Drivers of Japanese stiltgrass invasion into suburban forests: an experimental approach

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Abstract

Fragmented suburban forests in the urbanizing mid-Atlantic region are generally subject to invasion by multiple non-native plant species, including Japanese stiltgrass (*Microstegium viminuem*), a species of significant concern. Its abundance varies widely among sites. Many studies examine why, but few utilize the controlled, experimental approach of staging novel invasions to uncover drivers of invasion. In 2013, I established a stiltgrass seed addition experiment in six central New Jersey forests (16-20 16 m^2 plots each), with all combinations of no-fence/deer-fence, and no-addition/addition of seeds of a potential co-invasive, garlic mustard (*Alliaria petiolata*). We annually estimated cover of all species in the herb layer through 2017 in each plot, and also measured a suite of other variables per plot. Forest-level deer pressure was the most important determinant of stiltgrass success, with much greater establishment in forests with higher deer pressure (20.2% average cover over five years) than with lower deer pressure (4.8% average cover). Within the three forests with higher deer pressure (N=53), initial correlation analysis revealed that stiltgrass cover had no consistent relationship with soil water potential, PAR, soil pH, or shrub foliage density, on a per plot basis. Its cover was positively correlated with percent of full sun PAR in the herb layer, but when the unfenced plots were separated from the fenced plots for analysis, it appeared that the relationship with light was significant only in the fenced plot data (N=27, r=0.40, P<0.05). Average stiltgrass cover was somewhat greater when protected from deer trampling and possible herbivory in the fenced plots, suggesting that such protection allows for a stronger response to a potential environmental driver of its invasion, available light. These results will inform subsequent structural equation modeling to test system wide hypotheses about the interconnected drivers of stiltgrass invasion in suburban forests.

Introduction

Mid-Atlantic suburban forests are reservoirs of native biodiversity, but face invasion by many non-native plants species and damage from overabundant white-tailed deer.

Japanese stilt-grass (*Microstegium vimineum*) is a common, important invasive plant in the herb layer.

What drives its invasion into suburban forests?

- ❖ Response to environmental conditions?
- ❖ Competition from the resident plant community (natives and other invasives)?
- ❖ Direct effects from deer?
- ❖ Indirect effects from deer, via the invaded plant community?

The experimental approach of staging novel invasions – rather than removals or comparisons of invaded and uninvaded plots – is a powerful method for identifying causal factors.

In this study, stiltgrass has invaded over five years from seed additions to experimental plots located in suburban forests with differing deer pressure intensity; plots were either unfenced or fenced to exclude deer.

Methods

Study sites: six forests in Mercer County, central New Jersey, with differing deer pressure, determined by hunting history, browse rates on woody plants, oak seedling abundance, shrub foliage density; no stiltgrass present in experimental areas, but present elsewhere in the forests (there will be invasive removal at the conclusion of the study).

16 m^2 plots established in 2012 for baseline data collection

Stiltgrass seed added November 2012; seed collected from 10 local populations and pooled before allocating to plots; each plot received 2.95 g = approximately 2420 seeds/16 m^2
(garlic mustard also was added, but its recruitment has been very low)

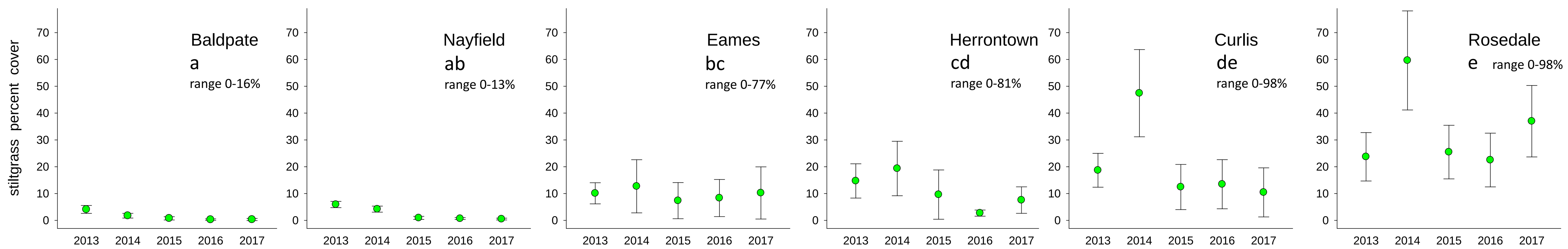
Deer exclusion fencing installed March 2013; 2.3 m tall; 0.5 m from plot perimeter

Percent cover of all herb layer species estimated in 10% intervals within 16 0.25 m^2 quadrats/plot, and averaged for one value per plot per species; measured annually in late Sept-early Oct, 2013-2017.

