

Garlic Mustard

Alliaria petiolata

Best Management Practices in Ontario



ontario.ca/invasivespecies

Foreword

These Best Management Practices (BMPs) provide guidance for managing invasive Garlic Mustard (*Alliaria petiolata*) in Ontario. Funding and leadership for the production of this document was provided by the Ontario Ministry of Natural Resources (OMNR). The BMPs were developed by the Ontario Invasive Plant Council (OIPC), and its partners to facilitate the invasive plant control initiatives of individuals and organizations concerned with the protection of biodiversity, agricultural lands, infrastructure, crops and natural lands.

These BMPs are based on the most effective and environmentally safe control practices known from research and experience. They reflect current provincial and federal legislation regarding pesticide usage, habitat disturbance and species at risk protection. These BMPs are subject to change as legislation is updated or new research findings emerge. They are not intended to provide legal advice, and interested parties are advised to refer to the applicable legislation to address specific circumstances. Check the website of the Ontario Invasive Plant Council (www.ontarioinvasiveplants.ca) for updates.

Anderson, Hayley. 2012. Invasive Garlic Mustard (*Alliaria petiolata*) Best Management Practices in Ontario. Ontario Invasive Plant Council. Peterborough, ON.

Printed April 2013

Peterborough, Ontario

ISBN: (to be confirmed)

This document was prepared for the Ontario Ministry of Natural Resources by the Ontario Invasive Plant Council.

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Garlic Mustard.

Photo courtesy of Rachel Gagnon, OIPC



Second year flowers of Garlic Mustard.

Photo courtesy of Ken Towle, Ganaraska Region Conservation Authority

Introduction

Garlic Mustard (*Alliaria petiolata*) is an adaptable, aggressive, biennial (2 year life cycle) herbaceous plant in the mustard (*Brassicaceae*) family, which is sometimes called Hedge Garlic or Sauce Alone. Garlic Mustard is native to Europe, and can be found from England to Italy. It was introduced to North America as a food source and was used as herbal medicine by settlers in the late 1800's. It has escaped cultivation to become a serious invader in Ontario's temperate forests, agricultural fencerows, public right of ways and residential lands.

This document has been developed to help guide the effective and consistent management of this invasive plant across Ontario. These BMPs emphasize targeting control efforts in areas where small populations of Garlic Mustard are present, but have not yet become dominant.

Description

The first record of Garlic Mustard in Ontario was in Toronto, in 1879. There are also records from Ottawa in 1891 and Kingston in 1898. Since its introduction, Garlic Mustard has spread throughout Southern Ontario, becoming a serious invader and threat to Ontario's biodiversity.

Garlic Mustard can harm biodiversity, the economy and society in a number of ways. It commonly grows in urban gardens, and carries diseases like mosaic viruses which may affect other garden plants. It is a nuisance for dairy farmers because when eaten by livestock the garlic flavour can be tasted in the milk, making it unusable.

Garlic Mustard forms dense monocultures that reduce the biodiversity and aesthetic value of natural areas. The effects of Garlic Mustard on ecosystems are long-lasting and may permanently alter forests, even after removal. It releases

allelopathic chemicals that change soil chemistry and prevent growth of other plants. It out-competes and actively displaces native woodland plants, many of which are now listed as species at risk, including American Ginseng (*Panax quinquefolius*), Drooping Trillium (*Trillium flexipes*), Hoary Mountain Mint (*Pycnanthemum incanum*), and Wood Poppy (*Stylophorum diphyllum*).

Garlic Mustard grows in a wide range of habitats and spreads quickly along roadsides, trails, and fence lines. Seeds fall close to the parent plants, and rarely disperse by wind or water. The main pathway for seed spread over long distances is through humans, pets and wildlife inadvertently carrying seeds to new areas on boots, clothing or fur. Recreational trails also seem to be a major corridor for seed dispersal and the spread of Garlic Mustard plants. Garlic Mustard can self-pollinate, so only one plant is required to start a new population.

Garlic Mustard is a threat to woodland plants, including these species at risk:



American Ginseng
(*Panax quinquefolius*)

Photo courtesy of US Fish and Wildlife Service



Drooping Trillium
(*Trillium flexipes*)

Photo courtesy of Penny Stritch, US Forest Service



Hoary Mountain Mint
(*Pycnanthemum incanum*)

Photo courtesy of Ted Bodner, USDA



Wood Poppy
(*Stylophorum diphyllum*)

Photo courtesy of Wikimedia Commons



Garlic Mustard often spreads along recreational trails.

Photo courtesy of Matt Smith, Ontario Federation of Anglers and Hunters

Biology and Life Cycle

Garlic Mustard is a biennial (two year life cycle) plant. The first year, it grows as a basal rosette (low-growing leaves arranged in a circle) of kidney shaped leaves. Garlic Mustard over-winters in this stage, and the leaves stay green under the snow, giving it an advantage over other plants by allowing for photosynthesis to begin much earlier in spring.

In early to late May of the second year, it grows one or more flowering stalks, reaching up to 1 metre in height, before setting seed and dying. In North America, Garlic Mustard spreads only by seed. The seeds are dropped from seed pods (siliques) in July and August as the pods crack and dry out. However, some plants will continue to drop seeds until early November and some may even retain seeds over the winter. The number of siliques produced depends on the size and health of the plants. In ideal conditions, plants can produce up to 150 seed pods, with up to 22 seeds per pod. In one study, a dense population of Garlic Mustard produced over 105,000 seeds per square metre. Most seeds are dropped within 1-2 metres of the parent plants.



First year Garlic Mustard plants grow as a basal rosette.

Photo courtesy of Matt Smith, Ontario Federation of Anglers and Hunters



Second year plants grow one or more flowering stalks and can reach 1m in height.

Photo courtesy of Wasyl Bakowsky, Ontario Ministry of Natural Resources



Garlic Mustard forms seed pods called siliques, seeds are dropped as these dry out.

