

**Annual Report on Garlic Mustard, *Alliaria petiolata*, an Alien
Invader of NJ's Deciduous Forests.**

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INTRODUCTION

Garlic mustard (*Alliaria petiolata* (M. Bieb.) Cavara and Grande) is a cool-season, shade-tolerant, obligate biennial herb that is native to northern Europe (Blossey et al. 2001). It is an important invader in deciduous forests in North America where it can dominate the understory. Garlic mustard frequently occurs in moist shaded soils of roadsides, forest openings, edges of woods, trail edges and in urban areas. The species was first recorded in North America in Long Island, NY in 1868. It now ranges from eastern Canada, south to Virginia and as far west as Kansas and Nebraska. The plant can be found throughout NJ, but it appears to be most prolific in the northern and central part of the state. It is not found in the pinelands. Once garlic mustard invades an area it can quickly outcompete native flora, partially due to its allelopathic abilities, which can eventually lead to dense monocultures of the plant on the forest floor and a reduction in the population of native plants (Nuzzo 1993).

Conventional control methods such as herbicides, fire, hand pulling or combinations of these treatments may reduce small, localized populations, but do not offer any long-term control over large areas. The development of a classical biological control program, similar to the ones used on purple loosestrife and mile-a-minute in New Jersey, may be the best hope for a successful long-term management program for the weed. Field investigations conducted in Europe from 1998-1999 revealed a number of insects and several fungi that are associated with garlic mustard (Hinz et al. 1998, 2001). From this group, six insects were selected as potential biological control agents for garlic mustard. In anticipation of receiving the beneficials once they are released from quarantine, the Phillip Alampi Beneficial Insect Laboratory (PABIL) of the NJ Department of Agriculture (NJDA) entered into an agreement with the USDA-Forest Service in 2002 to establish test sites to gather pre-release, baseline, local data on garlic mustard before any beneficials are released. The Garlic Mustard Monitoring Protocol, developed by Dr. Bernd Blossey of Cornell University and Victoria Nuzzo of Natural Area Consultants, was followed to record the data. PABIL's participation in this joint monitoring program would also place it higher on the priority list to receive the insects when they are approved for release. Four monitoring sites were established in northern (1), central (2) and southern (1) NJ in the fall of 2002. Two additional sites were set up in northern NJ in 2004 but were dropped in 2007 due to poor site conditions and difficulty in collecting the data.

Garlic Mustard

Garlic mustard is a biennial herb in the mustard family (Brassicaceae) that spends the first year as a rosette before completing flowering during the second season. Its ability to self-pollinate and produce a large amount of seed allows a single plant to quickly establish an infestation that can out-compete other vegetation in the area (King County Noxious Weed Control Program 2000 <http://dnr.metrokc.gov/wlr/lands/weeds/GarMust.htm>). Garlic mustard seed germinates in early April. The rosettes are dark green, triangular to heart shaped, coarsely toothed leaves that will overwinter into the following spring (Rowe et al. 2002) (Figure 1).



Figure 1. First year rosettes



Figure 2. Second year bloom and siliques

Photos by M. Mayer, NJDA, PABIL

The young leaves when crushed release a garlic odor that diminishes as the leaves get older. This is a characteristic that can be useful in helping to identify the plant. The following spring the rosette bolts and blooms, producing a single stalk that stands up to three feet high with small white flowers and alternate leaves (Figure 2). By June, seeds are produced in green, slender, erect seedpods (siliques). Each plant can produce from 66-356 seeds, with a robust plant capable of producing as many as 7,900 seeds which can remain viable in the soil for 3-5 years (Nuzzo 1993).

