Deer pressure in suburban/exurban forests and its relation to deer browse on invasive plants

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Introduction

Increasing levels of anthropogenic activity over the last century have led to dramatic changes in land use. Farmlands and large forests have transitioned into residential/commercial areas, resulting in the proliferation of small, fragmented forests. Combined with the loss of natural predators and limited hunting, this has resulted in overabundant populations of white-tailed deer. Additionally, invasions of non-native plants have redefined these small-forest plant communities.

Deer may avoid unpalatable invasive plants, which may help account for their success. However, some research also suggests that deer do eat these plants when other vegetation is scarce. In this case, deer may even disperse invasive plants' seeds. It is important to better understand the relationship of overabundant deer populations and invasive plants in order to prevent and halt further forest degradation.

We investigated whether deer feed on two important invasive species of the eastern temperate deciduous forest, garlic mustard (*Alliaria petiolata*, ALPE) and Japanese stilt-grass (*Microstegium vimineum*, MIVI). We conducted the study in 12 second-growth, small forests in central New Jersey, where we related the level of deer herbivory to the species' abundances and the intensity of deer pressure. To be able to do this, we first investigated three methods of measuring deer pressure, since accurate quantitative measures of deer density and pressure are difficult to make within fragmented forests in suburban/exurban landscapes.

Fig. 1 "Shreddy ends" indicating browse by white-tailed deer. This characteristic frayed end is due to a deer's crushing of the stem between the lower incisors and canines against the pad and results in striping of the woody stems and twigs.

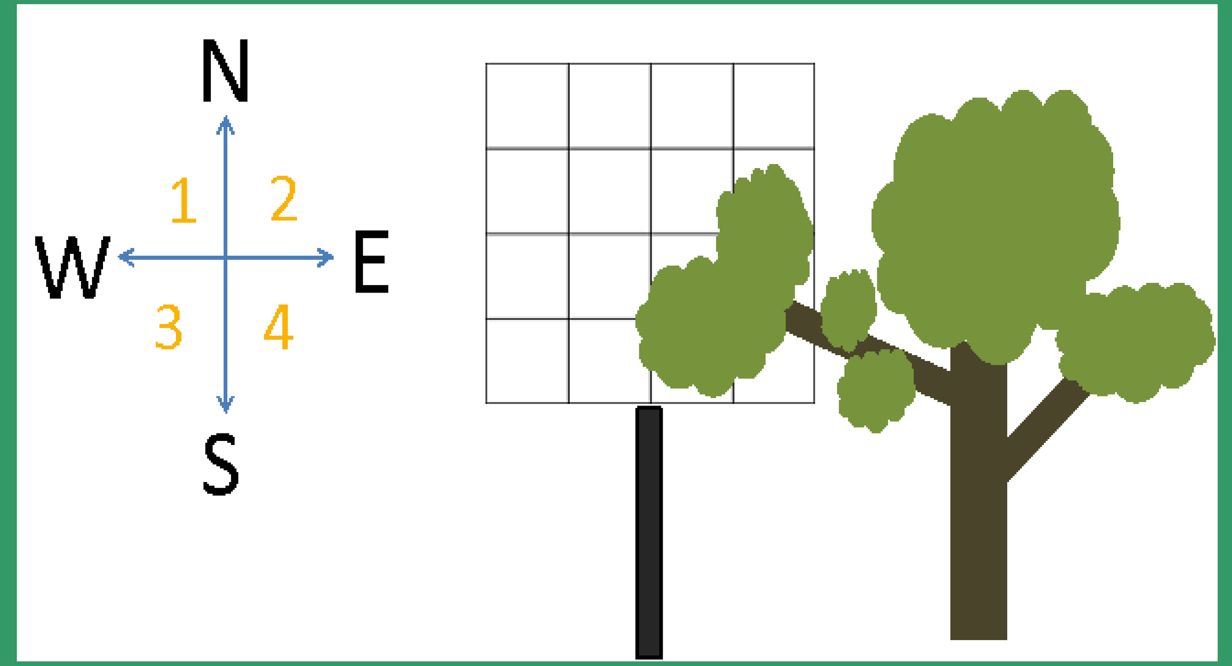


Fig. 2. Diagram of vertical shrub cover measure depicting obstruction of eight squares. Observations were recorded in four cardinal directions at ten points in each forest.