Photo courtesy of Rod Krick, Credit Valley Conservation

Seeds are usually dormant for at least one year prior to sprouting. They can stay dormant over winter and remain viable in the soil for up to five years. Once germinated, seedlings grow rapidly, which allows Garlic Mustard to out-compete slower-growing native species.

Garlic Mustard is allelopathic, which means that its roots produce chemicals (including *glucosinates*, *sinigrin* and *cyanide*) that change soil chemistry and prevent other species from growing nearby. Some of these chemicals are also present in the leaves, which deter herbivores from eating the plant.

Garlic Mustard grows in an advance-retreat pattern. Since the plants have a two year life-cycle, there may be many rosettes and few flowering plants one year, and few rosettes and many flowering plants the following year, making the population appear to expand and retract. As a result of this fluctuation in flowering plants, the density and number of Garlic Mustard plants will vary widely from year to year, but over time, infestations will continually expand.

Populations expand through advancing "satellite" populations. Smaller populations are established a few metres away from the main population, and then fill in the space between within roughly 2 years. This growth pattern should be kept in mind when implementing control; managing these smaller satellite populations first is recommended. Populations expand rapidly, and can double in size every 4 years, averaging an expansion rate of 5m/year. Populations tend to spread most rapidly into uninvaded areas, especially after disturbance.

If Garlic Mustard roots are damaged but not removed, there are small buds (called axillary buds) on the roots which will sprout additional stems. If the plants are damaged, they are able to produce replacement flowers, as late as July and August.



An expanding population of 2nd year Garlic Mustard plants.

Photo courtesy of Rachel Gagnon, OIPC



Garlic Mustard growing in the understory of a temperate forest in Southern Ontario.

Photo courtesy of Freyja Whitten, Credit Valley Conservation

Habitat

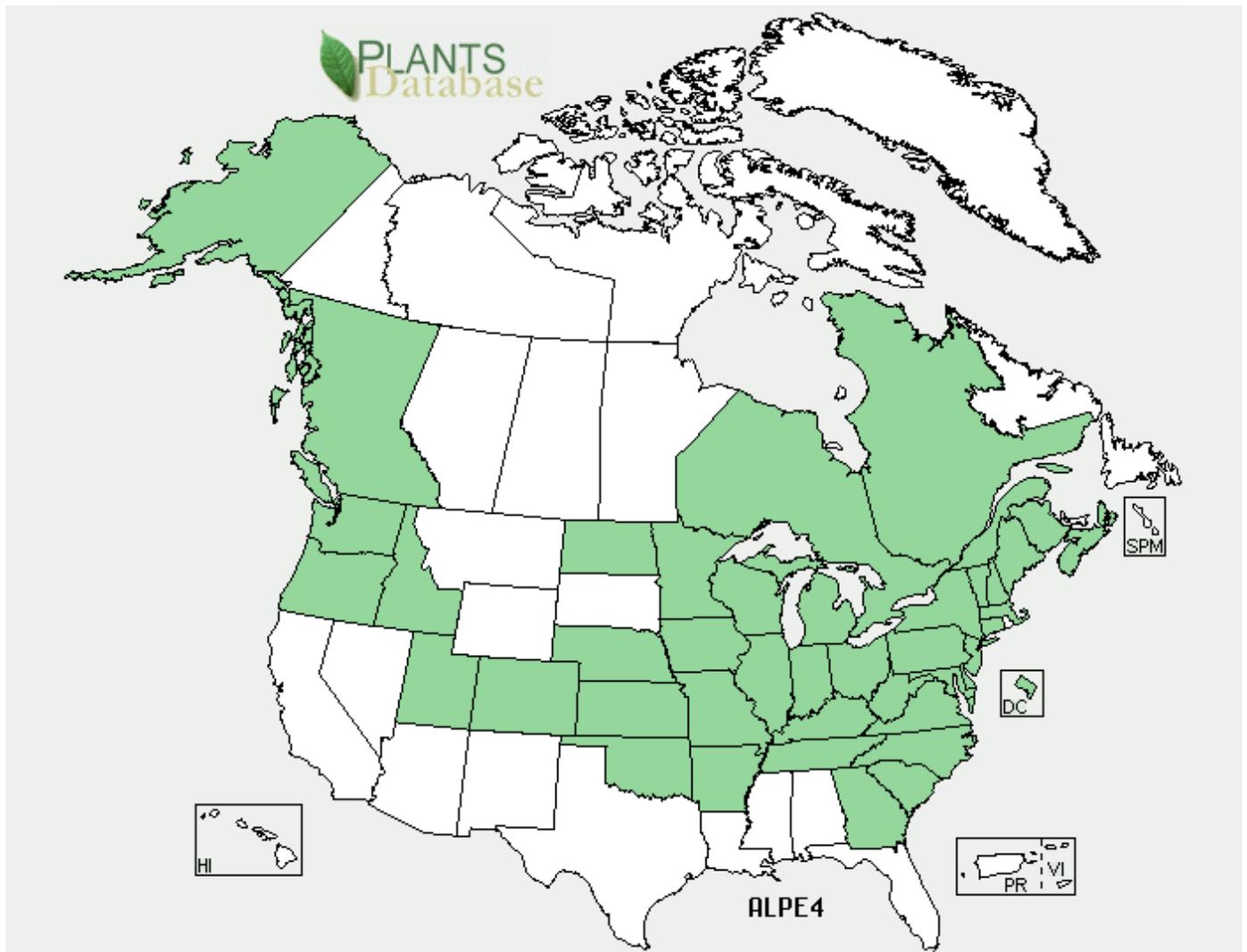
Garlic Mustard can grow in a variety of habitats and in a wide range of soils (from clay to loam to sand). It is commonly found in disturbed sites, such as forest edges, fence lines, roadsides, trail sides and urban gardens, as well as in the forest understory.

It prefers calcareous-based (limestone) soils and is somewhat intolerant of acidic conditions. It will grow in full sun to full shade, but seems to grow best in damp, partially shaded soil, such as the understories of temperate forests in Southern Ontario.