Control Measures

The control measures that are presently being used to reduce garlic mustard infestations are hand pulling, cutting flower stems, burning, and chemical treatments. The best time for implementing any of these control measures is before seed production takes place. Hand pulling is an acceptable measure when the infestation is small or mixed among desirable plants, but impractical in a natural environment such as a forest understory. It is important that the entire root system be removed to achieve total weed control. That ensures no supplemental growth of remaining rootstock can occur. Where pulling weeds is not an option, plants can be cut off at ground level which kills 99% of the plants, while cutting at least 4 inches and above ground level only kills 71% (Nuzzo 1991). Burning has been used to control large infestations. An herbicide (chemical control) can also be used to control either large or small infestations. The drawback to all these methods is that they open up the understory, which allows viable garlic mustard seeds in the seed bank to germinate more freely. So realistically, whatever control measures are chosen, annual monitoring and repeated control applications are needed for at least five years to ensure the seed bank has been depleted (Rowe et al. 2000).

These control methods, while providing some temporary control, do not provide a long-term control for this invasive weed. A classical biological control program that uses the natural enemies of garlic mustard appears to be the best approach for a long-term solution. Initially six insects, five weevils and one flea beetle, were identified as

potential biological control agents for garlic mustard. The five weevils are in the genus *Ceutorhynchus*. *C. alliariae* and *C. roberti* adults feed on the leaves while their larvae mine stems and leaf petioles; *C. scrobicollis* is a root mining weevil; *C. constrictus* adults feed on leaves and the larvae consume developing seeds; *C. theonae* also attacks seeds, but appears to be more damaging than *C. constrictus*. The adult flea beetle *Phyllotreta ochripes* (Coleoptera: Chrysomelidae) feeds on leaves and their larvae feed on the roots of both bolting garlic mustard plants and rosettes (Hinz et al. 1998, 2001). From this group, the two stem miners, *C. alliariae* and *C. roberti*, and the root and crown miner, *C. scrobicollis* appear to be the most promising. The first shipments of *C. scrobicollis* were delivered to a quarantine facility in St. Paul, MN in 2003 for host range testing (Skinner 2003). In anticipation of these biological control agents becoming available, the PABIL has continued to monitor the garlic mustard sites in New Jersey since that time.

Biological Control Update: Since 2005, laboratory personnel at PABIL, worked on developing procedures for growing garlic mustard in PABIL's greenhouses in anticipation of rearing the biological control agent *C. scrobicollis* (Figure 3). This weevil is currently undergoing evaluation at the University of Minnesota's quarantine facilities. New Jersey plans to begin a mass-rearing biological control program when the weevil is released from quarantine, hopefully in 2009.



Figure 3. *Ceutorhynchus scrobicollis*
Photo by H. Hinz and E. Gerber, CABI Bioscience Centre, Switzerland

MATERIALS AND METHODS

Study Sites

In the fall of 2002, PABIL field personnel set-up four study sites throughout NJ. Data gathered from these study sites prior to the release of any beneficial insects will be used to provide baseline information that can be used to measure the effectiveness of the biological control agents. The four sites are Union Lake WMA in Cumberland County, Thompson Park in Monmouth County, Jones State Prison Farm in Mercer County and Point Mt. County Park in Hunterdon County. Two additional sites were set-up in 2004 in

Morris County in northern NJ; one at Great Swamp NWR and the other at Lewis Morris County Park but these two sites have been dropped. All sites were set up according to the Garlic Mustard Monitoring Protocol, First Draft/June 2002 developed by Dr. Bernd Blossey of Cornell University and Victoria Nuzzo of Natural Area Consultants. Twenty, one-half square meter quadrats, each at least 10 meters apart were set up along a 200 meter transect throughout the garlic mustard infestation at each of the six sites. Data was collected twice, once in the summer to assess plant density and seed production and once in the fall to assess rosette abundance.