Methods

Deer Pressure

Deer Density: Pellet Group Surveys (FAR; Fecal Accumulation Rate) – Spring and Fall 2010

- Measured relative, localized deer density in 6 forests.
- Systematically scanned 15 random plots (112 m^2) for deer pellet groups in Spring 2010; recorded presence and removed. Re-scanned in Fall 2010 measured to obtain fecal accumulation rate, FAR.
- Estimated deer density (deer/ km^2) as a function of FAR: number of pellet groups per forest, number of days between surveys, and published defecation rates.

Current Deer Pressure: Browse Transects – Fall 2008 and 2010

- Measured damage to native woody plants by recent deer browse.
- Three 100 m transects in 6 forests. At each 10 m mark, examined the closest native, woody plant (within deer browse height range 0.5m – 1.5m) for evidence of deer browse damage.
- Mature plants: examined furthermost 10 cm of the lowest main branch tip. Juvenile plants: examined furthermost 10 cm of the highest main branch tip. Identified deer browse damage by a shredded end (Fig. 1); otherwise labeled as "other damage" or "intact."

Chronic Deer Pressure: Shrub Cover – Fall 2008 and 2010

- Measured vertical shrub cover as an indicator of effects of chronic deer browse in 6 forests.
- Placed 1 m^2 board with 16 grid squares at deer browse height (0.5 m – 1.5 m) (Fig. 2).
- Recorded number of squares obscured by native, woody plants for a viewer standing 10 m away; converted to percent cover.
- 40 observations per forest (10 random points with observations in 4 cardinal directions.

Deer Herbivory on MIVI and ALPE

Abundance of MIVI and ALPE: Visual Scans – Fall 2011 (MIVI & ALPE), Winter and Spring 2012 (ALPE only)

- Conducted nine 10-minute visual scans of paths that were in ALPE and MIVI stands: three hiking paths, three interior deer paths, three deer paths extending from the forest edge to the interior (Fig. 3).
- Scored each path and its surrounding area's abundance of MIVI and ALPE on a scale from 0 (absent) to 4 (75 – 100% cover).

Deer herbivory on ALPE and MIVI: Visual Scans – Fall 2011 (MIVI &ALPE), Winter and Spring 2012 (ALPE only)

- During each scan: counted the number of plants with evidence of deer browse (shreddy, bitten stem ends).

Preliminary Structural Equation Modeling:

- Did structural equation modeling (SEM), using AMOS software and maximum likelihood estimation, with observed variable models.
- Modeled one response variables for each species: 'NUMBER OF PATHS WITH HERBIVORY PRESENT' and 'MEAN # OF PLANTS BROWSED PER PATH'. (n=11 forests, where both species were present)
- Specified the initial model to reflect theoretical predictions :

(1) Deer herbivory on ALPE and MIVI is influenced by the level of chronic deer pressure in the forest;
(2) Deer herbivory is influenced by the species' abundance in the forest;
(3) Native shrub cover and the abundances of ALPE and MIVI are correlated.
The data were transformed as log10 (x + 0.5) before SEM in order to improve the fit to normality.