The density and health of Garlic Mustard populations is somewhat light-dependent. While they can grow in a wide range of conditions, populations will generally be larger, and produce more seeds in higher light conditions. It will invade most disturbed sites, but can also spread into invasion-resistant habitats, such as previously undisturbed mature forests. Garlic Mustard invasion may be facilitated by non-native earthworms, as forests with low leaf litter (those that have an abundance of earthworms to quickly break down the fallen leaves on the forest floor) are ideal sites for plant establishment.

Distribution

Garlic Mustard is widespread in Southern Ontario, from Windsor to Ottawa, and has also been found as far north as Sault Ste Marie. In Canada, it has been found in British Columbia, Alberta, Ontario, Quebec, New Brunswick, Nova Scotia and Prince Edward Island. It is common in the US, being found in more than 30 states, and extends south to Kentucky, and west to North Dakota. It has also been introduced to North Africa, India, Sri Lanka, and New Zealand.



Garlic Mustard is found across the US and Canada.

Map courtesy of USDA

Garlic Mustard – Lookalikes

Garlic mustard resembles several native Ontario plants, as well as some other invasive species. The leaves at the base of the plant look like those of several plants in the carrot family (*Apiaceae*), the daisy family (*Asteraceae*), the violet family (*Violaceae*) and the mint family (*Lamiaceae*). The seed pods look like those of several other species within the mustard family (*Brassicaceae*).

1st Year

Garlic Mustard (*Alliaria petiolata*) (Basal Rosette, no flowers)



Photo courtesy of Matt Smith, Ontario Federation of Anglers and Hunters

Native Violets (*Viola spp.*)



Photo courtesy of Tom Barnes, University of Kentucky

Creeping Charlie or Ground Ivy (*Glechoma hederacea*) *also invasive/non-native



Photo courtesy of Christian Fischer

Height	<ul style="list-style-type: none"> • Low growing 	<ul style="list-style-type: none"> • Low growing, usually up to 30 cm tall 	<ul style="list-style-type: none"> • 5 – 50 cm
Stem	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • Square stem
Leaves	<ul style="list-style-type: none"> • 3-4 leaves per rosette • 2-12 cm diameter • Dark green and kidney shaped • Scalloped margins, deep veins which makes the leaves look wrinkled • Smell strongly of garlic when crushed 	<ul style="list-style-type: none"> • Grow in a rosette or along stems, depending on species • Usually on long, slender, hairy petioles • 1– 5 cm in diameter • Kidney shaped to broadly oval with heart-shaped bases and pointed tip • Often cupped 	<ul style="list-style-type: none"> • Grow in runners, not rosettes • Hairy upper surface • Leaves smell minty when crushed • Kidney to fan shaped, opposite leaves • 2-3 cm in diameter • 3-6 cm long petioles (leaf stem) • Stems are attached in the middle of the leaf
Roots	<ul style="list-style-type: none"> • Slender, white "S" shaped taproot (key ID feature) 	<ul style="list-style-type: none"> • Fibrous white roots, many species form rhizomes 	<ul style="list-style-type: none"> • Roots form at the nodes where leaves join the stem
Flowers	<ul style="list-style-type: none"> • N/A 	<ul style="list-style-type: none"> • 5 petals, the lower petal is usually larger and spurred at the base, range of colours but usually purple, appear in early spring/summer 	<ul style="list-style-type: none"> • Purple, funnel shaped, grow in clusters, flowers from May – July

2nd Year (Flowering Stalk)

Garlic Mustard (*Alliaria petiolata*)



Photo courtesy of Wasyl Bakowsky

Dame's Rocket (*Hesperis matronalis*) *also invasive



Photo courtesy of Christian Fischer

Cut-leaved Toothwort (*Cardamine concatenata*)



Photo courtesy of Wikimedia Commons

Early Saxifrage (*Saxifraga virginica*)



Photo courtesy of Mason Brock

Height	<ul style="list-style-type: none"> Up to 1 m 	<ul style="list-style-type: none"> 1 m or taller 	<ul style="list-style-type: none"> 20-40 cm 	<ul style="list-style-type: none"> Up to 30 cm
Stem	<ul style="list-style-type: none"> Hairy 	<ul style="list-style-type: none"> Multiple hairy stems 	<ul style="list-style-type: none"> Smooth to slightly hairy 	<ul style="list-style-type: none"> Smooth to slightly hairy
Leaves	<ul style="list-style-type: none"> Alternate, 3-8 cm long, triangular and coarsely toothed 	<ul style="list-style-type: none"> No petioles, leaves are attached directly to main stem Long and narrow/lance-shaped leaves Leaves have short hairs Toothed margins 	<ul style="list-style-type: none"> Leaves have long stems and are deeply dissected into five parts, large toothed margins 	<ul style="list-style-type: none"> Basal leaves only, stem is leaf-less
Flower	<ul style="list-style-type: none"> White, 4 petals; flowers in early May 	<ul style="list-style-type: none"> Fragrant, pink, purple or white, 4 petals, flowers in early summer 	<ul style="list-style-type: none"> White to pinkish with 4 petals, blooms until May 	<ul style="list-style-type: none"> White, 5 petals, blooms in early May, in loose branched clusters
Fruit (Seeds)	<ul style="list-style-type: none"> Seed pods (called siliques) 2.5 – 6 cm long, each contains 10-20 small black seeds 	<ul style="list-style-type: none"> Produces seed pods (siliques) 5–14 cm long that contain two rows of seeds 	<ul style="list-style-type: none"> Seed pods up to 4 cm long 	

Impacts

Impacts to Biodiversity

Vegetation Communities

Garlic Mustard does not appear to require disturbance to become established, making it a threat to mature forests. It can enter, establish itself and become the dominant plant in the forest understory in 5-7 years. It actively displaces native spring ephemeral wildflowers through direct competition and/or through changes to the soil/leaf litter.

