Characteristics of expanding and stable populations of garlic mustard in Carolinian parks

J. Carrie Firanski, Nancy Falkenberg, Saewan Koh, Dawn R. Bazely
Department of Biology, York University

Abstract

*Garlic Mustard (*Alliaria petiolata*) is a short-lived monocarpic perennial introduced to North America in 1868 which reached Canada in 1879. It was first introduced to Point Pelée National Park in 1969 and Rondeau Provincial Park in the 1980s. Both parks have long histories of human-induced disturbance, with most recently high deer grazing pressure. We show that garlic mustard has become (Point Pelée NP) and is becoming (Rondeau PP) a predominant understorey herb from 1994 to the present, and that the two parks are in different phases of colonization. Our research suggests that the garlic mustard population at Point Pelée has stabilized while the Rondeau population is continuing to expand. We found a significant negative relationship between species diversity and garlic mustard density for both of the parks. However, it is unknown whether garlic mustard is suppressing native herbaceous species diversity, or whether low diversity is an outcome of the intense long-term grazing pressure exerted by deer on the native species. Interestingly, the garlic mustard populations at both parks have alternate years of high and low flowering densities, driven by intra-specific density effects. This may explain the lack of negative association between garlic mustard density and native diversity in some years. Further research will include experiments with native species transplants into garlic mustard dominated sites to determine competitive interactions, and analysis of changes in distribution throughout the transects to determine rate of spread of expanding garlic mustard populations at Rondeau.*

Introduction

In the last twenty years, many high-profile ecologists and conservationists have been sounding the alarm over the current "biodiversity crisis" (Chapin *et al.* 2000). Extinction rates are estimated to be occurring at a greater rate than at any other time in the fossil geological record (Lawton & May, 1995). The main extinction threats are human activities and human-induced disturbances, including habitat destruction, habitat fragmentation, over-exploitation, introduced species and secondary effects or "chains of extinction", cascading through an ecosystem (Diamond, 1989). The least direct of these, exotic species introductions, has become an important management issue for park staff, and stewardship and naturalization promoters throughout southwestern Ontario (e.g. Dunster, 1990; Havinga, 2000; Rondeau Provincial Park, 2001). This is the most urbanized, industrialized and intensely farmed, part of Canada, with highly fragmented natural habitat. Exotic or non-native plant species are mostly weedy plants that have originated in Europe and usually evolved in the context of early agricultural practices. The association of these species with agricultural processes enabled them to easily invade disturbed and grazed habitat (Cox, 1997).

There are four major factors that determine whether an introduced species will become established in a new habitat: (1) the suitability of the habitat; (2) the species suitability (health, number of individuals and behaviour) for the new habitat; (3) the escape of the species from predators and pathogens in the new habitat, and (4) the outcome of inter-specific competition with other species in the new habitat (Cox, 1997). Certain species have been described as being "invasive", and over time, coming to dominate a habitat. So-called "invasive" plant species include purple loosestrife (*Lythrum salicaria*), glossy buckthorn (*Rhamnus frangula*), and garlic mustard (*Alliaria petiolata*) (Havinga 2000). Such species may be termed "keystone" exotics if they are species that can cause almost complete biotic reorganization of the ecosystem that they invade (i.e. trigger a switch to an alternate stable state) (Cox, 1997). Highly successful invaders are typically different in morphological structure, physiology and/or behaviour from the native species, so as a result, competitive adaptation against them is often absent in native species (Cox, 1997).

Garlic mustard was selected for this study because of its increasing presence in upland forests and woodlots in southwestern Ontario. It is a biennial that flowers in its second growing year (Cavers *et al.* 1979). Because garlic mustard grows in dense stands, it is believed to out-compete and displace native spring ephemerals, especially after disturbance (Dunster, 1990; White *et al.* 1993; Hough *et al.* 1995; Johnson, 1995; Anderson *et al.* 1996). The first Canadian record of garlic mustard was in Toronto in 1879 (Cavers *et al.* 1979) and it is now found extensively throughout southern Ontario (Havinga, 2000).