Environmental variables

- ❖ **SWP:** soil water potential, with a bench top WP4 soil potentiometer (Decagon Devices); 5 soil cores/plot and averaged; collected fall 2014,.
- ❖ **PAR:** percent of full-sun photosynthetically active radiation at ground level, with an AccuPAR ceptometer (Decagon Devices); measured at 5 positions/plot and averaged; measured annually in late summer.
- ❖ **Soil pH:** pHStick test on 5 samples/plot, and averaged; measured summer 2016
- ❖ **Shrub foliage density:** used 1 m^2 "forest secchi" board, held vertically and sighted on from across the plot to count number of squares intercepted by foliage between 0.5 and 1.5 m from the ground; two measurements/plot, and averaged; measured annually in late summer

Results



1. Stiltgrass cover over five years varied among forests [Means ± 95% CL; ANOVA on logit(avg cover+0.0001), $F_{5,\ 106}$=32.5, P< 0.0001] Letters show significant differences among forests' 5-year averages.

2. Forests differ in deer pressure.

	Forest	Years of hunting	Percent native shrub cover	Herb layer native species richness per 16 m^2	# Plots with red/black oak juveniles in spring, fall	Percent browse index
	Baldpate (BAL)	12	55.5 (4.08)	22.2 (0.88)	18, 17 (IV=33.1, #3)	0.54% (of 1238)
LOWER	Nayfield (NAY)	5	29.7 (3.94)	12.9 (0.48)	18, 22 (IV=84.7, #2)	3.75% (of 799)
	Herronton (HER)	17	14.6 (3.40)	20.6 (0.75)	9, 11 (IV=32.4, #5)	2.69% (of 605)
	Eames (EAM)	5	6.2 (2.71)	7.9 (0.33)	6, 0 (IV=16.0, #5)	8.53% (of 215)
HIGHER	Curlis (CUR)	0	2.5 (0.85)	6.8 (0.37)	4, 5 (IV=94.0, #2)	11.06% (of 327)
	Rosedale (ROS)	0	0.5 (0.42)	8.7 (0.40)	2, 1 (IV=29.8, #4)	5.34% (of 342)

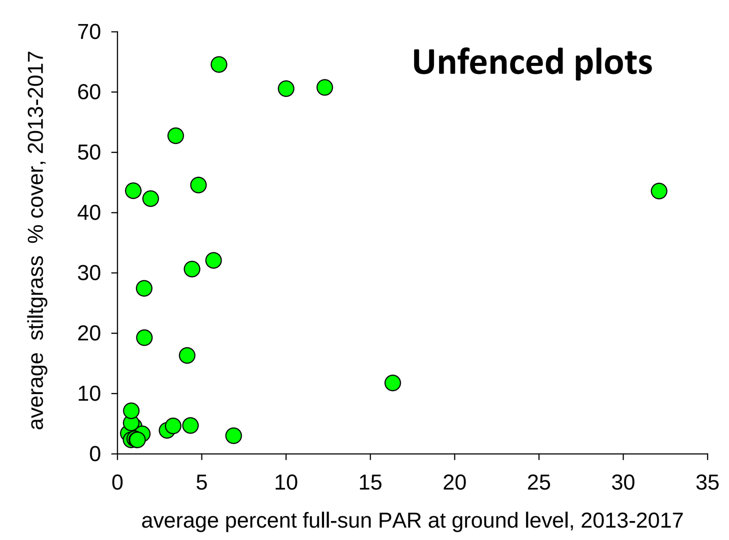
First-year, experimental Japanese stiltgrass invasion in a fenced plot in Curlis Lake Woods