Forest Ecosystems and Wildlife

Garlic Mustard is allelopathic; the chemicals produced in the roots have been shown to prevent the growth of other plants and grasses. These chemicals also affect the growth and regeneration of arbuscular mycorrhizal fungi (AMF); beneficial fungi in the soil that help trees and plants absorb nutrients and water into their roots. The reduced AMF in Garlic Mustard-infested forests inhibits growth of most native tree seedlings and plants, which depend on AMF. Loss of AMF changes the forest ecosystem. Non-native species are better able to grow and displace native seedlings, including those which would eventually become canopy trees such as maples, and oaks. This effect can last for years after the Garlic Mustard has been removed.

Ontario's forests have evolved to depend on leaf litter, which provides a layer of slowly decomposing organic matter on the forest floor, to function properly. Garlic Mustard leaves have a high nutrient content. When they die, they

accelerate the rate of decay of native leaf litter, altering the natural decomposition cycle, and changing the structure and function of forest ecosystems.

This effect is compounded by non-native earthworms which have also caused ecosystem changes to Ontario's forests by reducing the amount of leaf-litter available. Garlic Mustard is able to establish itself in these low-leaf litter environments, whereas many native species are not well suited to these conditions. By changing the composition of the litter layer on the forest floor, it reduces habitat for ground-nesting birds and affects habitat for salamanders and other forest floor dwelling animals.

Areas with high-density deer populations may promote Garlic Mustard invasion. Deer tend to prefer browsing on native plant species over Garlic Mustard and as a result, may reduce competition from nearby native plants. Garlic Mustard also affects other wildlife by reducing the amount of native plant pollen, seeds and fruits available, due to the reduction of native species as a result of competition.



Garlic Mustard can negatively impact forest ecosystems and wildlife.

Photo courtesy of Rachel Gagnon



Garlic Mustard inhibits the growth of native plants and trees in the forest understory.

Photo courtesy of Freyja Whitten, Credit Valley Conservation

Horticulture and Agriculture

Garlic Mustard is a host to several viruses (cucumber mosaic virus, cabbage black ringspot virus, turnip mosaic virus) which may affect horticultural plants and agricultural crops. Garlic Mustard is a nuisance to dairy farmers, as cows grazing on Garlic Mustard may produce milk that is tainted with a garlic flavour.

Regulatory tools

Federal

Garlic Mustard is not a federally regulated species.

Provincial

Garlic Mustard is not a provincially regulated species.

Municipal – Property Standards Bylaw

A municipality can pass a property standards bylaw under the Building Code Act to address the presence of weeds deemed noxious or a threat to the environment or human health and safety.

Best Management Practices

It is recommended that an integrated pest management (IPM) plan is used for managing Garlic Mustard. IPM combines 2 or more methods in to a long term plan that follows up initial treatments with frequent monitoring and re-assessment, and subsequent treatments if necessary. Case-by-case assessments will help determine which combination of control measures will be most effective in a given area.

Controlling Garlic Mustard before it becomes locally established will reduce its impacts on biodiversity, the economy and society.

Once Garlic Mustard has been confirmed at a location, a control plan should be developed based on infestation size, site accessibility, potential for spread and the risk of environmental, economic or social impacts. Site specific conditions such as native plant diversity and wildlife usage should also be considered when developing control plans. A detailed inventory of each site is strongly recommended prior to starting control efforts. This will help ensure proper control methods and timing are selected to minimize negative impacts to the ecosystem.

With large infestations and limited time and resources, control work can seem daunting. It is important to develop a feasible, long-term strategy.

The following BMPs can be used as a guide to develop a control plan. A number of natural resource considerations, such as species at risk and habitat disruption, should be assessed before creating a control plan.