As a first step in determining the impact of garlic mustard on native vegetation, we evaluated the spread of garlic mustard through a habitat and its impact on plant community composition in two geographically and ecologically complementary parks. The study covers 4 field seasons over a 5-year period (1995-2000) at Rondeau Provincial Park and Point Pelée National Park, in southwestern Ontario. The garlic mustard population is thought to be expanding in Rondeau Provincial Park (introduced ca. mid-1980s) while at Point Pelée National Park it has become a dominant understorey herb throughout the park (introduced ca. 1969). Our aim was to (1) compare the spread of garlic mustard in a previously uncolonized habitat (Rondeau) with variation in its presence in permanent plots in an established population (Point Pelée); and (2) assess the impact of garlic mustard on species diversity. If garlic mustard has a negative impact on other plant species, then we predicted that we should find a negative relationship between plant diversity and garlic mustard density.

Methods

This study was carried out in Rondeau Provincial Park and Point Pelée National Park. Fifteen patches of garlic mustard were randomly chosen at each park and 60 m transects were established in each patch. Five sites with three transects each were selected at Point Pelée: (old) Administration building, Sanctuary, Blue Heron Beach, Sleepy Hollow and (old) Warden Services areas. Three sites were selected at Rondeau: Southpoint (n=3 transects), Pony Barn (n=6 transects) and Lakeshore (n=6 transects). Nineteen 3600 cm^2 (60 x 60 cm) quadrats were located at 3 m intervals along each transect. Stem counts of each species present, including garlic mustard (and whether the plant was a first-year rosette, or second-year flowering adult), were recorded twice during the growing season, once in late spring (May-June) and again in mid-summer (July-August) for 1995 and 1996, and the Shannon-Weaver diversity index (H) was calculated for each plot (Magurran 1988). In 1997 and 2000 only garlic mustard presence and density were scored in the quadrats.

Statistical analyses were performed using Systat (Wilkinson 1989). All data were tested for normality and homogeneity of variance, and were transformed appropriately when required. In a given year, data were not obtained from plots which were found to be flooded or otherwise damaged.

Results

A comparison of the proportion of permanent plots in which garlic mustard was present or absent showed that the population is increasing at Rondeau and stable at Point Pelée (Figure 1). The percentages of permanent plots with garlic mustard were: 49% and 98% (1995), 63% and 93% (1996), 58% and 99.6% (1997) and 73.7 % and 99.4% (2000) at Rondeau and Point Pelée respectively. Garlic mustard was significantly more widespread in Point Pelée than in Rondeau (1995—G (Williams)= 242.7, $p<0.001$; 1996—G (Williams)= 76.3, $p<0.001$; 1997—G (Williams)= 170.7, $p<0.001$; 2000—G (Williams)=76.7, $p<0.001$). Regressions of Shannon-Weaver diversity on garlic mustard density showed overall negative relationships in 1995 but not in 1996 (Figure 2).

Discussion

Clearly, garlic mustard is expanding at Rondeau and is already well-established in Point Pelée. If the current rate of occupation of new patches continues (approximately 20% expansion into previously uncolonized plots over a 5-year period), we may expect to see all of the permanent transect plots occupied by the year 2008. However, this assumes that factors such as disturbance level will have no impact on the "invasive" abilities of garlic mustard.

While the general relationship found between garlic mustard density and species diversity was negative in 1995, this broke down in 1996. This raises the question of whether garlic mustard density was causing the trend in 1995 or whether it was

