Interactive effects of deer and non-native plant invasion on the herb layer of suburban forests

Giovanna Tomat-Kelly and Janet A. Morrison
Department of Biology, The College of New Jersey, Ewing, New Jersey

Abstract

Background/Questions/Methods
Forest plant communities in the suburban landscape face joint challenges from overabundant deer and invasion by multiple non-native plant species. Deer can have direct negative effects on plants in the herb layer by herbivory and trampling, and indirect negative effects by facilitating the invasion of non-natives, if deer avoid them as food. We studied change in species richness in New Jersey, with a factorial experiment in three suburban forests with high deer pressure. We combined deer treatments (excluded or not) with addition treatments of two common forest invaders (Microstegium vimineum, MIVI; Alliaria petiolata, ALPE; both; or neither) in a total of 103 4x4 m plots. The experiment is conducted by one professor and changing teams of 4-8 undergraduates. The students begin with no knowledge of the flora. Accurate identifications must be done non-destructively and rapidly, so that the census is completed in a short time frame. We developed a training method that builds from field teaching by the professor, to peer teaching, to peer pairs. We rely heavily on Smartphone technology, which allows students in different locations to check an identification in real time with the professor, or to make a record of an unknown species for later identification when the professor is at the plot. The students become adept at identifying most species (over 130).

Results/Conclusions
Species richness increased by an average of two species per plot from Fall 2012 to Fall 2014. Deer exclusion from March 2013 - October 2014 had no significant effects on species richness of native herbaceous plants, native woody plants, or non-native woody plants. ALPE addition resulted in sparse establishment, while MIVI established dense stands in many plots. Species richness of both native herbs and native woody species (tree and shrub species) increased by 2-3 species on average in plots without MIVI added, but very little with MIVI added (ANOVA, P<0.0001 for both herbs and woody), regardless of fencing (fencing x addition, NS). Bottom-up suppression by MIVI invasion of the natural increase in native species richness contrasts with the lack of any top-down influence by overabundant deer, especially for woody species, which are subject to deer browse all year.

Introduction

- Suburban forests are a major reservoir for biodiversity, and they provide access to nature for many people in densely populated regions. These forests are challenged by the combination of overabundant deer and multiple invasive species, which may act together as important drivers of plant community structure. Deer can have direct negative effects on people in the herb layer by herbivory and trampling, and indirect negative effects by facilitating the invasion of non-natives if deer avoid them as food. In turn, invasive plants may be super-competitors, with negative effects on the native plant community.
- We are experimentally investigating change in plant species richness in response to deer exclusion and addition of two common invaders, garlic mustard (*Alliaria petiolata*) and Japanese stilt-grass (*Microstegium vimineum*). We work in central New Jersey, where deer density is about 30 deer/km², and where forests are fragmented, depauperate in native flora, and harbor many dominant, non-native species in the herb and shrub layers.
- The five-year experiment is being conducted by one professor and changing teams of 4-8 undergraduates. They must quickly learn the flora and work independently from the professor, who can not always be in the field. Accurate identifications must be done non-destructively and rapidly, so that the census is completed in a short time frame. A strong team/peer mentoring and training model and reliance on smart phone technology are essential for completion of this research.

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Methods

- Factorial experiment, replicated in six suburban forests in central New Jersey.
- Forty 16 m² plots in each forest (a few lost to Hurricane Sandy), with 5 reps of 8 treatment combinations: equal invasive seed addition (stilt-grass, garlic mustard, both, neither; added late fall 2012) X deer fence (yes/no; installed early spring 2013).
- For this analysis, used just three forests - where invasion has been substantial.
- Every spring and fall since 2012: percent cover of all species in the herb layer, estimated from 16 0.25 m² quadrats per plot.
- Throughout the course of the experiment: measurements of many of other biotic and abiotic variables