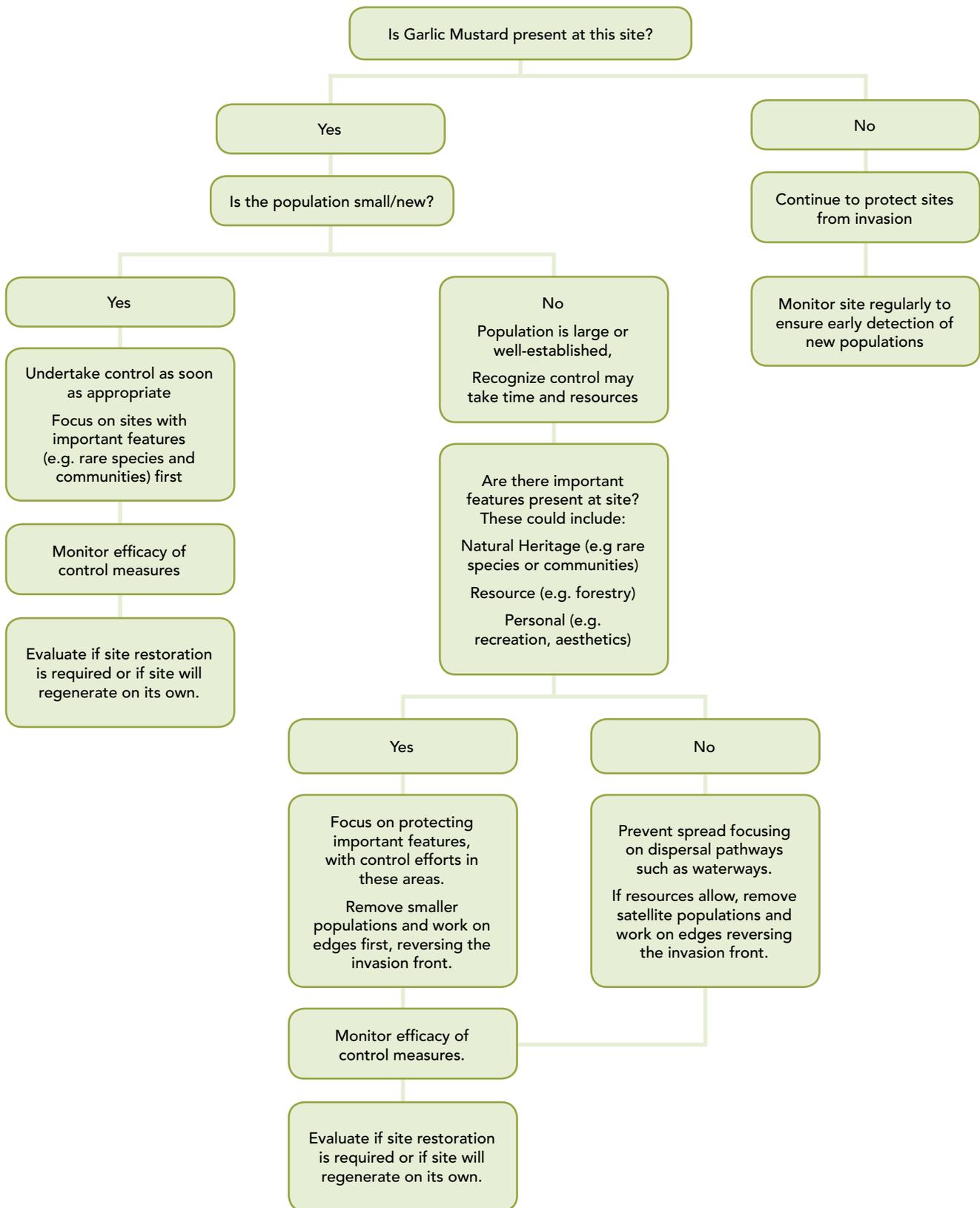
Natural Resource Considerations

You are responsible for ensuring that your project follows all relevant laws, including the Endangered Species Act (ESA). If protected species or habitats are present, an assessment of the potential effects of the control project may be required. Consult with your local MNR district office early in your control plans for advice.

Setting Priorities

When creating management plans, it is important to use your time and budget wisely by prioritizing invasive species control. The following will help you to prioritize sites and areas within sites for control of Garlic Mustard.

This flow chart can assist land managers in determining which site to focus control efforts first:



Site Prioritization

(This section modified from “The Landowners Guide to Managing and Controlling Invasive Plants, published by Credit Valley Conservation)

1. Protect areas where Garlic Mustard is absent or just appearing.
2. Protect rare species and communities. These include federal, provincial, and regionally listed rare species.
3. Protect important habitats and land values (i.e. forestry, maple syrup production).
4. Cost and effort: Will the area where the Garlic Mustard has invaded require restoration or can it be left to regenerate naturally? (Note – it is usually recommended to restore control areas to make them more resilient to future invasions.)

Prioritizing within a Control Area

It is crucial to prioritize within a control area by determining where the satellite populations are, and eradicating those before they join the larger populations.

1. Focus on large blocks of un-invaded areas, and keep them free of invaders
2. Control small, younger, satellite populations first
3. “Unfragment” the boundaries of invaded areas by removing outlying plants
4. Reverse the invasion, expand the un-invaded area outward

Garlic Mustard is often spread along trail edges in natural areas, so for this species, starting control work along trails should be a priority to reduce the spread.

Assessing Regeneration vs. Restoration

Consider the following factors:

- **Level of disturbance at the site**

What is the level of disturbance at site? Was it a heavily invaded site? (I.e. a lot of disturbance was caused when things were removed) Will it continue to be disturbed? (I.e. through trail use and management)

- **Invasive Species Biology**

What is the biology of the invasive species removed and is there a seed bank to consider?

- **Re-invasion Risk**

Are there invasive species in the area that could re-invade the site from certain pathways of introduction, such as nearby trails or watercourses?

- **Existing native vegetation**

What native vegetation is left? How long before it regenerates by itself? Does it need help?

Control Measures

Control measures must be continued for at least 5 years to ensure that the seed bank is depleted. Many of these measures, if only done once, will actually increase Garlic Mustard densities by stimulating seed germination through soil disturbance. It is also important to remove both stages (1st and 2nd year plants) if both are present, as removal of only the tall flowering plants may reduce competition to the basal rosettes, increasing their chances of survival and flowering in the next year. If an area is cleared of Garlic Mustard plants, it should be re-planted immediately with a cover crop or covered with leaves or mulch at least 5cm thick to reduce/prevent Garlic Mustard seed germination.

Size of the Infested Area

		Size of the Infested Area			
		Isolated Plants	Small (.1-.5ha)	Medium (.5-2ha)	Large (more than 2 ha)
Density of Infested Area	Low Density (1-50 plants or less than 10% cover)	<ul style="list-style-type: none"> • Pulling • Mowing/Cutting • Chemical 	<ul style="list-style-type: none"> • Pulling • Mowing/Cutting • Clipping Flower Heads • Chemical 	<ul style="list-style-type: none"> • Mowing/Cutting • Clipping Flower Heads • Chemical 	<ul style="list-style-type: none"> • Mowing/Cutting • Chemical
	Medium Density (50-1000 plants or between 10% and 30% cover)		<ul style="list-style-type: none"> • Pulling • Mowing/Cutting • Clipping Flower Heads • Chemical 	<ul style="list-style-type: none"> • Mowing/Cutting • Clipping Flower Heads • Chemical 	<ul style="list-style-type: none"> • Mowing/Cutting • Chemical
	High Density (more than 1000 plants or 30 – 100% cover)			<ul style="list-style-type: none"> • Mowing/Cutting • Clipping Flower Heads • Chemical 	<ul style="list-style-type: none"> • Mowing/Cutting • Clipping Flower Heads • Chemical

*controlled burns should only be used where fire is part of the natural disturbance regime. Controlled burns should only be applied by authorized personnel, and safe burning practices should always be followed.

