

**NS Transportation and Infrastructure Renewal (NSTIR) partners with the local community to eradicate a restricted invasion of garlic mustard (*Alliaria petiolata*)**

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## **ABSTRACT**

Garlic mustard (*Alliaria petiolata*), a shade-tolerant invasive alien plant from Europe, may threaten Nova Scotia's unique Acadian Forest type. In 2002, a roadside population of garlic mustard was reported in the community of Grand Pré, NS, the only known occurrence of this plant in the province. In six years, the population has subsequently spread along roadsides, infested the Grand Pré National Historic Site, crossed a major watershed divide and formed a new colony in Hantsport, 10 km east of the original infestation. This plant becomes established in disturbed areas, such as ditches, then spreads into undisturbed areas. The Nova Scotia Department of Transportation and Infrastructure Renewal (NSTIR) has an important role in preventing further spread of this plant by adjusting right-of-way (ROW) maintenance practices in areas infested with garlic mustard.

NSTIR, working cooperatively with numerous partners, is developing and implementing a set of best management practices (BMPs). These include: 1 – training for proper identification of plants in all life history stages, 2 – physical (mechanical/hand) removal of plants at the correct time, 3 – proper disposal of cut plant material, 4 – annual quality assurance surveys of managed areas, 5 – proper on-site equipment cleaning, and 6 – long-term commitment with partners to implement the BMPs until complete seedbank depletion. NSTIR and its partners began implementing these BMPs in May 2008, and by following an adaptive management approach, expect eradication of garlic mustard from NS within 7-10 years.

## **INTRODUCTION**

The only known population of the invasive alien plant garlic mustard (*Alliaria petiolata*) 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). Since its establishment, botanists at Acadia University and local community members have been recording the spread of this population along roadside ditches to Lower Wolfville and Hantsport (Figure 1). Garlic mustard thrives in rich upland forest habitat types, outcompetes native spring ephemeral flora, and secretes allelopathic chemicals that affect mycorrhizal soil fungi (1), all potentially negative impacts on the unique and endangered Acadian Forest Ecotype (2). Despite these real and potential threats, no management action has been taken to prevent further spread. Plants now occur on federal, provincial, and private property.

Responsibility for invasive plants, at present, does not fall under any federal, provincial or municipal government agency (with the exception of noxious weeds – Nova Scotia Department of Agriculture). At this time, the opportunity exists to eradicate the only known occurrence of garlic mustard in the province. If left unchecked due to uncertainty of jurisdictional responsibility, the spread of this plant has the potential to cause significant ecological and socio-economic impacts, as it has done in other provinces and in the US. By taking initiative, and forming key partnerships to control the current garlic mustard outbreak, NSTIR can demonstrate Nova Scotia's commitment to proactive management of invasive species.

In an effort to initiate some discussion about the management of this isolated population of garlic mustard, the Clean Annapolis River Project (CARP), a community-based environmental non-

government organization, organized a meeting of managers from key government agencies in July 2007. Given the limited size of the infestation, and based on professional experience and scientific research, numerous experts feel that immediate action to eradicate the existing garlic mustard population would be the best course of action. As a result of this meeting, Parks Canada and NSTIR both expressed a keen interest in working towards the long-term management of this species.

Parks Canada staff hand-pulled plants on federal property in 2007, and are committed to ongoing management efforts at the Grand Pré National Historic Site of Canada. CARP conducted targeted outreach with local community groups and gardening clubs on seven occasions between August 2007 and April 2008. To educate the public about threats posed by the continued spread of garlic mustard, and to obtain community buy-in for concerted action in 2008, outreach activities are ongoing. CARP and the Applied Geomatics Research Group (AGRG), of the Nova Scotia Community College (NSCC), collaborated on the development of best management practices (BMPs) for NSTIR Operations staff. After circulating the BMP guidelines within their department, NSTIR agreed to implement them in the spring/summer of 2008. Working in partnership with CARP, Parks Canada, and communities in the Grand Pré area, NSTIR is developing a long-term, adaptive management plan for garlic mustard. It is widely accepted that an adaptive management approach (AMA) is the only way to effectively mitigate the impacts of invasive alien species (3). AMA has been used for garlic mustard control in Ontario (Silvia Strobl, personal communication 2007), and Prince Edward Island (Kirby Tulk, personal communication 2007). Control techniques for garlic mustard are well documented by Nuzzo (1) in an "Element Stewardship Abstract" (ESA), compiled for The Nature Conservancy (TNC).