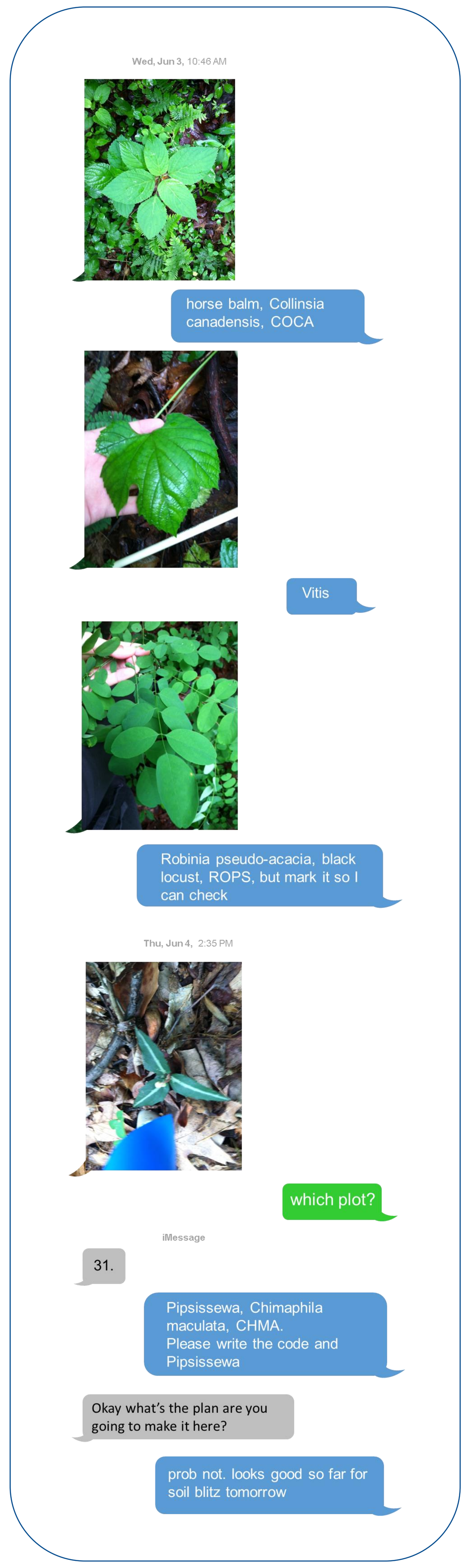
Over-browsed suburban forest

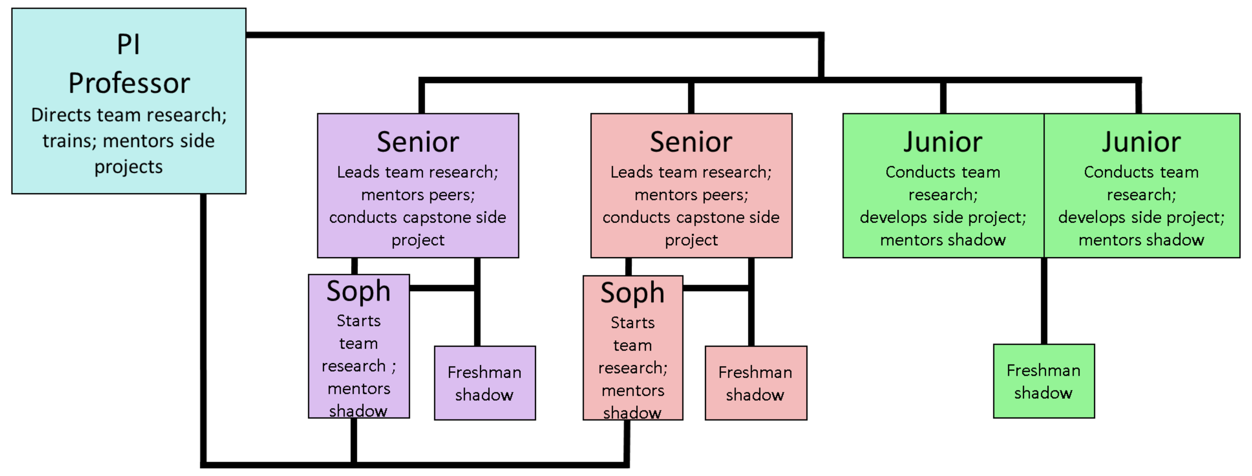
Typical deer herd at suburban forest edge