Method	Population Characteristics	Objective of Control	Timing	Restoration	Notes
Hand Pulling	Small populations	Remove plants, prevent seed production, eradication	Early spring (April-May) before plants have set seed	Re-planting or soil rehabilitation may need to be completed after Garlic Mustard seed bank has been depleted	Must be repeated, soil disturbance will stimulate seed bank germination
Mowing/Cutting	Small to medium populations	Prevent yearly seed production, eventually eradicate population through stopping seed production	Just after plants flower and before they produce seed (May)	Re-planting or soil rehabilitation may need to be completed after the Garlic Mustard seed bank has been depleted	Must be repeated, may flower at different times so may be repeated more than once in a growing season
Clipping Flower Heads	Small to medium populations	Prevent seed production	Just after plants flower and before they produce seed (May)	Re-planting or soil rehabilitation may need to be completed after the Garlic Mustard seed bank has been depleted	Must be repeated continually until the end of growing season
Over-planting	Medium to large populations	Eradication through competition	After removal of Garlic Mustard, best done in early spring	None required	Best used in combination with other control measures, or as a restoration measure to out-compete seedlings that may sprout from an established seed bank

Method	Population Characteristics	Objective of Control	Timing	Restoration	Notes
Controlled Burns	Large populations	Eradication	Fall or early spring	Re-planting or soil rehabilitation may need to be completed after Garlic Mustard seed bank has been depleted	At sites with a seed bank Garlic Mustard will re-colonize the burned areas, meaning burning may have to occur annually until the site is restored, or other control measures are utilized
Chemical	Small to large/ established populations	Herbicide application; eradication or control to manageable levels	Early spring or late fall (when other plants are dormant)	Re-planting or soil rehabilitation may need to be completed after Garlic Mustard seed bank has been depleted	
Biological	Large/established, dense populations	Once a population is past manageable or treatable levels, often the only viable control option is biological control (introduction of a predator, disease or pathogen to reduce populations)	N/A	None required	Biological controls are currently being researched

Mechanical Control

Hand Pulling:

Hand pulling is a viable strategy for small populations or few plants. Hand pulling Garlic Mustard will create soil disturbance, which stimulates the germination of seeds in the seed bank. The entire “s” shaped root must be removed to avoid re-sprouting from buds on the root system. Hand pulling must be repeated more than once, and is more likely to be successful when followed with replanting with native species.



Hand Pulling is an effective control measure for small populations.

Photo courtesy of OFAH

Basal Cutting/Mowing:

Basal cutting involves cutting 2nd year plants at the base of the stem. The best time to do basal cutting is just after the plants flower, and before they produce seeds. Garlic Mustard plants can flower at different times, so it may need to be repeated more than once in a season. Basal cutting is preferable to hand pulling because it reduces the soil disturbance. Plants that have been mowed can still send up flowering stalks, but continuous mowing throughout the growing season can prevent seed production.

Clipping Flower Heads:

Clipping the flower heads will prevent seed production but must be repeated continually until the end of the growing season as it encourages new flowers to emerge.



Garlic Mustard can re-grow after clipping, so it must be repeated several times.

Photo courtesy of Paula Davies

Chemical Control

Herbicide Application – Garlic Mustard

Herbicides must be applied in accordance with all label directions. For an up-to-date list of herbicides labeled for Garlic Mustard control, visit the Pest Management Regulatory Agency's web site at www.pmra-arla.gc.ca. The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)'s Publication 75, Guide to Weed Control is an excellent reference for all aspects of weed control, and includes a section on invasive plant management. To determine if a federally registered herbicide is also classified for use in Ontario, visit <http://app.ene.gov.on.ca/pepsis/>.

Chemical Control Timing:

Based on the life cycle and physiology of Garlic Mustard, spot application of herbicide in the early spring or late fall (when other plants are dormant, but rosettes are still green) may provide control of Garlic Mustard populations. This process will need to be repeated for several years if there is an existing seed bank. Because most herbicides currently used for Garlic Mustard control are non-selective, care must be taken to avoid other species.

Foliar Spray:

Refer to the label of the herbicide you are using for rates and instructions for foliar application. Spray just until the leaves are covered; ensure that the herbicide is not dripping off the leaves.

Wick or wiper applications:

Some herbicides can be applied with wick or wiper applicators directly to the leaves of Garlic Mustard or other plants. This can be used in place of foliar spray if there are concerns over spray drift. Follow label instructions for the appropriate herbicide concentration and application methods.

Anyone using a pesticide is responsible for complying with all federal and provincial legislation. Most non-domestic (i.e. commercial, restricted etc.) herbicides can only be applied by licensed exterminators. For more information, refer to the Ontario Pesticides Act and Ontario Regulation 63/09 (available on <http://www.elaws.gov.on.ca>), or contact the Ontario Ministry of the Environment (<http://www.ene.gov.on.ca/environment>).

Legislation Governing Pesticide Use

While using herbicides is not always an ideal solution, in some situations the detrimental effects of allowing invasive Garlic Mustard to flourish can far outweigh the negative effects of pesticide use. There are many regulations surrounding the use of chemicals for the control of invasive species and specific precautions must be taken prior to application. In Ontario, herbicide storage, disposal, use, transport and sale is regulated under the Pesticides Act and Regulation 63/09 which can be viewed at: www.e-laws.gov.on.ca/html/source/regs/englis/2009/elaws_src_regs_r09063_e.htm

The Ontario Pesticides Act and Ontario Regulation 63/09 provide natural resources, forestry and agricultural exceptions which may allow chemical control of invasive plants on your property. Other exceptions under the Act include golf courses, and for the promotion of public health and safety.

Natural Resources Exception

A 'natural resources' exception exists for the use of prohibited pesticides to manage, protect, establish or restore a natural resource. This exception allows the use of prohibited herbicides for control of invasive plants on your property provided your project meets specific conditions and you obtain the necessary approvals.

If your project meets the natural resources criteria specified in section 33 of Ontario Regulation 63/09 and includes pesticide use according to the Integrated Pest Management principles outlined in the BMP guide you will need to contact the Ontario Ministry of Natural Resources (www.

ontario.ca) to obtain a written letter of opinion from the MNR Regional or Branch Director.

Forestry Exception

If Garlic Mustard is within a forest, chemical control may fall under the exception for forest management, and a letter of opinion may not be required. Class 9 pesticides can be used under the forestry* exception to protect trees from pests and to control competing vegetation.