Overall project goals are to develop a practical training program for project partners, expand the list of partners, map the infestation area, identify key mowing period(s), and establish an effective disposal method. In the first year of management (2008), NSTIR and its partners hope to undertake the following tasks:

- 1) prior to treatment, locate all populations of garlic mustard within the infestation area, accurately map their coordinates using GPS, and determine population size;
- 2) identify adequate performance measures for monitoring the success of the management program;
- 3) form a stewardship committee consisting of committed landowners;
- 4) provide training to committee members in plant identification and GPS use, through courses and factsheets; and
- 5) implement flower removal and facilitate disposal.

In the fall of 2008, the program will be evaluated and revised as appropriate, and the management plan and BMPs will be adapted to reflect the first-year findings. In the following text, we will briefly summarize the key biological features of garlic mustard and then describe the six BMPs that were developed for NSTIR. Whenever possible, we have included notes and recommendations for improvements to the BMPs based on our experience during the June 2008 (first) control efforts.

## **GARLIC MUSTARD**

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 2) that may be confused with several native ground cover species, including violets (*Viola* sp.), and ground ivy (*Glechoma hederacea*). Garlic mustard, as the name implies, has a strong garlic odor in spring and fall, which differentiates it from all native species. In early spring of the second year, the plant produces a single or few-branched 1m-tall (approx) flowering stalk (Figure 3; in Nova Scotia, June 2008, flowering stalks ranged from 8 cm to almost 2 m). Alternate leaves on the flowering stem are triangular in shape, and sharply toothed. Small flowers have four white petals arranged in a cross shape. Seeds are borne in linear siliques, 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, including mowing (1) and possibly other ditch maintenance activities, including snow plowing. Garlic mustard seed can remain viable in the soil for up to five years (1), and some sources claim up to seven years (4).

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 (1). The Canadian Council of Forest Ministers (5) describes garlic mustard as “highly invasive” in reference to Canadian forests. This is of particular concern in Atlantic Canada, where the remaining Acadian Forest is considered to be an endangered ecosystem type (2).

Havinga et al. (6) 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 (7), of the Atlantic Canada Conservation Data Centre (ACCDC), 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.

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 (8).

## **BEST MANAGEMENT PRACTICES**

The goals of the BMPs are to minimize spread of the invasive alien plant garlic mustard in Nova Scotia, and, in known populations, to prevent further garlic mustard seed production until the existing seedbank is depleted. Achieving these goals relies on the following practices: 1 – proper identification of garlic mustard plants in all life history stages, 2 – physical (mechanical or hand) removal of the plants during the flowering stage and prior to seed production, 3 – proper disposal of cut plant material to reduce the risk of spread, 4 – quality assurance surveys to inspect cut areas and the entire infested area for missed or late-blooming plants and longer term monitoring to determine effectiveness of the management practices, 5 – cleaning of equipment before it leaves the affected area, and 6 – long-term commitment by NSTIR, Parks Canada, and the local community to implement the BMPs until the seedbank is depleted. Effectiveness of

BMP recommendations is dependent on proper identification of the plant at all life history stages, and on management practices continued through to eradication.

### BMP1 – Plant Identification and Staff Training

Prevention of new introductions is the most cost-effective means of mitigating the impacts of invasive alien species (9). NSTIR Operations crews are encouraged to be familiar with common roadside plants in Nova Scotia and have access to a practical field manual (10). Staff are asked to report potential new problem species to the Environmental Services section at NSTIR. However, the manual does not mention garlic mustard as it does not pose any safety or maintenance issues, and is not widespread in the Province. Hence, custom training materials and guided tours will be delivered to the local Operations Supervisor and maintenance staff (see Figure 4).

*Outcomes for Year 1:* A training pamphlet was developed by a project summer student to illustrate both first and second year plants and is intended to help NSTIR staff and local community members identify and report locations of the plants. The pamphlet was distributed to NSTIR staff assigned to the project, and to more than 150 residences in the Grand Pré area. In addition, NSTIR Operations staff were trained to identify garlic mustard “in the field” prior to implementing control. Workers stated that after hand-pulling plants for half a day, they were very familiar with the appearance of first and second year garlic mustard plants.