1. **Summer.** Data was collected in June when the plant had completed flowering and the siliques (seed pods) were green and fully formed. The data included the percent cover of all garlic mustard (both adult and seedling) and all other vegetation, the percent damage to the garlic mustard leaves, seedling density, the percent cover of soil, wood, leaf and rock, the litter depth, and the name(s) and percent cover of other plant species within the quadrat. Data was also collected on the adult garlic mustard, if present. The height of each plant and the number of siliques on each plant within each quadrant were recorded.
2. **Fall.** Data collection takes place about the time that deciduous trees lose their leaves, usually in November. Rosette density replaced the seedling density category since it is normally the only life stage of the plant present at this time of the year. The data was similar to that collected in the summer with the exception that the data on adult garlic mustard plants (i.e. height of plants and number of siliques) and seedling density is not included.

RESULTS AND DISCUSSION

This program is currently in the pre-release mode until such time as the potential beneficial insects are released from quarantine. Presently four test sites have been established to gather baseline data, which will be used to measure the control effectiveness of any beneficials released in the future. Figure 4 shows the average height of the plants and Figure 5 shows the total number of siliques per site from each of the four study sites over a six-year period. Figure 6 shows the average number of siliques per quadrat.

Blossey et al. (2002) found that the average height/quadrat for a mature garlic mustard plant is 85 cm and the average number of siliques is 22. From the graphs (Figures 4 and 6) it can be seen that the garlic mustard in NJ falls below these averages, which could suggest that both the habitat and growing conditions may be different from the conditions in the Blossey study. The total number of siliques in Figure 5 is quite variable and is probably not a good measurement of the garlic mustard. The average height and the average number of siliques are somewhat stable and would appear to be good measures of the garlic mustard at a site so when the beneficials are released then any impact that they have could be shown using these two measurements.

Figure 4. Average Height of Garlic Mustard Stalks 2003-2008

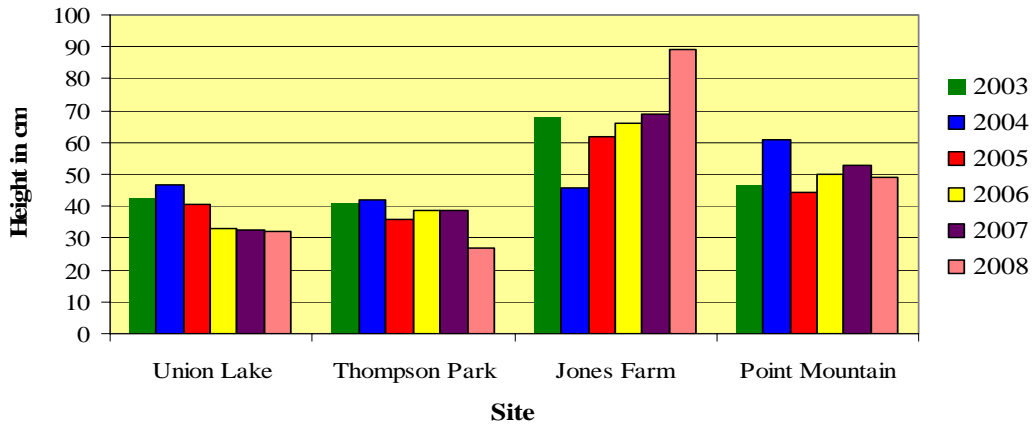


Figure 5. Comparison of the Total Number of Garlic Mustard Siliques/Site 2003-2008