*O. Reg. 63/09 defines "forestry" and "forest" as:

Forestry means activities relating to any of the following: harvesting, renewing, maintaining or establishing a forest, protecting forest resources derived from a forest, and accessing a forest for these purposes.

Forest means a treed area of land that is one hectare in size or larger and is not used for producing an agricultural crop as part of an agricultural operation.

Refer also to the Ministry of Environment's factsheet titled "Pesticides Act and Ontario Regulation 63/09 Private Land and Woodlot Owners April 2011" http://www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_085367.pdf.

Agriculture Exception

There is an exception for the use of Class 9 pesticides by a farmer for agricultural purposes. This exception may apply to the control of Garlic Mustard in agricultural fields or near farm operations.

A farmer is an individual who owns or manages an agricultural operation.

An agricultural operation is an agricultural, aquacultural or horticultural operation and includes:

- Growing, producing or raising farm animals.
- Production of crops, including greenhouse crops, maple syrup, mushrooms, nursery stock, tobacco, trees and turf grass, and any additional agricultural crops.
- Activities that are part of an agricultural operation such as maintenance of a shelterbelt for the purposes of the agricultural operation.
- The production of wood from a farm woodlot, if at least one of the activities described earlier is carried out on the property where the farm woodlot is located.

Refer also to the Ministry of the Environment's factsheet titled "Pesticides Act and Ontario Regulation 63/09 Agriculture May 2011"

www.ene.gov.on.ca/stdprodconsume/groups/lr/@ene/@resources/documents/resource/stdprod_080128.pdf

Cultural Control

Overplanting of Native Spring Ephemerals:

Some native plant species have been shown to out-compete Garlic Mustard when planted in higher densities than are usually found in forests. Bloodroot (*Sanguinaria canadensis*) and Mayapple (*Podophyllum peltatum*) are such species. Planted at densities of 9 or 11 plants/m²; they can successfully outcompete Garlic Mustard. This method is best used in combination with other control measures, or as a restoration measure in areas where Garlic Mustard has been removed and the high-density planting can out-compete any growth from the seed bank.



Mayapple can out-compete Garlic Mustard if planted densely.

Photo courtesy of Wikimedia Commons

Additional native plants which may out-compete Garlic Mustard when planted densely include:

- Zigzag Goldenrod (*Solidago flexicaulis*)
- Canada Anemone (*Anemone canadensis*)
- Virginia Waterleaf (*Hydrophyllum virginianum*)
- Canada Waterleaf (*Hydrophyllum canadense*)
- White Aven (*Geum canadense*)
- Ostrich Fern (*Matteucia struthiopteris*)
- Woolly Blue Violet (*Viola sororia*)
- Woodland Sedge (*Carex blanda*)
- Starry False-Solomon's-Seal (*Mianthemum stellatum*)
- Lady Fern (*Athyrium filix-femina*)
- American Currant (*Ribes americanum*)
- Bush Honeysuckle (*Diervilla lonicera*)

Prescribed Burning:

Prescribed burning is the planned and deliberate use of fire by authorized personnel. It can be included in an integrated management plan where fires are part of the natural disturbance regime (i.e. in degraded tallgrass oak savannas and oak woodlands). It is not recommended in deciduous forest ecosystems as burning may further reduce the leaf litter layer, making the site more conducive to Garlic Mustard growth. Post-burn monitoring is crucial. If the burn was spotty, there may be large patches of Garlic Mustard remaining, which will deposit seed into the bare patches created by the burn. In these instances other control methods are required. Burning is only effective in the year it occurs. At sites with a seed bank, Garlic Mustard will re-colonize the burned areas, meaning burning may have to occur annually until the site is restored, or other control measures are utilized. Spot burns may also be conducted for smaller populations. The burns must be hot enough to kill the root crown of the Garlic Mustard, and sites will need to be monitored to determine if additional burns or follow-up control measures are needed. If you are considering burning as a control option, remember to always follow safe burning practices, obtain all necessary permits, and follow all regulations.



Canada Anemone.

Photo courtesy of John B., Wikimedia Commons

Biological Control

Biological control is the use of an herbivore, predator, pathogen or other natural enemy to reduce established populations of invasive species. Most invasive species succeed because they have few or no predators or natural enemies in their new habitat. Biological control aims to re-establish an ecological balance between the introduced species and its natural enemies. Highly host-specific natural enemies are chosen from the species' native range and are moved to the site of the new invasion. This is only done after extensive research, to ensure that the natural enemy chosen will only affect the invasive species. This method has been used successfully for invasive plants in North America, including Purple Loosestrife (*Lythrum salicaria*), Leafy Spurge (*Euphorbia esula*), Diffuse Knapweed (*Centaurea diffusa*) and St. John's Wort (*Hypericum perforatum*).

In its native range, Garlic Mustard has predators and pathogens which control its growth. While some species do feed on it in North America (e.g. leaf mining and "windowpane" damage has been observed on some Garlic Mustard plants), this hasn't affected seed production or plant growth. Several predators from its native range have been identified for potential use as a biological control. Four weevils have been chosen as candidates for further study. One in particular, *Ceutorhynchus scrobicollis* is the most promising as a future biological control agent. *C. scrobicollis* is a root crown-mining weevil, and its presence on Garlic Mustard in trials has shown increased plant mortality, reduced biomass, and reduced seed production.



C. scrobicollis has shown promise as a future biological control agent for Garlic Mustard.

Photo courtesy of Harriet Hinz & Ester Gerber, CABI Biosciences, Bugwood.org

There may be additional advantages for biological control. Recent studies show that due to lack of predators, Garlic Mustard plants growing in North America are missing many of the natural defenses found in European plants. This means Ontario's Garlic Mustard plants may be more susceptible to biological control, making it a promising future control option once more research is completed.



Garlic Mustard plants in North America are missing many of the natural defenses found in European plants.