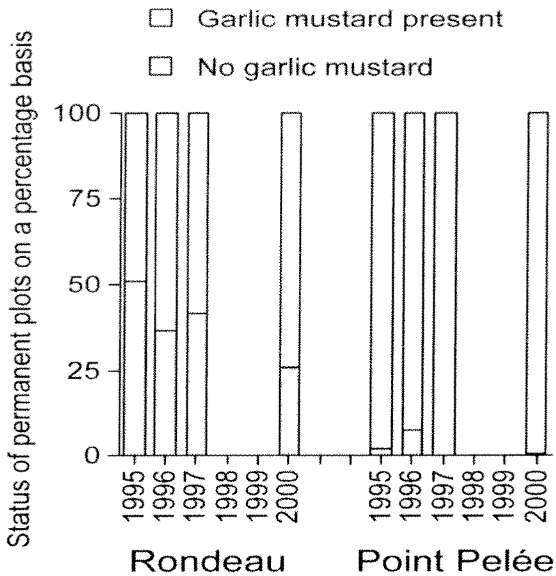

Figure 1. Percentage of permanent plots in Rondeau Provincial Park and Point Pelée National Park containing garlic mustard

simply a correlation. There is a great deal of concern in the statistical literature over confusing correlation with causation (e.g. see Mendenhall *et al.* 1986). Both parks have long histories of human induced disturbance, and more recently have undergone disturbance caused by intense long-term overgrazing by white-tailed deer (Pearl *et al.* 1995). It is possible that garlic mustard may simply be dispersing into suitable habitat patches opened by disturbance in the forest understorey, before the native species can recover from local mortality due to deer overgrazing, as opposed to moving into an area by out-competing and suppressing the native species. Alternatively, the finding that there are years in which flowering plants are more common than rosettes and alternate years in which rosettes dominate (McLachlan 1997), may explain why the negative effects of garlic mustard on native species diversity was not found in 1996. In rosette dominated years the native flora may not be as affected as in adult dominated years.

The question of whether garlic mustard is a true invasive species is still open. While it is widely perceived as being a problem invader (e.g. Anderson *et al.* 1996; Havinga, 2000), there are few quantitative data to support this conclusion. There is a similar lack of evidence for purple loosestrife (Anderson, 1995). To further examine this hypothesis, we can examine our long-term data set for various patterns. For example, we can look at specific plots, especially those that were not occupied by garlic mustard at the beginning of the study, and determine if and how the species diversity within the quadrat changed once garlic mustard moved into the plot. We also plan to carry out experiments in 2001, which introduce seeds and seedlings of native species to plots with varying densities of garlic mustard to test

