic mustard is spread into Acadian forest and domination of the understory herbaceous layer causing a loss in diversity, conservation interest groups may be interested in future monitoring and, or research. Monitoring for garlic mustard could be integrated into existing stewardship plans with conservation NGOs.

The following publicly available resources:

- NS Wet areas mapping (online)
- Forest Inventory Maps (NSDNR library in Halifax or Truro)
- Aerial Photographs
- Roads maps
- CEC's Canadian Environmental atlas (online)
- ACCDC – Atlantic Canada Conservation Data Center
- Topography
- Nova Scotia Nature Trust

could be used to examine hydrology, road networks and key conservation areas in order to predict where garlic mustard is most likely to spread, and to which areas this would be of greatest concern. Priorities could be established in collaboration with conservation and naturalist groups and detailed maps could be created using GIS.

Strategic Monitoring Areas should include high value sites and high risk sites. Using existing knowledge, an initial list of these areas was created.

High Value sites:

- Wolfville conservation area owned by Nova Scotia Nature Trust
- Greater extents of watersheds where garlic mustard has previously been found
- Areas with high ecological value and integrity (e.g. protected areas, areas of intact Acadian forest and wetlands)

High Risk Sites:

- Local compost sites where garlic mustard seed may accidentally be transported
- Streams and ditches

# Appendix G – Notice Distributed by the E.C. Smith Herbarium (Acadia University) to Solicit New Reports of Garlic Mustard Occurrences

## **WANTED:**

### **ADDITIONAL INFORMATION ON THE LOCATION OF**

#### **GARLIC MUSTARD**



First year rosettes

#### ***ALLIARIA PETIOLATA***



Second year plant with flowers and fruit

FAST FACTS

Biennial plant (1<sup>st</sup> and 2<sup>nd</sup> year have different forms)

Both forms are shade tolerant

2<sup>nd</sup> year plant has small white flowers and is 1m tall (average)



Close up shot of silique (seeds are inside pods)

FAST FACTS

May impact forest soils, native plants and wildlife

Can invade undisturbed forests

Known to inhabit disturbed sites in Grand Pré, NS

Please report new sightings of garlic mustard to the E.C. Smith Herbarium at Acadia University.

Email: [ruth.newell@acadiau.ca](mailto:ruth.newell@acadiau.ca) OR Telephone: 902-585-1335

# Appendix H – Informational Flyer Distributed by Clean Annapolis River Project to Increase Awareness of Garlic Mustard Identification and Impacts

Outside:

The flyer features a background image of a field with green plants and trees. It is divided into several sections with text and images.

**Have you seen this plant?**



Garlic mustard  
*Alliaria petiolata*  
is an invasive alien  
biennial plant of the  
mustard family.  
It's only known location  
in NS is in the Grand Pré  
area!

If you see this plant anywhere,  
please let us know!  
Report new sightings to the E.C. Smith  
Herbarium at Acadia University  
902.585.1335 or to the Clean Annapolis  
River Project 888.547.4344

Brochure produced by:  
**Clean Annapolis River Project**  
151 Victoria Street, P.O. Box 395  
Annapolis Royal, NS B0S 1A0  
902.532.7533 or 888.547.4344  
[www.annapolisriver.ca](http://www.annapolisriver.ca)



Funded by the Invasive Alien Species Partnership Program,  
a Government of Canada Initiative &  
by the Nova Scotia Department of Transportation and Infrastructure  
Renewal  
Background photo by H. Stewart, AGRG

**Garlic Mustard**  
Identification  
&  
Impacts

What you  
**NEED**  
to know to help  
stop the spread  
of this  
**INVASIVE ALIEN**  
plant...



Inside:



**FRUIT**

Oblong pods (siliques) contain up to thousands of seeds.



**FIRST-YEAR PLANT**

Basal rosette with regularly toothed, kidney shaped leaves.

**Identification**

Use the pictures provided to identify various life history stages.

Occurs in disturbed AND undisturbed sites (forest understories) – keep your eyes open for white flowers in May and June.

Crushed stems and leaves smell like garlic!

**Impacts**

Can invade undisturbed forests, where it competes for light and space with native spring plants.

Inhibits the growth of a soil fungus that is important for the regeneration of native hardwood trees.

Prevents the development of some native species of butterfly larvae when eggs are laid on the foliage.

Currently threatens 2 native plant species-at-risk and 1 rare native butterfly in ON.

**Invasive alien species threaten native biodiversity, species at risk, productive forests, farmland, water quality, human health, trade and our economy.**



**FLOWER**

Terminal clusters with four small white petals in a cross shape.



**SECOND-YEAR PLANT**

1m tall with alternate, coarsely toothed, triangular leaves.