Earthworms, the herb layer, and invasion success of two non-native plants in eastern, suburban forests.

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Abstract

North American forest ecosystems are greatly affected by earthworm populations. They modify soil microenvironments and affect bottom-up change by shifting nutrient cycling and interacting with native and non-native invasive plants. Garlic mustard (*Alliaria petiolata*) and Japanese stilt-grass (*Microstegium vimineum*) are two invaders that can dominate the herb layer in eastern, suburban forests, including our study forests. We aimed to assess the potential for earthworms to influence both the herb layer plant community and the success of these two invaders. We investigated the relationship between earthworm abundance, native abundance, and invasion success of *A. petiolata* and *M. vimineum*, in 4 x 4 m plots that are part of a large field experiment in which we have staged novel invasions. In late June 2014, we extracted earthworm samples in each plot by electroshocking, and censused all plants in the herb layer in early fall. We recovered six non-native and one native earthworm species from 96 plots across six forests in central New Jersey. Worm abundance was highly variable among forests (3 to 312 total worms) and plots (0 to 30 per sample). Two forests had very few worms, so we excluded them from further analysis. The greatest abundance was in two forests with high white-tailed deer pressure (103 and 312 total worms), where worm abundance was negatively correlated with *M. vimineum* cover, but not with *A. petiolata* cover (which was very low). Worm abundance was positively correlated with the extent of exposed, bare soil in the plots, especially in forests with more worms. In the forest with the most worms, their abundance was positively correlated with cover of native plants in the herb layer, which counters the documented negative effects on plant communities by some non-native earthworms.

Introduction

- Plant diversity has been positively correlated with ecosystem nutrient retention and productivity.
- Earthworms affect soil properties by increasing soil mineral content and heterogeneity, and altering microbe communities. These modifications allow for increased seed germination, plant development, and productivity.
- Herb layer coinvaders, *Microstegium vimineum* and *Alliaria petiolata*, could potentially interact with earthworms to facilitate their invasion.
- We evaluated earthworm species richness across our 6 study forests and identified 7 earthworms:

Non-native	*Amynthas sp.*	*Lumbricus terrestris*
	Lumbricus rubellus	*Dendrobaena octaedra*
	Aporrectodea limicola	*Octolasion lacteum*
Native	*Eisenoides lonnbergi*	

- We are assessing the effect of earthworm biodiversity and abundance on plant diversity and invasion success in New Jersey suburban forests.
- These are early results in what will ultimately be a six-year study. It is our goal to understand how the invasion of these two species affect, or are affected by, earthworm populations.

Results

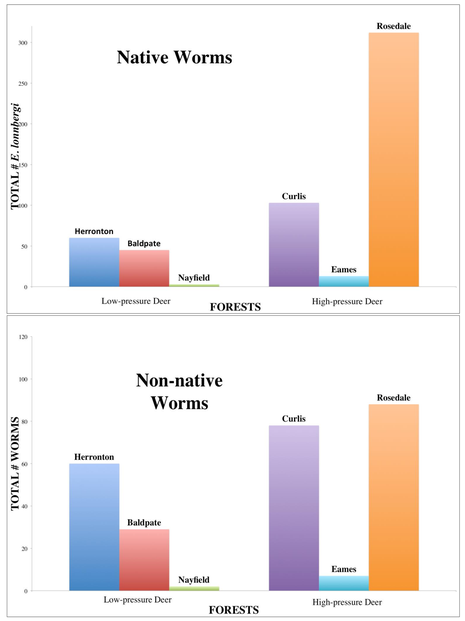


Figure 1. Earthworm abundance varied greatly among forests. The greatest abundances were in two forests with higher deer pressure (Curlis & Rosedale).

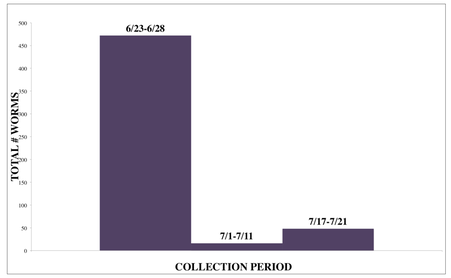


Figure 2. Earlier sampling dates yielded more worms (data from all six forests; from 6/23-26 n = 41; from 7/1-11 n = 32; from 7/17-21 n = 23). Worms from Herronton, Rosedale, and half of Curlis plots were collected in the first period; Nayfield and Eames in the second period; and Baldpate and the second half of Curlis plots in the final period. There is not enough evidence to conclude that collection period determined the number of worms extracted.