Photo courtesy of Rod Krick

Disposal

Do Not Compost. Any plant materials should be placed in black plastic bags or yard waste bags. Seal the bags tightly and leave them in direct sunlight for about a week. Pulled plants which have flowered are still able to produce seeds, so plant pieces should be removed from the site and either dried and burned, or sent to the landfill.



Pulled plants should be removed and taken to the landfill.

Photo courtesy of OFAH

Restoration

Restoration is a critical aspect of invasive species management to allow the site to become a healthier ecosystem, which in return will be more resilient to future invasions.

Types of Restoration

During Control

Mulching:

Mulching sites where mechanical or chemical control has taken place may aid in the recovery of native species and prevent immediate re-colonization by invasive species. Often, invasive species have a seed bank which will begin to germinate soon after control measures have been performed. Mulching reduces light which limits Garlic Mustard seed germination, allowing shade-tolerant native plants to grow and fill the gaps left by the invasive species removal.



This area was cleared of Garlic Mustard and covered with leaves/mulch to prevent Garlic Mustard seedling germination.

Photo courtesy of Paula Davies

Seeding:

Seeding an area with an annual cover crop or native plant species, immediately after management, may be necessary to prevent the growth of new invasive species. This will give desirable native species in the area the chance to become established.

After Control

Soil Rehabilitation:

Some invasive species alter soil chemistry (especially those that are allelopathic, such as Garlic Mustard). The soil may no longer support native plant species, and may in fact be better suited to other invaders moving in. Native species growth can be encouraged by replenishing the mycorrhizae in the soil to help reduce the allelopathic effects. Leaf mulch, logs and sticks (to provide food and protective cover for the fungi) and reducing soil compaction can promote growth of mycorrhizal fungi. Commercial mycorrhizal products can be purchased in Ontario at some garden centres.

Planting:

If there are invasive plants nearby which may colonize the control area. If larger native species are planted, they will out-compete invasive seedlings. Wait until all management is complete before doing a large stock re-planting, as it may be difficult to distinguish between newly planted native species and invasive seedlings. When planting at Garlic Mustard sites, it is important to consider earthworm impacts (little to no leaf litter), as well as light availability (have any trees recently been removed which have opened up the forest canopy?). When choosing plant species for restoration, consider these environmental changes to ensure you select the best plants for the site's new growing and soil conditions.

Preventing the Spread

Everyone can help prevent the spread of Garlic Mustard by following these tips:

Report it.

If you think you see Garlic Mustard, take a picture, record the location and contact the Invading Species Hotline to report it. For more information and guidance call the Invading Species Hotline at **1-800-563-7711** or visit www.invadingspecies.com or www.eddmaps.org/ontario.

Watch for it.

Learn what Garlic Mustard looks like and then monitor woodlands, hedges, property boundaries, riparian areas, fence lines and trails. Early detection of invasive plants can make it easier and cheaper to remove or control them.

Stay on trails.

Avoid traveling off-trail and in areas known to have Garlic Mustard or other invasive species. Keep pets on-leash to prevent them from spreading seeds.

Stop the spread.

Inspect, clean and remove mud, seeds and plant parts from clothing, pets (and horses), vehicles (including bicycles, car tires), and equipment such as camping gear, boot treads, mowers and tools. Clean vehicles, gear and equipment in an area where plant seeds or parts aren't likely to spread (e.g., wash vehicles in a driveway or at a car wash) before travelling to a new area. For more information on when/where to clean gear and vehicles, check the Clean Equipment Protocol available at www.ontarioinvasiveplants.ca.

Keep it natural.

Try to avoid disturbing soil and never remove native plants from natural areas. This leaves the soil bare and vulnerable to invasive species.

Use native species.

Try to use local native species in your garden. Don't plant Garlic Mustard in your garden and if you have removed it, try to replant with native species. Don't transplant invasive species such as Garlic Mustard. Encourage your local garden centre to sell non-invasive or native plants. The OIPC has a booklet called "Grow Me Instead" which lists non-invasive or native plants for gardens. For the booklet, and a list of nurseries which sell these plants, visit www.ontarioinvasiveplants.ca

Tracking the Spread

Locations of Garlic Mustard have been documented in much of Southern Ontario. However, there are gaps in our understanding of its distribution and scale of invasion in many locations.

Several reporting tools have been developed to assist the public and resource professionals to report sightings, track the spread, detect it early, and respond quickly. If you think you have Garlic Mustard on your property or if you see it in your community, please report it. You will be asked to send in photos that show the leaf, stem and flower (if flowering) for identification. Report it to:

1) EDDMaps is an on-line reporting tool where users can view existing sightings of Garlic Mustard and other invasive species in Ontario, and document their sightings. This tool, at www.eddmaps.org/ontario is free to use.

2) The toll-free Invading Species Hotline (1-800-563-7711) and website (www.invadingspecies.com), which individuals can use to report sightings verbally or on-line.

OIPC Resources

Best Management Practices Documents Series

- Common Buckthorn Best Management Practices for Ontario
- Dog-strangling Vine Best Management Practices for Ontario
- Giant Hogweed Best Management Practices for Ontario
- Japanese Knotweed Best Management Practices for Ontario
- Phragmites (Common Reed) Best Management Practices for Ontario

Additional Publications from the Ontario Invasive Plant Council

- Clean Equipment Protocol for Industry
- Compendium of Invasive Plant Management
- Grow Me Instead! Beautiful Non-Invasive Plants for Your Garden, a guide for Southern Ontario
- Grow Me Instead! Beautiful Non-Invasive Plants for Your Garden, a guide for Northern Ontario



Trail users can prevent the spread of Garlic Mustard!

Photo courtesy of Hayley Anderson

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Ken Towle, Ganaraska Region Conservation Authority

Freyja Whitten, Credit Valley Conservation

Special Thanks to:

Credit Valley Conservation (Rod Krick), for allowing the reproduction of information from the "Landowners Guide to Managing and Controlling Invasive Plants"

Editing Services: Sarah Higginson

Design by: Adam Connor, www.AdamConnor.ca