*Planned AMA changes for Year 2:* NSTIR staff do a significant amount of traveling within their districts, and drive along many secondary and rural roads. Given that they may have opportunity to identify new or previously unreported occurrences of garlic mustard, we recommend that all NSTIR Operations crew receive some form of training in 2009. Ideally, this training would take the form of a field presentation so that employees could ask questions and see the plants in their roadside habitat. In order to solicit further reports of garlic mustard, a local botanist who conducts naturalist walks in the area has volunteered to distribute posters (see Figure 5).

### BMP2 – Mowing to Control Seed Production

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 (1). 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 (1). Plants cut, pulled or mowed prior to full flowering may have enough resources to send up additional stems (1) and hence a second mowing may be required together with comprehensive quality assurance surveys (see BMP4). Depending upon the type of mower used, the flowers on cut flowering stems may also have sufficient resources to sustain seed production (11; pulled plants with flowerbuds were still able to produce seed when laid in piles on the ground). It is believed this latter risk will be minimized by the use of a “Brush-Hog” mower that effectively mulches the plants and eliminates the need to collect and dispose of cut materials.

Upon assessing available options and resources for control, NSTIR and its partners will implement a combination of mowing, cutting, and pulling. NSTIR operations staff will time their ROW mowing in garlic mustard-infested ditches to coincide with peak flowering. Peak flowering in this region typically occurs in June, similar to flowering time in adjacent PEI (Kirby Tulk, PEI National Park, personal communication 2008). Plants on ROW that are inaccessible by mower will be cut using whipper-snippers or pulled.

Plants on the small federal property (Grand Pré National Historic Site) will be pulled by Parks Canada staff throughout the growing season. All other garlic mustard plants within the infestation area will be pulled or cut by community volunteers at peak flowering. Control at peak flowering should ensure minimal commitment from volunteers.

*Outcomes for Year 1:* Over a 2 week period between June 9 and 20, 2008, NSTIR, CARP staff, and community volunteers hand-pulled more than a 100,000 plants from the core infestation area and six outlier populations. 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 poses 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, were 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.

*Planned AMA changes for Year 2:* In 2009, NSTIR will either commit the pressure washer for use on this project at a specified time, or mowing and whipper-snipping will be implemented prior to peak flowering (i.e., early-mid May) so that risk of seed dispersal is minimized. Currently, we are leaning towards the latter option. Peak flowering occurred earlier than anticipated, near the end of May (first flower noted on May 10, 2008). To further engage members of the Grand Pré community, project partners plan to suggest the organization of a “community work day” to take place during *Environment Week* (first week of June), which coincides with garlic mustard flowering time.

### BMP3 – Disposal of Cut Material

Because pulled and cut material can still generate viable seed (11), 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. 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 and purchasing one was not an option at this point in time.

A viable alternative to incineration is the “cooking” of plant material in black plastic, followed by disposal in a landfill (12, 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 (12). Though very rapid (days) decomposition has been recorded using clear bags (Kirby Tulk, personal communication 2008), the literature suggests leaving black bags in the sun for a minimum of three weeks to allow plant material to decompose (13).

*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 is recorded on a datasheet: bag number, colour of plants, state of decomposition, odour, and presence of mould. Once bag contents have liquefied, all bags will be transported by NSTIR approximately five km to the Waste Resource Management Centre in Kentville, NS, for disposal in a landfill.

*Planned AMA changes for Year 2:* Given that on-site incineration is the most desirable option for disposal of highly invasive plant material, NSTIR, Parks Canada and its partners will reconsider acquiring a portable incinerator for burning cut/pulled plants in 2009. An asphalt staging area on Parks Canada property, adjacent to the management area, has been identified for temporary placement of an incinerator should we secure one, in addition to acceptance by the local community and government regulators. The collection of bags by NSTIR is a positive community relations exercise. Homeowners see NSTIR working in their community, may interact with them and discuss invasive plant management, and citizens are alleviated of the burden of disposing of large quantities of invasive plant material. We recommend that NSTIR continue to collect bags from roadsides in the Grand Pré area on days specified for garlic mustard removal. Plant material could be transported either to the incineration site, or to the NSTIR base, depending on the disposal method used in 2009.

#### BMP4 – Quality Assurance Surveys

Two types of monitoring are required for this program. The first is to determine that short-term goals 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 our ultimate goal of eradication. The short-term monitoring is a quality control mechanism to determine if the mowing is being done at the correct time, and if the cutting is getting rid of the material. This will monitor for presence/absence of new or remnant flowers and seed material after the mowing once or twice a year (1). The purpose is to locate and remove plants prior to seed production. This functions to determine if the treatment time matches the timing of the biology. There are circumstances that may change the flowering biology over time. For example, climate change may lengthen the growing degree days at either end of the flowering cycle and cause multiple flowering periods, or the flowering may be earlier and longer. Drier summers may change locations where these plants are located and therefore they may move into areas that they have not been encountered to date.