Results - DEER PRESSURE

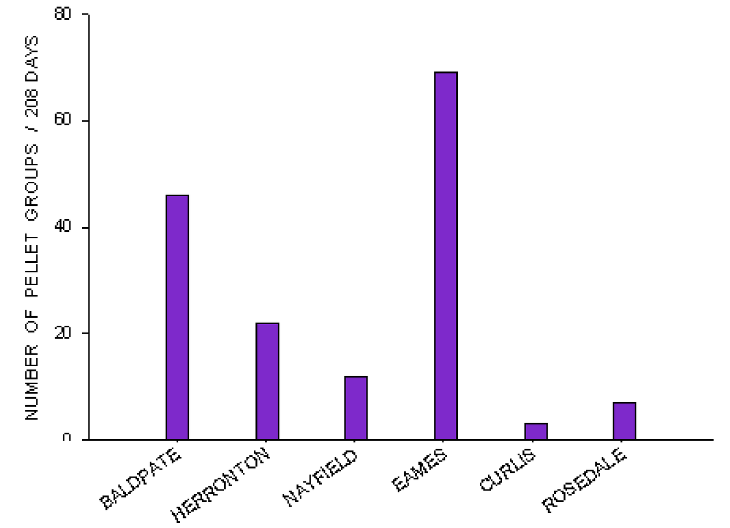


Fig. 4. Number of white-tailed deer pellet groups within each forest in Fall 2010 (fecal accumulation rate, over a period of ≈ 208 days (March – October).

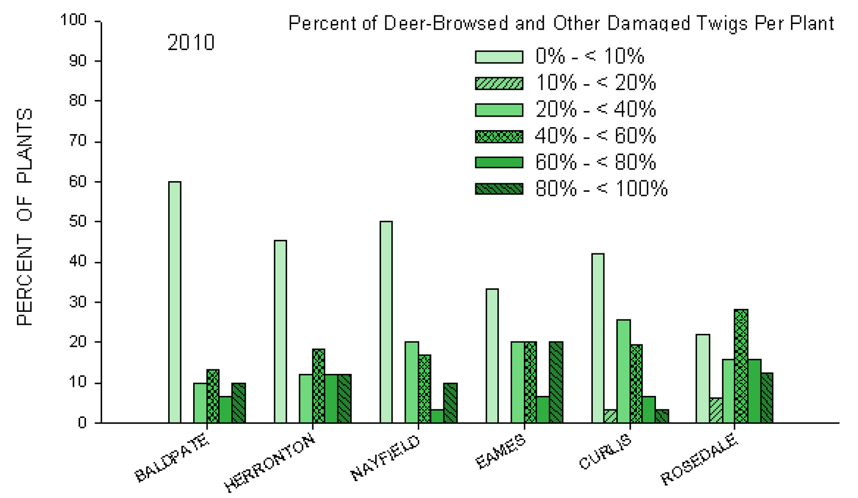


Fig. 5. Percent of native, woody plants browsed by deer + other damage, categorized into six levels of twigs browsed per plant, in Fall 2010. Kruskal-Wallis test; χ^2=9.83, df=5, P=0.08.