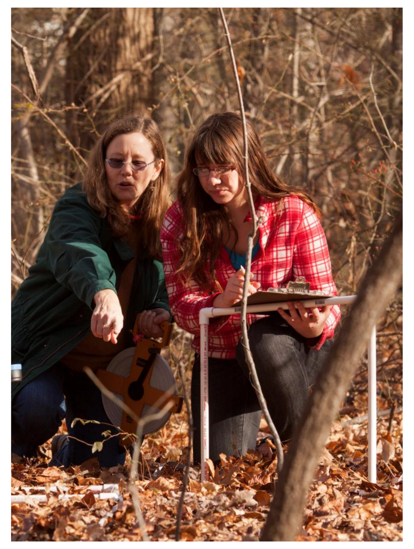
Japanese stilt-grass *garlic mustard*

- The field research was done with teams of undergraduates and one PI professor. Students earned course credit in the academic year or worked full-time in the summer, with a stipend and housing.
- Students must learn to quickly and accurately identify the flora. Census data must be completed in 224 16 m² plots within three weeks – fall and spring. The PI trains students directly in teams, and then experienced students assist in training and supervision of new students. Students are paired for a semester and typically have an assigned freshman "shadow" to mentor.
- Most students begin with no knowledge of the flora, but quickly become adept at identifying the majority of the ca. 130 species in the forest herb layers.
- However, complete accuracy requires frequent checks in person or by photo-text with the professor, who often is on campus with other duties. We have come to absolutely rely on Smartphone technology.