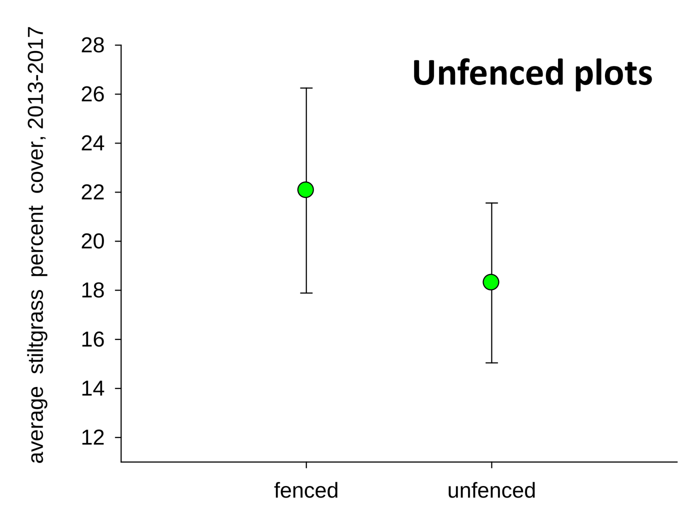
3. In the 53 plots within the three forests with higher deer pressure, average stiltgrass percent cover over five years was significantly correlated only with percent of full-sun PAR at ground level, averaged over five years.

Pearson correlations: avg stiltgrass cover with

- ❖ plot pH: -0.06, ns
- ❖ soil water potential: 0.21, ns
- ❖ shrub foliage density 2012: 0.11, ns
- ❖ **PAR: 0.36, P <0.01**
- ❖ PAR unfenced (n=26): 0.28, ns
- ❖ **PAR fenced (n=27): 0.40, P<0.05**

Stiltgrass cover was somewhat greater in fenced plots (ns; means + SE (n_{fen}=27, n_{unfen}=26)





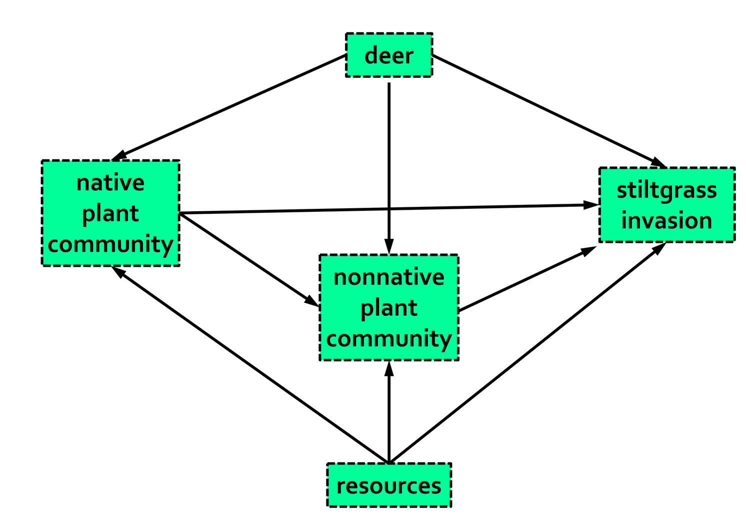
Discussion

All of the forests selected for this study harbored Japanese stiltgrass, but not in the location used in the experiment, so that we could study invasion ecology under more controlled conditions than is possible when relying on natural invasions or on removal experiments. Still, five-years of stiltgrass growth from seed added experimentally the first year did not uniformly result in vigorous invasion by this Asian species, which is known for its invasiveness in North America. Instead, forests differed drastically in their invasibility, and within the more heavily invaded forests variation among plots was extreme.

The six forests appeared to differ in deer pressure, with three having higher pressure and three lower. Stiltgrass invasion was extremely low in two of the forests with lower deer pressure, and was greatest in two with higher deer pressure, suggesting that deer may facilitate invasion by stiltgrass. Of the two forests with intermediate invasion, one had lower deer pressure, but it was subject to significant tree fall disturbance in 2012 from Hurricane Sandy, which may have facilitated stiltgrass invasion in 2013 and beyond.

The extreme variation of invasion among plots in the forests with higher deer pressure was directly correlated with only one of the environmental factors measured in this study, light availability. The significance of that correlation was due to the fenced plots, which on average were somewhat more heavily invaded that the unfenced plots. We have detected little browsing on stiltgrass from deer, so the benefit it gains from being fenced may be due to avoidance of trampling or leaf litter disturbance. It also may be due to indirect effects, e.g. the slightly more dense plant community in fenced plots may be creating a more suitable microclimate for annual stiltgrass recruitment, without yet causing increased competition for resources, especially light.

The next step in this research is to conduct structural equation modeling (SEM) to propose and test system-wide hypotheses about stiltgrass invasion in these suburban forests. SEM begins with the development of a SE meta-model (SEMM), to which measured variables can be assigned and analyzed. Just 112 plots had stiltgrass seed added, so any SEMM and subsequent SEM must be relatively simple:



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