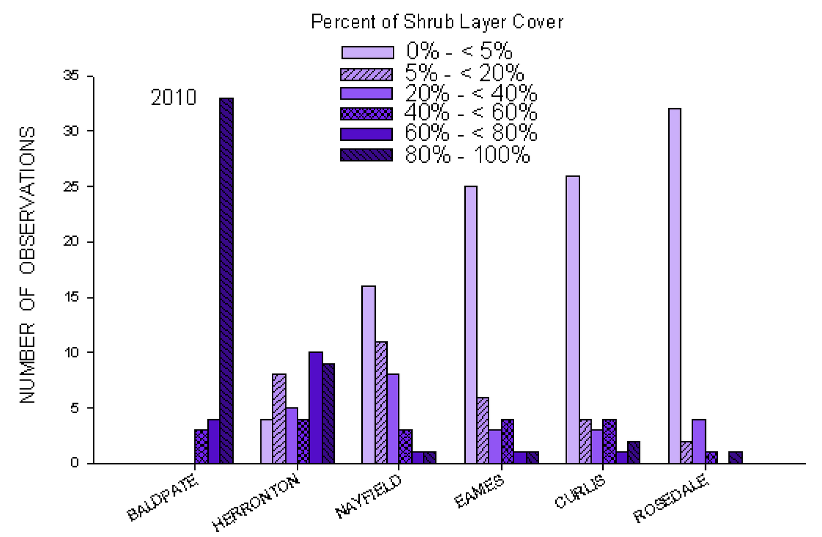
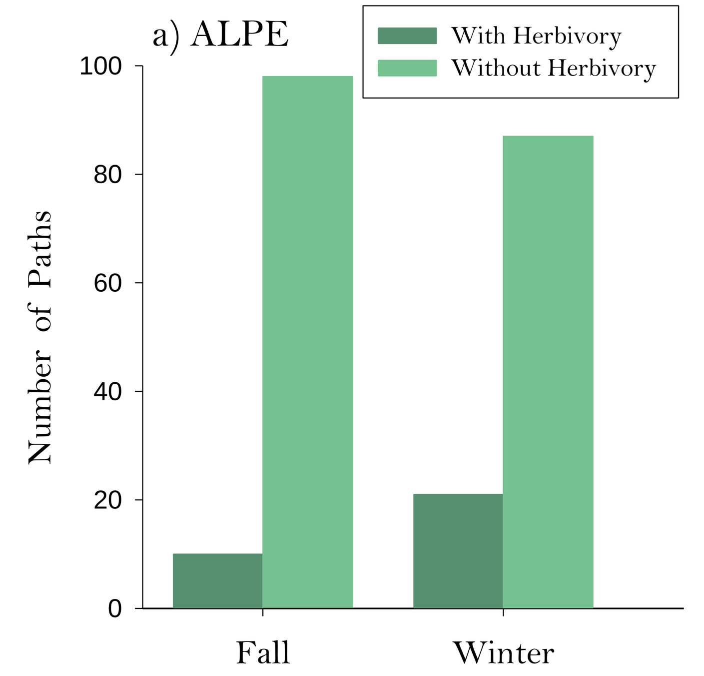


Fig. 6. Vertical percent cover of native shrubs (n=40 sample points per forest), categorized into six levels of cover, in early Fall 2010. Kruskal-Wallis test; χ^2=134.76, df=5, P <0.0001.

The six forests exhibited a high degree of variation in deer pressure, but the patterns among the forests were not identical across the three types of measures. For example, the FAR proxy for deer density indicated that Eames and Baldpate had the highest deer densities (Fig. 4), but they differed greatly in the percent cover of foliage in the shrub layer (Fig. 6). Also, while it may be expected that forests with high deer density should have higher browse intensity, comparison of the pellet data of Fig. 4 with the browse data of Fig. 5 show the opposite pattern.

Results - DEER HERBIVORY ON INVASIVE PLANTS



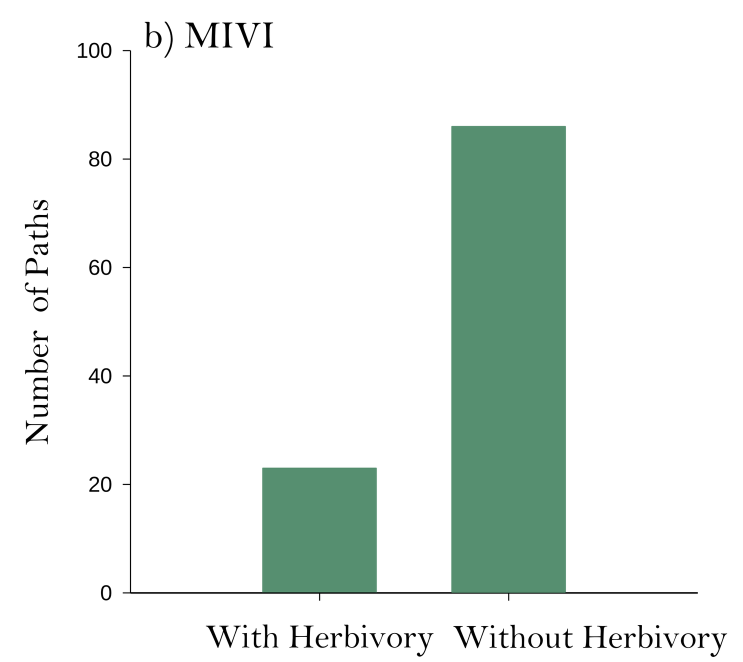


Fig 7. Number of paths (n=9/forest; 12 forests) with one or more MIVI or ALPE plants with deer herbivory. ALPE data (a) were collected in Fall 2011 and mid-Winter 2012. MIVI data (b) were collected in Fall 2011.