Actual text string during the spring census

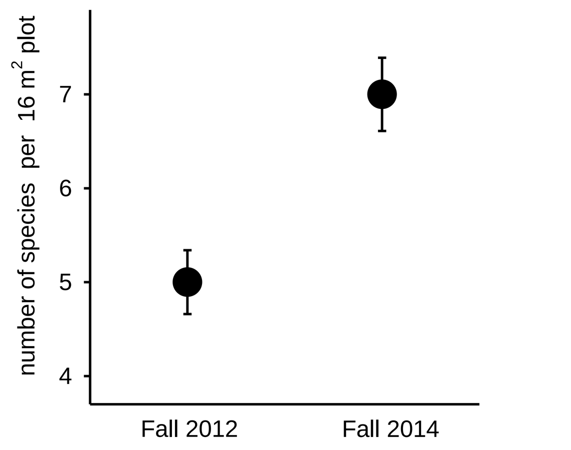




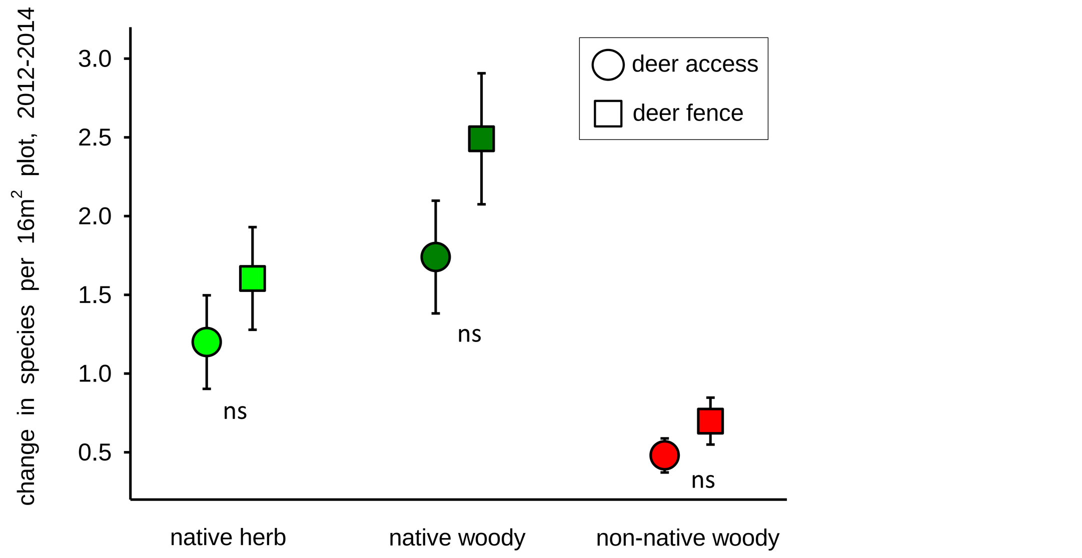


Results

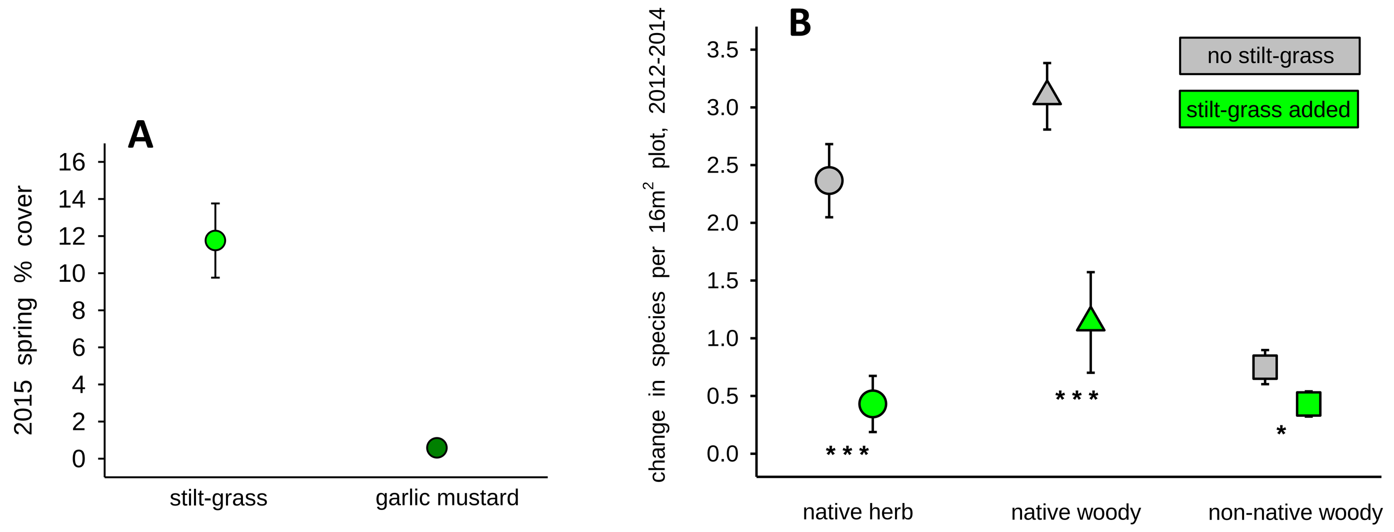
1 Species richness of all plants in the herb layer increased by two species on average, from Fall 2012, before the experiment began, to Fall 2014. (mean ± se; n=103 plots)



2 Exclusion of deer for 18 months had no significant effect on species richness in the herb layer, including for native herbs, native trees and shrubs, and non-native shrubs, although this early trend was toward a protective effect.
(mean ± se; n = 50 plots not fenced, 53 plots fenced; ANOVAs, native herb $F_{1,91}$=0.86 P=0.36, native woody $F_{1, 91}$=2.63 P=0.11, non-native woody $F_{1,91}$=2.51 P=0.12)



3 Stilt-grass established dense stands in many plots, but garlic mustard did not (A; mean ± se; n = 59, 58). The invasions of stilt-grass resulted in lower increases in herb layer species richness, for all plant guilds shown.
(B; mean ± se; n = 52 or 51; ANOVAs, native herb $F_{1,91}$=22.94 P<0.0001, native woody $F_{1, 91}$=16.58 P< 0.0001, non-native woody $F_{1,91}$=3.84 P=0.05).



Discussion

Experimentally investigating the effects of deer herbivory and plant invasions on the native flora allows us to determine if they are drivers of change in plant community structure. We observed an increase in plant species richness in our forest plots between 2012 and 2014, which could be influenced by various factors. The trend toward greater change in species richness in deer-exclosure plots may suggest a gradual sheltering effect of plants from deer herbivory and trampling, which would allow for plant species that are particularly sensitive to deer to be recruited back into the forest community. However, of our experimental treatments, stilt-grass presence had a much stronger effect on species richness; it exhibited a possible competitive or inhibitory effect on other plant species, resulting in a lesser increase in plant species richness in stilt-grass invaded plots. The stronger influence of stilt-grass on species richness compared to the deer-exclosures may indicate that bottom-up processes are stronger drivers/determinants of plant community composition within suburban forest communities.

In addition to studying change in ecological communities, our investigation experimented with the changing times by integrating technological advances, however simple, into our scientific methodologies. The basic but powerful Smartphone camera and instant messenger features have allowed for a small group of undergraduate students and a single professor at an undergraduate institution to efficiently and accurately identify thousands of plant individuals within short time frames. By creating a network of peer mentors and implementing the use of Smartphone technology, we are able to conduct a massive field experiment with only a small group of scientists who have limited time in their schedules for research.