Evaluating Environmental and Disturbance Conditions Associated with Invasive Plants Using Allegheny National Forest FHM Intensive Plot Data

Cynthia D. Huebner, Northern Research Station USDA Forest Service, Morgantown, WV; Randall Morin, Northern Research Station FIA USDA Forest Service, Newtown Square, PA; Daniel Twardus, Northern Area State and Private Forestry, Morgantown, WV; Ann Zurbriggen Region 9, Allegheny National Forest, Warren, PA; Robert L. White, Region 9, Allegheny National Forest, Warren, PA; April Moore, Region 9, Allegheny National Forest, Warren, PA

Abstract

We evaluated the relative importance of 22 variables for predicting the degree of forest invasion by early-establishing invasive plants in the Allegheny National Forest of northern Pennsylvania. The variables were divided into three categories: (1) six biotic, e.g. species richness, (2) seven environmental, e.g. topography, and (3) nine disturbance indicators, e.g., forest age. Both logistic regression and canonical correspondence analyses were used to compare within and among each variable category using five years of data (1999-2003) comprised of 172 plots collected as part of the Phase 3 (P3) Forest Inventory and Analysis (FIA) program. Nationwide, P3 FIA plots are located on a hexagonal grid with one plot per 96,000 acres. This intensified network established in 1998 has one plot per 3,000 acres. Fifty-three exotic (non-invasive) and six invasive exotic plant species were documented. Results showed that sites with relatively high exotic plant species (non-invasive) and native species richness were more vulnerable to invasion by exotic invaders, including *Berberis thunbergii* (Japanese barberry) and *Rosa multiflora* (multiflora rose) but not the native invader, *Dennstaedtia punctilobula* (hayscented fern). Exotic grass and native shrub species appear to be the primary driving forces behind this association. Topographic and other environmental variables including forest type were unimportant indicators of invasion by exotic plants in this landscape. In contrast, invasion by hayscented fern was defined by forest type or ecological land type, with *D. punctilobula* occurring most commonly in the Maple/Beech/Birch and Hemlock/Pine forest groups or on plateaus and side slopes. Moreover, sites with fewer standing dead trees and portions of non-forested land were more likely to be invaded by exotic plants but not by *D. punctilobula.* Canonical correspondence analyses indicated that younger forests, nearness to dirt and paved roads, and steeper slopes were important indicator variables of invasion by exotic plants, but that invasive herbs responded differently than invasive shrubs, which were more predominant in this landscape. While invasive shrubs were associated with younger forests, this was not true of invasive herbs, which were defined more by shorter distances to paved roads. The most common dispersal vectors associated with each plant habit (wind or water for herbs and birds for shrubs) may explain this response. Differences between native and exotic invaders may be due to overall abundance. All exotic invaders were relatively low in abundance compared to common native species. Also, the sampled sites were predominantly Maple/Beech/Birch and older than 70 years. Increasing the number of sites within each forest group and the number of younger sites may reveal the importance of topography and other environmental variables compared to disturbance variables. The analyses had relatively weak R^2's and eigenvalues and are considered preliminary. Future analyses will include additional variables (e.g., distance to power lines) and 2004 and 2005 P3 FIA data.

Introduction

Anthropogenic influences (e.g., fragmentation and urbanization), disturbance (e.g. harvesting), and resource availability are characteristics associated with high community invasibility. While anthropogenic influences in the landscape may promote seed dispersal by increasing proximity to seed sources and dispersal corridors, disturbance may promote invasion by increasing resources or reducing potential competitors. In addition, several landscape or regional scale studies show a positive relationship between richness and invasibility (Lonsdale 1999), and the driving force of this relationship is thought to be resource availability – native and nonnative species are expected to respond favorably to sites with greater resources (Davis, et al. 2000).

Our goal was to use landscape-level vegetation data of the Allegheny National Forest to determine if patterns exist among measured biotic, environmental, and disturbance variables which may serve as potential indicators of site vulnerability to invasion.

Methods

Phase 3 (P3) Forest Inventory and Analysis (FIA) understory and overstory data were collected between 1999 and 2003 from an intensified network of 172 plots located within the Allegheny National Forest (Figs. 1 and 2). These plots are composed of six major forest groups (Fig. 2) and a small percentage were re-sampled a second time (Fig. 3).

Data were combined into two data sets: 1) all 172 plots using the plots sampled for the first time for any re-sampled plots and 2) all 172 plots using the plots sampled for the second time for any re-sampled plots. There were only slight differences in the results for these data sets. We focused on subplot frequency data because more exotic and invasive species were detected in these larger 24 ' radius plots. There were four subplots per plot. All analyses were conducted with plot as the unit of analysis. Species were categorized as invaders if they made more than one state severe threat list.