About 25% of paths for ALPE-Winter had deer herbivory, while only about 10% of paths for ALPE-Fall had herbivory. About 25% of paths for MIVI had herbivory.

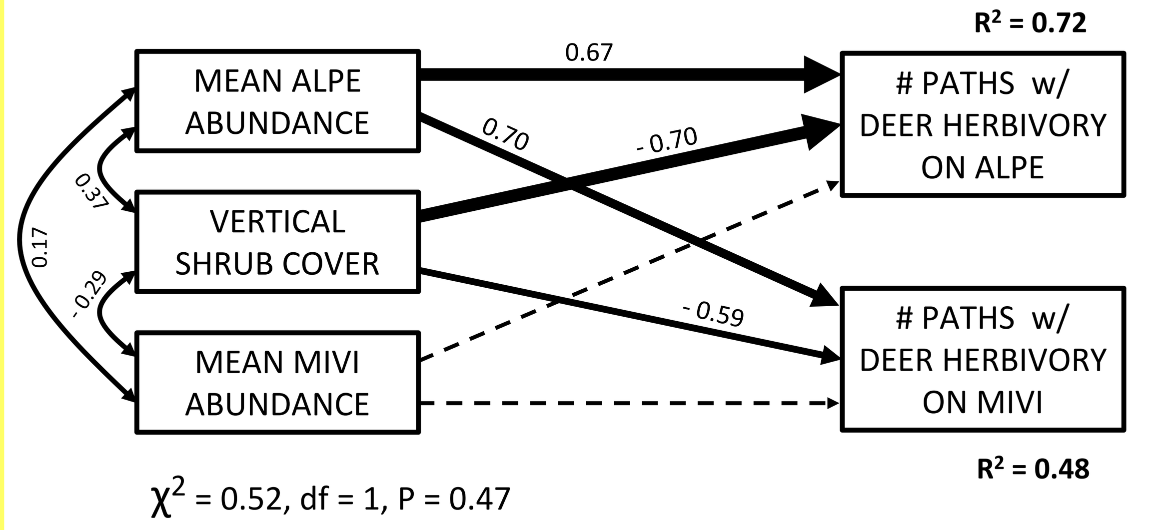


Fig. 8. Structural equation modeling (SEM) yielded this best model, indicating:

- Presence of herbivory on ALPE was higher in forests with lower shrub cover (i.e. chronic deer pressure) and higher ALPE abundance.
- Presence of herbivory on MIVI was higher in forests with lower shrub cover, but the overall MIVI abundance was not important. However, higher ALPE abundance led to higher presence of MIVI herbivory.
- The model explains more of the variation for ALPE than for MIVI.