Long-term monitoring is required to determine the success of the management program. Is the short-term success indicative of eradication, or is there an adjustment period where the success is temporary and then more plants are seen over time? 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 plants are actually decreasing. The use of standardized plant monitoring methods (14) is important to track management success, and to determine when success has been achieved using statistical sampling techniques. Recommendations by Nuzzo (1) 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, it was 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 should be focused on isolated, outlying populations. Six populations (the only known outliers) 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 quality assurance plan. In the short term, July – September 2008, all outlying sites will 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.

*Planned AMA changes for Year 2:* In the long term, outlying sites will be surveyed at the same time (May) every year for changes in number of plants. In addition, roadsides will be surveyed yearly for new populations. A monitoring protocol will be detailed by project partners, as a component of the management plan. It has been noted that small populations can appear and disappear from one year to the next (Sam Vander Kloet, personal communication 2008), which may indicate that there are aspects of garlic mustard biology that are not fully understood. It is likely that some 1m<sup>2</sup> plots will be established in the core population to monitor biological traits. This will be determined by the project partners in the fall of 2008.

#### BMP5 – Equipment Cleaning

Cleaning contaminated equipment on site is an effective means to prevent further spread of invasive alien plants (15). An asphalt staging area on Parks Canada property, adjacent to the proposed management area, was identified. The area will be used to clean equipment and clothing, using a portable pressure-washer provided by NSTIR. In addition, it is important to have all workers make sure their pant legs and boots are free of soil and seed material (Kirby Tulk, personal communication 2007). All persons involved in manual removal of plants will be directed to brush off their clothing and wash their footwear at the asphalt staging area prior to leaving the infested site. All material removed from vehicles, equipment and clothing will be manually collected and disposed of with cut plant material.

*Outcomes for Year 1:* Persons involved in manual removal of plants in 2008 cleaned off their clothing and footwear on roadsides adjacent to control areas, and will follow the same protocol



in 2009. Seeds had either not formed yet or were in a very early stage of development and hence unlikely to be transported off-site. NSTIR was unable to relocate its pressure washing equipment to the management area during the required timeframe (one washer is moved around the district for use at various project sites). As such, no mowing was conducted in the Grand Pré area specifically for the purpose of garlic mustard control.

*Planned AMA changes for Year 2:* As detailed in BMP2, in 2009, NSTIR will either commit the pressure washer for use on this project at a specified time, or mowing will be implemented prior to flowering (i.e., early May) so that risk of seed dispersal is minimized.

### BMP6 - Long-term Partnership Commitment

The last BMP involves a partnership commitment by the three main project partners, NSTIR, Parks Canada and the local community, to eradicate garlic mustard from Nova Scotia. Because of seed viability, management efforts are required for at least the next seven years. As more data becomes available on the persistence of the seedbank and trends in the distribution and dispersal of garlic mustard, the partners are expected to annually modify the management plan, the suite of BMPs, and their specific action plans to prevent further spread of this plant. This project can also be used as a demonstration model for application to other invasive plants in other areas of Nova Scotia and the Maritimes. The project is being assessed by the Nova Scotia Invasive Species Working Group (NSISWG), and the Invasive Alien Species Atlantic Network. Project partners fully expect valuable comments, and possibly new partners, from the wide range of government, non-government, academic and First Nations groups that makeup these provincial and regional bodies.

## **DISCUSSION AND CONCLUSIONS**

The concept of an adaptive management approach (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 Nature Conservancy (TNC) has modified the original concept of adaptive management to apply to invasive species (3). AMA begins with establishing goals for the site. After goal-setting, management follows a cyclical pattern of six steps, as detailed in Figure 6. At the end of each cycle (one management year), goals are modified to reflect outcomes of management actions. For the garlic mustard populations in NS, Steps 1 through 3 are complete, and Steps 4 to 6 are in progress. A newly revised set of BMPs, management targets and program goals will be finalized in the fall of 2008.