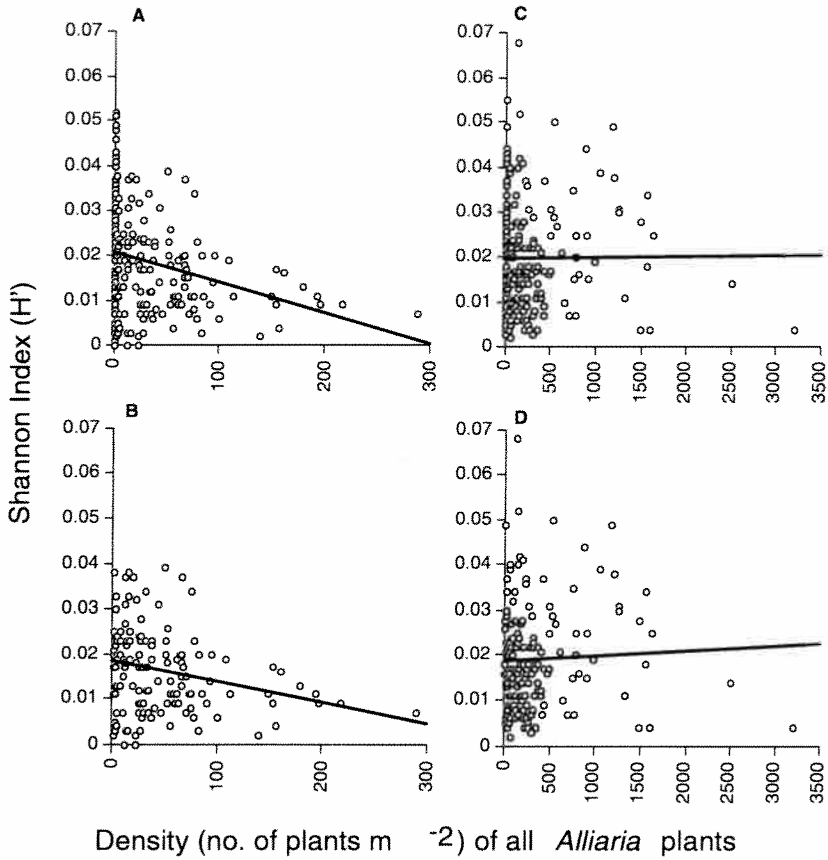

Figure 2a. The relationship between Alliaria plants (rosettes and adults) and species diversity at Rondeau Provincial Park

a) In 1995, including quadrats without Alliaria (y=-0.000069x+0.021, $F_{(1, 283)} = 19.53$, $p<0.0001$)

b) In 1995, excluding quadrats without Alliaria (y=-0.000047x+0.019, $F_{(1, 283)} = 9.25$, $p<0.005$)

c) In 1996, including quadrats without Alliaria (y=-0.00000x+0.02, $F_{(1, 270)} = 0.012$, p=0.9127 n.s)

d) In 1996, excluding quadrats without Alliaria (y=-0.000001x+0.019, $F_{(1, 172)} = 0.33$, p=0.5662 n.s)

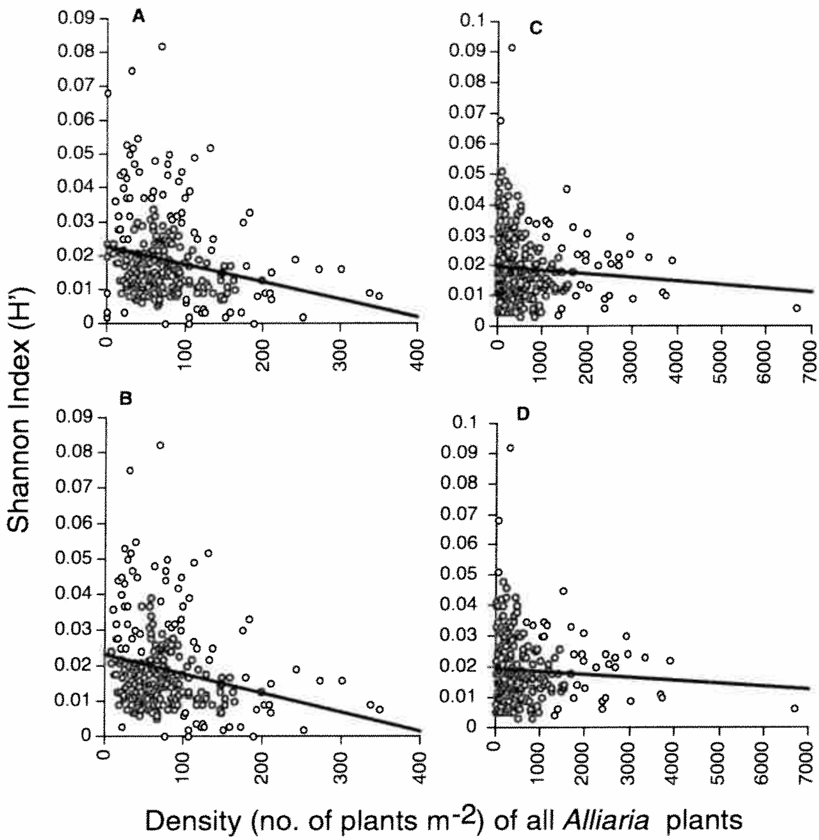

Figure 2b. The relationship between Alliaria plants (rosettes and adults) and species diversity at Point Pelee National Park

a) In 1995, including quadrats without Alliaria ($y=-0.000052x+0.023$, $F_{(1, 283)} = 15.6$, $p<0.0001$)
b) In 1995, excluding quadrats without Alliaria ($y=-0.000054x+0.023$, $F_{(1, 277)} = 16.4$, $p<0.0001$)
c) In 1996, including quadrats without Alliaria ($y=-0.00000x+0.02$, $F_{(1, 282)} = 2.196$, $p=0.1395$ n.s)
d) In 1996, excluding quadrats without Alliaria ($y=-0.00000x+0.019$, $F_{(1, 260)} = 1.30$, $p=0.2553$ n.s)

whether their germination and growth is suppressed in the presence of garlic mustard.