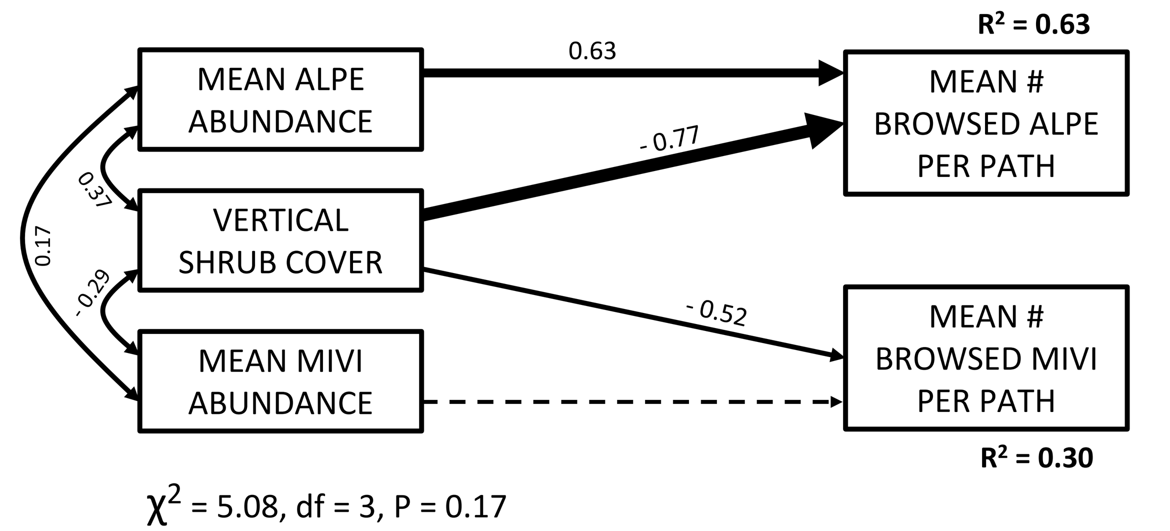


Fig. 9. SEM yielded this best model, indicating :

- Mean number of browsed ALPE (on paths where ALPE was present) was higher in forests with lower shrub cover and higher ALPE abundance.
- Mean number of browsed MIVI (on paths where MIVI was present) was higher in forests with lower shrub cover, but overall MIVI abundance was not important.
- For this response variable, inclusion of paths from abundance of the other species to herbivory did not improve the initial model.
- The model explains more of the variation for ALPE than for MIVI.

Fig. 3. Diagram of paths walked during survey periods (n= 9/forest) : 3 hiking paths, 3 deer paths from the forest edge, and 3 deer paths stemming from the hiking paths. Photos show typical stands of ALPE, MIVI, and a deer path.

Fig. 10. Deer browse line in a suburban forest.

Discussion

Assessment of deer pressure measures -- Forests with high levels of historical deer browse generally also exhibited high levels of current deer browse. The deer pellet surveys did not mirror this pattern, and our calculated estimates of deer density based on pellet group surveys were *much* lower than those using larger-scale methods such as aerial counts. Thus, we conclude that deer pressure estimates based on pellet surveys in small suburban forests are not accurate. Shrub cover reflects chronic deer pressure, is similar to the pattern shown for current browse, and also yielded the greatest variation among forests that had clearly visible browse lines (Fig. 10). For these reasons, we chose it for the study of deer browse on MIVI and ALPE.

Deer herbivory on MIVI and ALPE -- Forests within the suburban matrix are differentially affected by deer. In 12 forests, mean vertical shrub cover ranged from 0-57%. These forests typically also harbor large populations of multiple invasive species such as garlic mustard (ALPE) and Japanese stilt-grass (MIVI). **We observed deer herbivory on both in all forests, which challenges the assumption that deer avoid these species.**

Herbivory was more common and intensive in MIVI stands than ALPE stands. MIVI was also more abundant. Both species possess characteristics that should repel herbivores (ALPE's plant chemistry and MIVI's tough, fibrous tissues), but deer appear to be deterred more by ALPE. **This suggests a possible role for deer during co-invasion; with a more negative effect on stilt-grass they may promote garlic mustard invasion.**

A simple model that included the inter-related effects of shrub cover and ALPE and MIVI abundance explained a much greater amount of the variation in ALPE herbivory among forests than it did variation in MIVI herbivory. The models show that deer more readily turn to ALPE where native plant browse is scarce and ALPE is more abundant. For MIVI herbivory, the models suggest the need for further information: why is there a positive path from ALPE abundance to deer herbivory on MIVI, and what other, as yet unmeasured, factors are also important?

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