A total of 22 predictor variables (Table 1) were analyzed using logistic regression and canonical correspondence analysis (CCA) with richness of invasive exotic plants (all, herbs, or shrubs) or frequency of *D. punctilobula* as separate response variables. The 22 variables were divided into three major groups (1) biotic, (2) environmental, and (3) disturbance indicators. Logistic regression analyses were conducted first within each of these groups and then among the groups by combining any category-specific significant variables. CCA was conducted using the biotic variables as the species matrix and the environmental and disturbance variables as the predictor variable matrix.

Figure 1

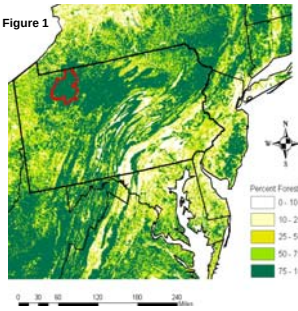

Figure 2

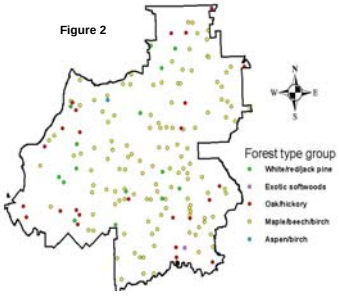

Figure 3

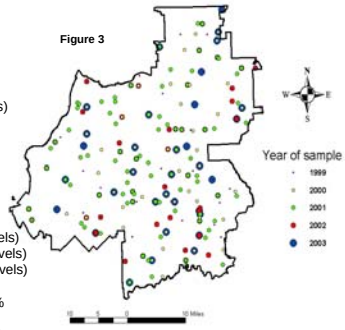

Table 1: Variables

Biotic
(1) Richness
- Native*
- Exotic*
- Invasive*+ (ordinal)
- Exotic gram.+ (ExGram)
- Exotic herb+ (ExHerb)
- Exotic vine+
- Invasive herb # (InvHerb)
- Invasive shrub # (InvShrub)
- Native gram.+ (NatGram)
- Native herb+ (NatHerb)
- Native vine+
- Native shrub+ (NatShrub)

(2) *Dennstaedtia punctilobula*#*+ Frequency % (ordinal)
(3) Tree (> 12.7 cm dbh) density
(4) Tree B.A. cm^2.
(5) Sapling (2.54 -12.4 cm dbh) density
(6) Sapling B.A. cm^2

Environmental
(1) Aspect (5 levels)
(2) Forest group (6 levels)
(3) ELT group (7 levels)
(4) Slope %
(5) CWD m^3
(6) Moss % (in $1m^2$)
(7) Bare soil % (in $1m^2$)

Disturbance
(1) Non-forest/Cut (2 levels)
(2) CSM defoliation (3 levels)
(3) ESW defoliation (3 levels)
(4) Crown density %
(5) Foliar transparency %
(6) Stand age (years)
(7) Dirt road distance (m)
(8) Paved road distance (m)
(9) Standing dead density

Table 1. Variables in red are the response variables (all evaluated separately); predictor variables with different symbols (*,+,#) were never included in the same models or matrices due to multicollinearity. Variables with levels are categorical. Response variables of the logistic regression model were ordinal with three (invasive) or four (*D. punctilobula*) levels. CWD = course woody debris, CSM = cherry scallopshell moth, ESW = elm spanworm, B.A. = basal area.

Cumulative Logistic Models

(1) Native richness

(2) Native richness + Exotic richness

(3) Exotic graminoid + Native graminoid + Exotic herb + Native herb + Exotic vine + Native vine + Native shrub

(4) Aspect + Slope + Forest group (or ELT) + CWD + Moss + Bare soil

(5) Paved road + Gravel road + Nonforest + Stand age + Standing dead trees + Crown density + Foliar transparency + ESW defoliation + CSM defoliation

(6) Native richness + Exotic richness + Standing dead trees

Results

Response variable: Invasive species (3 levels; CI = confidence interval)

Model	Adj. R^2	Significant Variable(s)	Odds Ratio (CI)
(1)	0.04	Native richness $\chi2 = 4.97$ ($p = 0.026$)	1.07 (1.01 – 1.14)
(2)	0.12	Exotic richness $\chi2 = 14.8$ ($p < 0.001$)	2.86 (1.68 – 4.89)
(3)	0.28	Exotic graminoid $\chi2 = 12.1$ ($p < 0.001$) Native shrub $\chi2 = 14.4$ ($p < 0.001$)	8.48 (2.54 – 28.3) 2.01 (1.40 – 2.88)
(4)		NONE	
(5)	0.15	Standing dead trees $\chi2 = 7.08$ ($p = 0.008$) Nonforest $\chi2 = 6.25$ ($p = 0.012$)	0.78 (0.65 – 0.94) 4.29 (1.38 – 12.8)
(6)	0.21	Exotic richness $\chi2 = 12.05$ ($p < 0.001$) Standing dead trees $\chi2 = 5.55$ ($p = 0.016$)	2.92 (1.59 – 5.34) 0.77 (0.62 – 0.96)