A long-term garlic mustard management plan for the village of Grand Pré and surrounding areas (including Hantsport) is being jointly developed by NSTIR, CARP, and Parks Canada. Management planning is based on communication with other land managers working to eradicate garlic mustard, extensive literature review, and available resources and project support. We view 2008 as a trial year, with adaptations made as required for future years.

We have already achieved or made a good start on many of the expected results and benefits of an adaptive management plan for garlic mustard in Nova Scotia, including the following:

- Contribution to the eradication of the only known occurrence of garlic mustard in NS;

- Increased community awareness about garlic mustard, and sense of community stewardship;
- Increased capacity for prevention and early detection/rapid response of new garlic mustard occurrences;
- Long-term management plan developed for the only known population of garlic mustard in NS;
- Assessment strategies defined to measure management success, based on scientifically accepted practices and in-place at the outset of the management plan; and
- Demonstration of a partnership model for developing effective BMPs for application with other species or in other areas of NS and the Maritimes.

To-date, the control efforts for garlic mustard have cost on the order of \$8,000, or \$0.08 per plant (using a conservative estimate of 100,000 plants pulled). These costs include NSTIR staff and vehicle expenses, CARP staff and travel expenses, and garbage bags. Costs do not take into account private landowner time or supplies, the NSTIR Operations Supervisors time, volunteer time, use of the NSTIR base for temporary storage, costs to dispose of the 106 bags of plant material, nor any of the Parks Canada efforts. Control efforts for 2009 are expected to be similar or slightly cheaper if less hand pulling occurs and mowing and cutting occurs prior to peak flowering. At some point in the future, NSTIR and its partners will have to determine if we should continue to spend public dollars (and community efforts) to continue the control program. Decisions will definitely 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. We look forward to another TAC session on this topic in the following years.

## REFERENCES

- (1) Nuzzo, V. 2000. Element Stewardship Abstract for *Alliaria petiolata* (*Alliaria officinalis*) Garlic Mustard. The Nature Conservancy, Arlington, VA. Accessed online: <http://tncweeds.ucdavis.edu/esadocs/documnts/allipet.pdf>
- (2) Ricketts, T., E. Dinerstein, D. Olson, C. Loucks, W. Eichbaum, D. DellaSalla, K. Kavanagh, P. Hedao, P. Hurley, K. Carney, R. Abell, and S. Walters. 1999. World Wildlife Fund Ecoregion Assessments Vol. 1. Terrestrial ecoregions of North America: a conservation assessment. Island Press, Washington, DC. 508p.
- (3) Smith, L.L. 2008. Invasive Exotic Plant Management Tutorial for Natural Lands Managers. Online tutorial prepared for Mid-Atlantic Exotic Pest Plant Council, Inc. (MA-EPPC) and hosted on the Pennsylvania Department of Conservation and Natural Resources (DCNR) website. Accessed in April 2008: <http://www.dcnr.state.pa.us/forestry/invasivetutorial/index.htm>
- (4) Johnson, L. 2001. University of Wisconsin Garden Facts. Invasive Plant Series, Garlic Mustard. University of Wisconsin – Extension. Accessed online: <http://wihort.uwex.edu/gardenfacts/X1081.pdf>