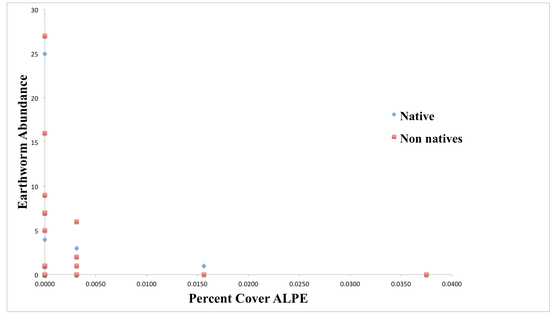


Figure 3. Total worms per plot during extraction vs. percent cover of *A. petiolata*, extracted at various time intervals. Earthworm abundance showed no relationship with *A. petiolata* in the two forests with sufficient worms to look for this relationship (n=16).

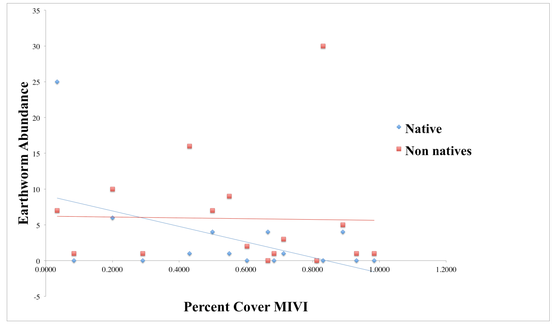
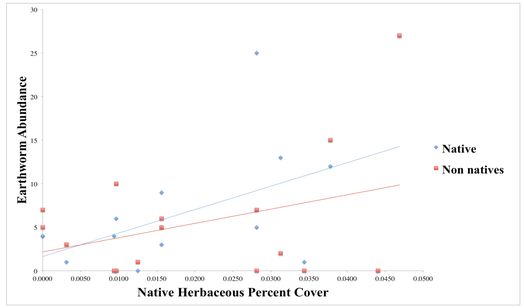


Figure 4. Total worms per plot during extraction vs. percent cover *M. vimineum*, extracted at various time intervals, in the two forests with sufficient worms for analysis. There was a negative relationship between native earthworm abundance and *M. vimineum* ($r = -0.52$, $P < 0.05$; n=16).

Figure 5. Total native and non-native worms per plot in Rosedale vs. percent cover of native herbaceous species. Native and non-natives earthworm abundances were both positively correlated with native herbaceous percent cover (natives worms: $r = 0.49$, $P = 0.05$; non-natives: $r = 0.35$, $P = 0.09$; n = 16).



Methods

Experimental Sites
- Experiment replicated in 6 similar suburban, central NJ forests that have *M. vimineum* (MIVI) and *A. petiolata* (ALPE) present, but initially absent in the plot area

Invasion Study Plots
- 16 m^2 plots, 16 per forest (96 extractions total)
- 8 possible treatments (unfenced/fenced & MIVI, ALPE, ALPEMIVI, NONE)
- Staged novel invasions: seeds of *A. petiolata* and *M. vimineum* added to plots November – December 2012
- Deer exclosures constructed March – April 2013
- Fall 2014 census and plant cover valuation

Earthworm Extraction
- Electrical apparatus for soil extraction of earthworms. Extractions June – July 2014
- Earthworm extractions in 2 of each treatment per forest (plots with most growth of experimental additions were preferred)
- 8 metal rods were placed into the ground in a circular fashion (A=0.22m^2)
- Rods attached to electrical device powered by a 12-V battery

Preservation & Identification
- Collected earthworms stored in isopropanol, then transferred to 4% formaldehyde solution overnight
- Transferred to isopropanol for long-term storage
- Sent samples to Dr. Chih Han Chang (Johns Hopkins University) for identification
- Earthworm abundances and species richness determined

Discussion

Earthworm abundance may affect the invasion success of plants, and the species of earthworms present may influence which plant species dominate communities. We observed the greatest abundance of worms in forests with high deer pressure, and the native worm (*E. lonnbergi*) was the most abundant among seven total species. We did not uncover an overall trend between high- and low-pressure deer scenarios and earthworm abundance, even though the reduced vegetation in high-pressure forests could provide a very different soil environment. Earthworm abundance correlated positively with bare-soil level, especially in Rosedale and Curlis, which had highest earthworm abundances. Earthworms consume leaf litter, and reduced leaf litter can affect plant communities by reducing safe sites for seedlings. Moderate leaf litter may also be beneficial to some worm survival, especially worms of the epigeic (topsoil-dwelling) functional group. Determining more precise earthworm interactions with soil microenvironments and, in turn, plant communities, requires species-specific investigations.

Worm abundance also correlated negatively with *M. vimineum* cover. Certain worms may negatively influence soil microenvironments, preventing *M. vimineum* from establishing in high-worm plots; they also could have consumed the plant's seeds at the time of initial additions. Worm abundance showed no correlation with *A. petiolata* cover. We will be investigating if ALPE and MIVI independently interact with specific earthworm species, and if this may increase plant invasion success. Native and non-native earthworms behaved similarly among the forests and had similar projected trends against percent cover of invasive plant species.

Acknowledgements

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