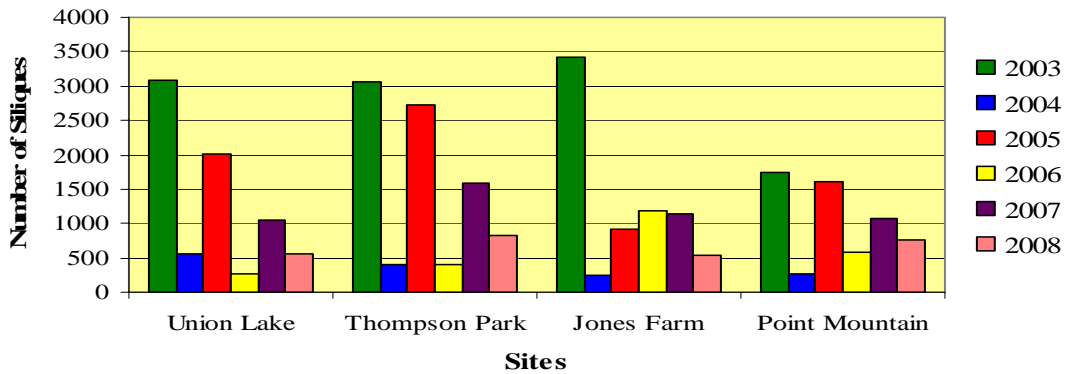
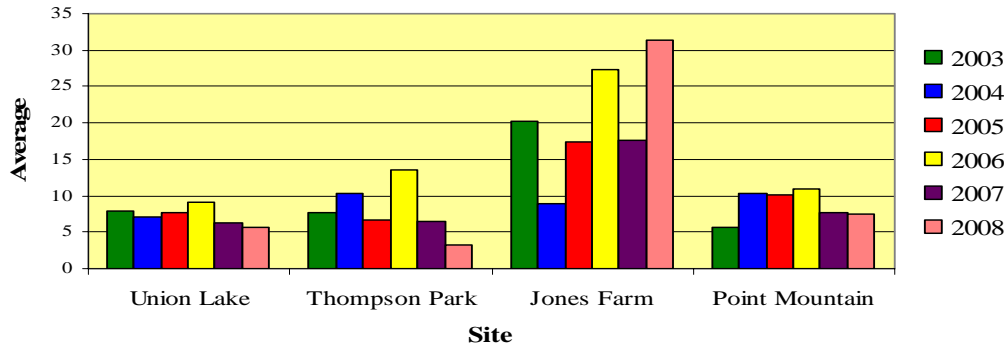


Figure 6. Average Number of Siliques/Quadrat 2003-2008



Garlic mustard spreads entirely by seed, with the seed being dispersed from the mother plant as ballistic projections (Cavers et al. 1979). The spread of this plant has often been characterized as an “advance-retreat” pattern, which, along with its biennial life cycle accounts for the variation in plant density from year to year (Nuzzo 1999). Figure 7 shows a comparison of the rosette density between the fall of 2002 to fall 2008 that demonstrates this cyclic variation of plant density from year to year.

One can see from the data in Figure 7 that rosette density can be extremely variable from one season to the next. A high rosette density in the fall of one year was generally followed by a high seedling density the following spring. The plant competition from the bolting seedlings inhibits the germination of other garlic mustard seeds, which results in fewer rosettes being produced in the fall. It follows then that with less plant competition the following spring season, it could be expected that a greater number of garlic mustard seed should germinate and produce more rosettes that fall. This cycle may explain why there is an observable outbreak of rosettes one year and fewer rosettes the following year. The “advance-retreat” habit of this plant continued to be demonstrated at the four original test sites when the number of rosettes decreased at a greater rate following a higher rosette density. Based on what has been observed over the past five years with this “advance-retreat” habit, an increase in the rosette was expected and occurred in 2008.

Figures 8-10 show the average spring percent cover of: all garlic mustard plants (Figure 8), mature garlic mustard (Figure 9) and garlic mustard seedlings (Figure 10). This measurement also shows the “advance-retreat” habit of the plant. The weevils will be shown to be effective if the number of rosettes is lowered and this “advance-retreat” habit will show lower peaks.