- (5) (CCFM) Canadian Council of Forest Ministers. 2006. Criteria and Indicators of Sustainable Forest Management in Canada: National Status 2005. Canadian Forest Service, Natural Resources Canada, Ottawa, ON. 154p.
- (6) Havinga, D., and the Ontario Invasive Plants Working Group. 2000. Sustaining Biodiversity: A Strategic Plan for Managing Invasive Plants in Southern Ontario. City of Toronto, Toronto ON. 28p.
- (7) Blaney, S. 2001. Exotic and Invasive Plants in Maritime Canada. Blomidon Field-Naturalist Newsletter, Summer 2001. Accessed online: [http://www.elements.nb.ca/Theme/invasive\\_species/sean/blaney.htm](http://www.elements.nb.ca/Theme/invasive_species/sean/blaney.htm)
- (8) Stinson, K.A, S.A. Campbell, J.R. Powell, B.E. Wolfe, R.M. Callaway, G.C. Thelen, S.G. Hallett, D. Prati, and J.N. Klironomos. 2006. Invasive plant suppresses the growth of native tree seedlings by disrupting belowground mutualisms. PLoS Biol 4(5): e140. DOI: 10.1371/journal.pbio.0040140.
- (9) Environment Canada. 2004. An Invasive Alien Species Strategy for Canada. Environment Canada, Ottawa, ON. 40p.
- (10) LaRue, D. 2004. Integrated Roadside Vegetation Management Field Manual. Accessed online: <http://www.gov.ns.ca/tran/vegetation/>
- (11) Solis, K. 1998. Update: new results indicate flowering garlic mustard should be bagged and destroyed (Wisconsin). Restoration and Management Notes 16: 223-224 (described in Nuzzo 2000).
- (12) Adirondack Park Agency. 2006. Adirondack Park Invasive Plant Program, Terrestrial Invasive Plant Project, Best Management Practices. Accessed online: <http://www.adkinvasives.com/terrestrial/Management/documents/BMPsGeneral2006.doc>
- (13) Hamilton County Soil and Water Conservation District. Publication date unknown. Suggested Control Methods for Terrestrial Invasive Plants (brochure). Accessed online: [http://www.hamiltoncountyswcd.com/terrestrial\\_invasive\\_control.pdf](http://www.hamiltoncountyswcd.com/terrestrial_invasive_control.pdf)
- (14) Elzinga, C. L., D. Salzer, and J. Willoughby. 2001. Measuring and Monitoring Plant Populations. Bureau of Land Management BLM Technical Reference 1730-1. Online copy.
- (15) Evans, C.W., D.J. Moorhead, C.T. Barger, and G.K. Douce. 2006. Invasive Plant Responses to Silvicultural Practices in the South. The University of Georgia Bugwood Network, Tifton GA, BW-2006-03. 52p.

## FIGURES

Figure 1. Map depicting known distribution of the invasive alien plant garlic mustard (*Alliaria petiolata*) in Nova Scotia. Source: Data collected by Dr. Sam Vander Kloet, map produced by the Atlantic Food and Horticulture Research Centre, Kentville, NS.

Figure 2. First-year garlic mustard (*Alliaria petiolata*) plant. Source: Chris Evans, University of Georgia, [www.forestryimages.com](http://www.forestryimages.com).

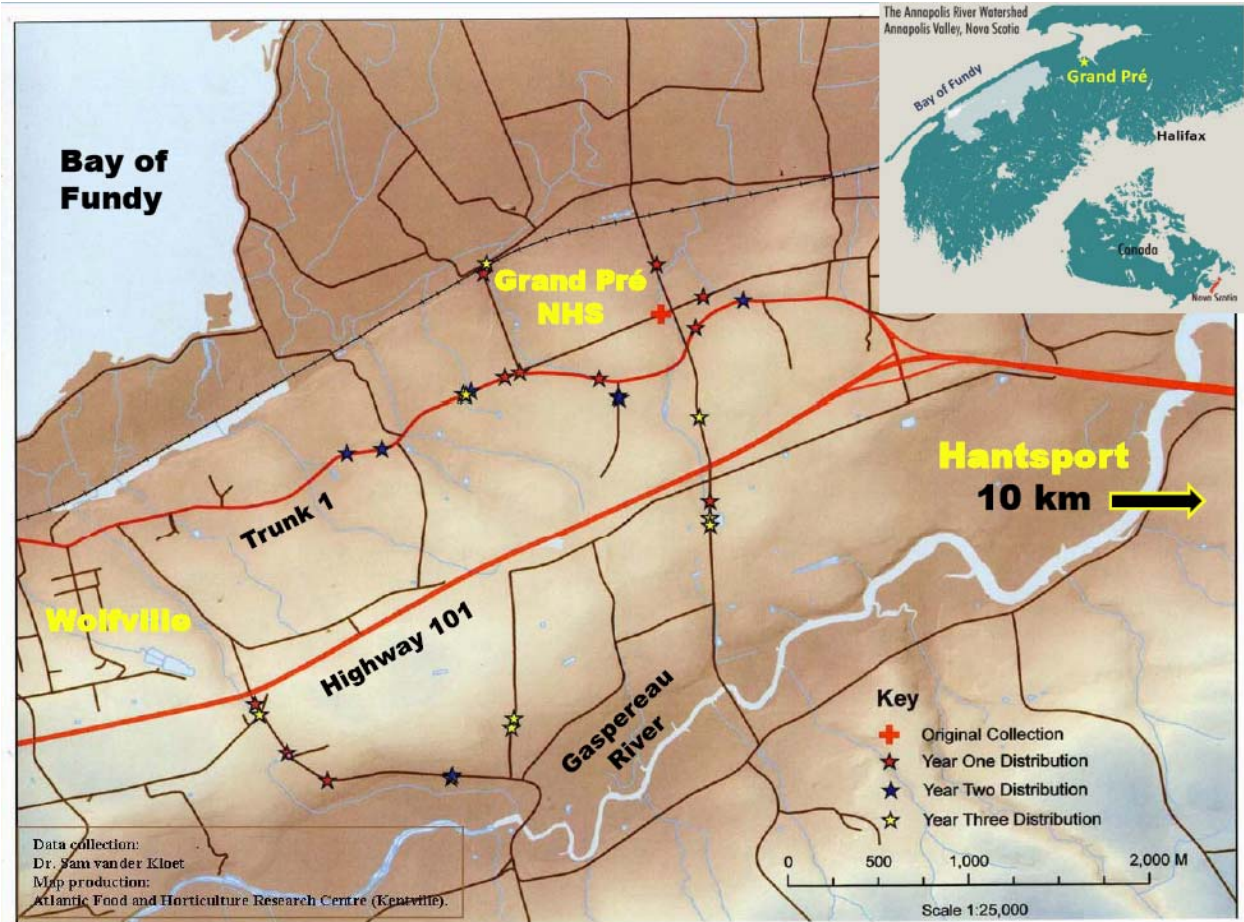
Figure 3. Second-year garlic mustard (*Alliaria petiolata*) plant. Source: Marika Godwin, Clean Annapolis River Project.