Acknowledgements

We thank NSERC (Research Grant to DRB), Rondeau Provincial Park and Point Pelee National Park for supporting this research both financially and logistically. We thank Gary Mouland (Point Pelee) and Rick Hornsby (Rondeau) for much support and encouragement. Many people have helped with field work over the years, and we thank all of them.

References

Anderson, M.G. 1995. Interactions between *Lythrum salicaria* and native organisms: a critical review, *Environmental Management*, 19: 225-231.

Anderson, R.C., Dhillion, S.S. & Kelley T.M. 1996. Aspects of the ecology of an invasive plant, garlic mustard (*Alliaria petiolata*), in central Illinois. *Restoration Ecology*, 4:181-191.

Chapin, F. S. et al. 2000. Consequences of changing biodiversity. *Nature*, 405: 234-242.

Cox, G. W. 1997, Human impacts on grassland ecosystems. *Conservation Biology*, McGraw-Hill Company Inc., Dubuque, IA, U.S.A.

Cavers, P.B., Heagy, M.I. & Kokron R.F. 1979. The biology of Canadian weeds. 35. *Alliaria petiolata* (M. bieb.) Cavara and Grande. *Canadian Journal of Plant Science*, 59:217-229.

Diamond, J. M. 1989. The present, past and future of human-caused extinctions. *Phil. Trans. Royal Soc., Series B.*, 325: 469-477

Dunster, K. 1990. *Exotic Plant Species Management Plan, Point Pelée National Park.* Report prepared for Parks Canada, Ontario Region.

Havinga, D. 2000. Sustaining Biodiversity: A Strategic Plan for Managing Invasive Plants in Southern Ontario. Ontario Invasive Plants Working Group. Toronto, Ontario, Canada.

Hough Woodland Naylor Dance Limited & Gore& Storrie Ltd. 1995 *Restoring Natural Habitats.* Waterfront Regeneration Trust, Toronto, Canada.

Johnson, J.W. (1995) *Vascular Flora of Three Regions Comprising Bruce and Grey Counties, Ontario with Emphasis on Rare Native Types.* Ontario Ministry of Natural Resources, Owen Sound, Ontario.

Lawton, J. H. & May, R. M. 1995. *Extinction Rates.* Oxford University Press, Oxford, UK.

Magurran, A.E. 1988. *Ecological Diversity and its Measurement.* Princeton University Press, Princeton, New Jersey, U.S.A.

Mendenhall, W., Scheaffer, R. & Wackerly, D. 1986. *Mathematical Statistics with Applications* 3rd Ed. Duxbury Press.

McLachlan, S. M. 1997. PhD Dissertation York University Toronto

Pearl, D.L., Koh, S., Bazely, D. R., Voigt, D. R., Tang, M. & Soo, W. (1995) *Interactions between deer and vegetation in southern Ontario, Canada: Moni-*

toring and restoration of overgrazed plant communities in Pinery and Rondeau Provincial Parks. Report prepared for the Southern Region Science and Technology Transfer Unit, Ontario Ministry of Natural Resources, London, Ontario, Canada.

Rondeau Provincial Park 2001. *Vegetation Management Plan*. Ontario Parks, Ontario Ministry of Natural Resources, London, Ontario.

White, D.J., Haber, E. & Keddy C. 1993. *Invasive plants of natural habitats in Canada*. Environment Canada. Ottawa.

Wilkinson, L. 1989. *SYSTAT: The System for Statistics*. SYSTAT Inc., Evanston, Illinois.