Figure 4

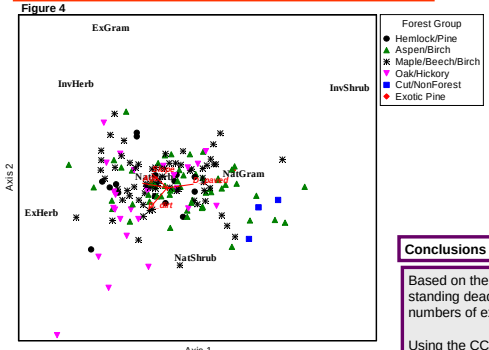

Figure 4: Linear combination scores are presented in the graph, showing only environmental variables with canonical coefficients ≥ 0.2. Axes were significantly different from random (Monte Carlo test: null hypothesis = no relationship between matrices).

	Axis 1 ($p < 0.01$)	Axis 2 ($p < 0.006$)
Eigenvalue	0.016	0.007
Total Explained % Variance	4.9	7.3
Intraset Correlations		
Slope	-0.326	0.464
D_Dirt	-0.403	-0.728
D_Paved	0.567	0.115
Age	-0.536	0.145
Species Scores		
ExGram	-0.579	1.513
ExHerb	-1.101	-0.306
InvHerb	-0.844	0.966
InvShrub	1.258	0.922
NatGram	0.431	0.078
NatHerb	-0.245	0.050
NatShrub	0.057	-0.744

Figure 5

Invasive Exotic Species Present in the Study Area

1. ***Berberis thunbergii* DC.(Japanese barberry; BETH)**
2. ***Coronilla varia* L.(crown vetch; COVA2)**
3. ***Frangula alnus* P. Mill. L. (glossy buckthorn; FRAL4)**
4. ***Polygonum caespitosum* (long-bristled smartweed; POCA49)**
5. ***Rosa multiflora* Thunb. (multiflora rose; ROMU)**
6. ***Rumex acestosella* L. (sheep sorrel; RUAC3)**

Figure 5: Distribution of the 30 plots with one or more of these six species (17% of all plots). *Frangula alnus* exhibited some clustering (in the southeastern part of the forest).

Response variable: *Dennstaedtia punctilobula* (4 levels; CI = confidence interval)

Model	Adj. R^2	Significant Variable(s)	Odds Ratio (CI)
(1)		NONE	
(2)		NONE	
(3)	0.05	Native graminoid $\chi2 = 5.33$ ($p = 0.021$) Native herb $\chi2 = 4.56$ ($p = 0.033$)	1.22 (1.03 – 1.44) 0.89 (0.79 – 0.99)
(4)	0.12	Maple/Beech/Birch vs. Oak/Hickory $\chi2 = 5.60$ ($p < 0.018$) Maple/Beech/Birch vs. Hemlock/Pine $\chi2 = 9.42$ ($p = 0.002$)	2.52 (1.17 – 5.43) 0.22 (0.08 – 0.58)
	0.15	Plateau vs. Steep slope $\chi2 = 5.13$ ($p = 0.024$) Side slope vs. Steep slope $\chi2 = 8.79$ ($p = 0.003$) Side slope vs. Colluvial $\chi2 = 6.10$ ($p = 0.014$) Side slope vs. Alluvial $\chi2 = 5.24$ ($p = 0.020$)	5.97 (1.27 – 28.0) 10.2 (2.20 – 47.5) 2.90 (1.25 – 6.76) 8.45 (1.36 – 52.5)
(5)		NONE	
(6)		NONE	

Conclusions

Based on the logistic regression analyses, sites that have relatively low numbers of standing dead trees with non-forest land present and that have relatively high numbers of exotic (non-invasive) plants are most likely to be invaded.

Using the CCA, invasive herbs appear to be best defined by shorter distances to paved and dirt roads and older sites, while invasive shrubs are defined by younger sites that are further from paved roads but closer to dirt roads.

Hayscented fern's (native invader) distribution is defined more by land and forest type than by disturbance or proximity to roads.

Invasion in the Allegheny National Forest appears to be related to biotic variables, landscape features, and disturbances associated with exotic non-invaders, roads, and forest age/tree death. The varied response between herbs and shrubs may be related to differences in seed dispersal vectors.

Unfortunately, both analyses are relatively weak (low R^2 values and eigenvalues). Future analyses will add more sites and limit comparisons to only a few forest types and age groups. Additional variables to be tested include distance to power lines, fire history, gypsy moth defoliation, and known plantings of exotic species. In doing so, we hope to explain the relationship between exotic species invasion, standing dead trees, forest age, road proximity, and native species invasion.

Literature cited: Davis, M.A., Grime, J.P. and Thompson, K. 2000. Fluctuating resources in plant communities: a general theory of invasibility. Journal of Ecology 88: 528-534; Lonsdale, W.M. 1999. Global patterns of plant invasions and the concept of invasibility. Ecology 80: 1522-1536.