Figure 4. Training pamphlet developed to assist NS Transportation and Infrastructure field staff, community members and private landowners to identify garlic mustard (*Alliaria petiolata*).

Figure 5. Poster to increase public awareness and solicit new reports of garlic mustard plants.

Figure 6. Diagram identifying the six steps in the adaptive management approach (AMA) to managing invasive alien plants. Source: Lisa L. Smith. Invasive Exotic Plant Management Tutorial for Natural Lands Managers. Online tutorial prepared for Mid-Atlantic Exotic Pest Plant Council, Inc. (MA-EPPC) and hosted on the Pennsylvania Department of Conservation and Natural Resources (DCNR) website. Accessed in April 2008: [http://www.dcnr.state.pa.us/forestry/invasivetutorial/Management\\_planning.htm](http://www.dcnr.state.pa.us/forestry/invasivetutorial/Management_planning.htm)

**Figure 1.** Map depicting known distribution of the invasive alien plant garlic mustard (*Alliaria petiolata*) in Nova Scotia. Source: Data collected by Dr. Sam Vander Kloet, map produced by the Atlantic Food and Horticulture Research Centre, Kentville, NS.



**Figure 2.** First-year garlic mustard (*Alliaria petiolata*) plant. Source: Chris Evans, University of Georgia, [www.forestryimages.com](http://www.forestryimages.com).





**Figure 3.** Second-year garlic mustard (*Alliaria petiolata*) plant. Source: Marika Godwin, Clean Annapolis River Project.





**Figure 4a.** Training pamphlet developed to assist NS Transportation and Infrastructure field staff, community members, and private landowners to identify garlic mustard (*Alliaria petiolata*; Side 1 of 2).





**Figure 4b.** Second side of the training pamphlet.

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

**FIRST-YEAR PLANT**  
Basal rosette with regularly toothed, kidney shaped leaves.

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

**SECOND-YEAR PLANT**  
1m tall with alternate, coarsely toothed, triangular 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.

Figure 5. Poster to increase public awareness and solicit new reports of garlic mustard plants.

**WANTED:**

**ADDITIONAL INFORMATION ON THE LOCATION OF**

**GARLIC MUSTARD**      *ALLIARIA PETIOLATA*



First year rosettes



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 siliques (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@acadiu.ca](mailto:ruth.newell@acadiu.ca) OR Telephone: 902-585-1335

**Figure 6.** Diagram identifying the six steps in the adaptive management approach (AMA) to managing invasive alien plants. Source: Lisa L. Smith. Invasive Exotic Plant Management Tutorial for Natural Lands Managers. Online tutorial prepared for Mid-Atlantic Exotic Pest Plant Council, Inc. (MA-EPPC) and hosted on the Pennsylvania Department of Conservation and Natural Resources (DCNR) website. Accessed in April 2008:  
[http://www.dcnr.state.pa.us/forestry/invasivetutorial/Management\\_planning.htm](http://www.dcnr.state.pa.us/forestry/invasivetutorial/Management_planning.htm)