Figure 7. Comparison of the Average Number of Garlic Mustard Rosettes (Autumn) 2002-2008

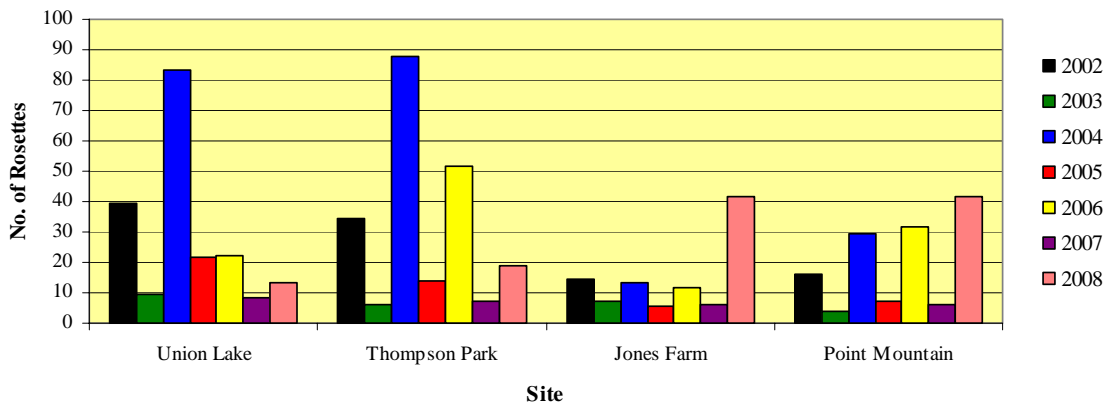


Figure 8. % Cover for All Garlic Mustard 2003-2008

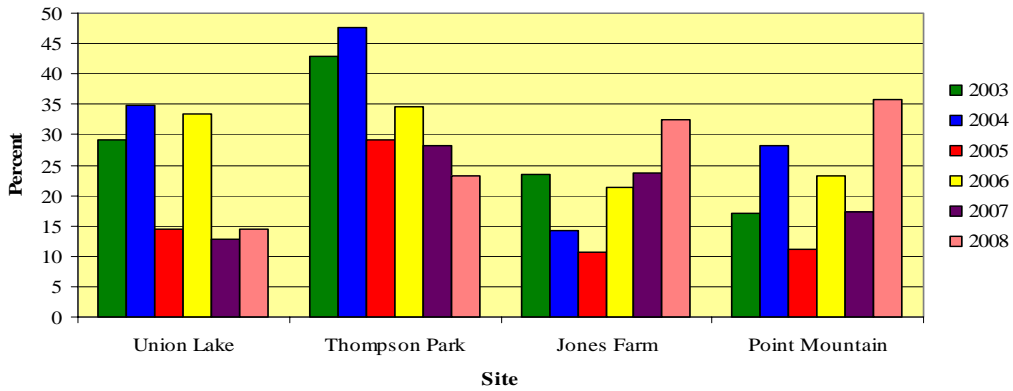


Figure 9. % Cover for Mature Garlic Mustard Plants 2003-2008

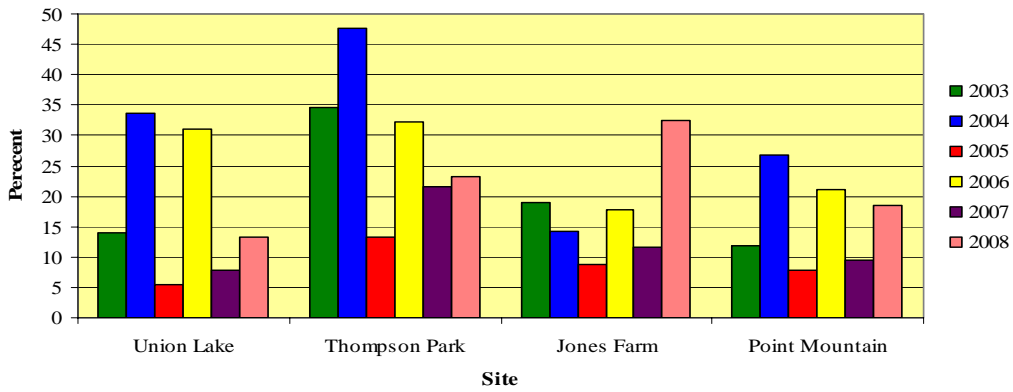
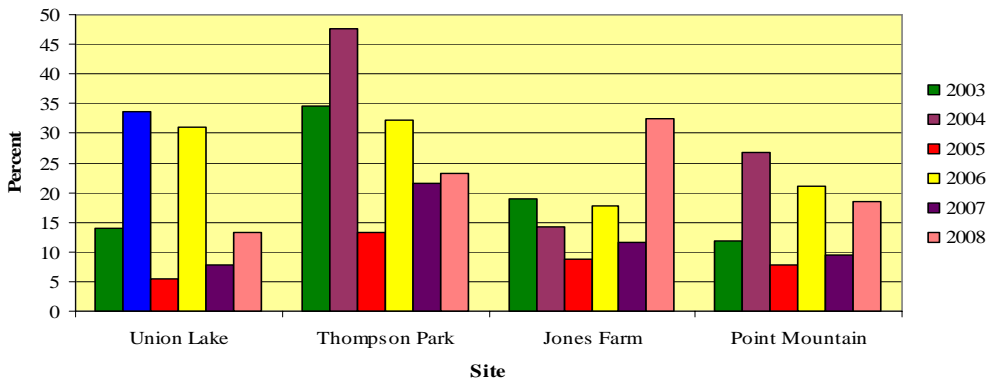
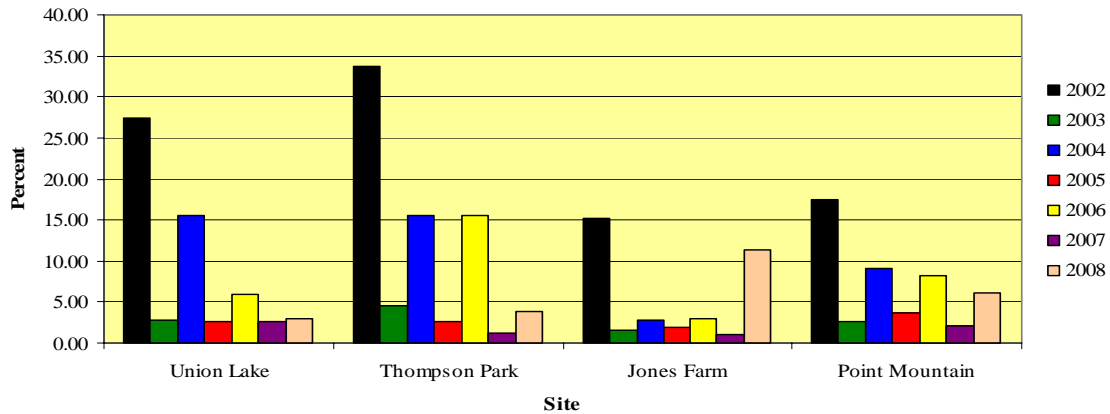


Figure 10. % Cover of Garlic Mustard Seedlings 2003-2008



The fall % cover for the rosettes is seen in Figure 11. Unlike the previous figures, the fall data are quite variable and seem to be most unsuitable to evaluate the effectiveness of any released beneficial insect.

Figure 11. % Cover of Garlic Mustard Rosettes Autumn 2003-2008



CONCLUSION

This program remains in the pre-release survey mode and the NJDA will continue to monitor the four study plots to gather baseline data. The PABIL is anticipating receiving the first supply of *C. scrobicollis* weevils from quarantine in the fall of 2009, at which time they will begin a mass rearing program. All four of the test sites have an adequate population of garlic mustard in and around the test quadrats, which should ensure that there would always be plants available to support the biocontrol agents once they are released. The test data for effectiveness should be the average height of the garlic mustard stalks in the spring, the average number of siliques per quadrat and percent cover of the spring garlic mustard.

FUTURE PLANS

The plans are to continue monitoring the original four study sites through the first releases.

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