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Exotic Plant Distributions along Disturbance Corridors at the Grassy Hill Natural Area Preserve, Franklin County, Virginia

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ABSTRACT

The Grassy Hill Natural Area is a mountain preserve containing forest, open woodland, grassland, and rock outcrop habitats northwest of Rocky Mount, Virginia. The preserve was created in 1999 and is managed by the Virginia Department of Conservation and Recreation to protect forest communities and rare plant species. In 2005, nine 0.25-ha plots were randomly established in forestlands located along disturbance corridors traversing the preserve. Plots were sampled for exotic plant species richness and frequencies to assess exotic presence and encroachment into the preserve from the corridors. Exotic species richness was low in all plots, but was highest closest to corridor edges. Exotic species were not widely distributed across corridors, except for Tree of Heaven (*Ailanthus altissima*) and Japanese Stilt Grass (*Microstegium vimineum*), which were found along all corridors. Silk Tree (*Albizia julibrissin*), an exotic hawthorn (*Crataegus* sp.), Chinese Privet (*Ligustrum sinense*), and Japanese Honeysuckle (*Lonicera japonica*) were present in a few plots. Eleven other exotic species were encountered along the corridors, outside of the plots. While the plots were dominated by native plants and had low exotic species richness and invasion, high frequencies of the aggressively invasive *M. vimineum* along corridor edges, and encroachment by *A. altissima* into the forest, suggest that invasion by these and other exotic species could increase with potentially negative consequences for forest community integrity and native plant conservation at the preserve.

Key words: diversity, exotic invasive plants, Grassy Hill Natural Area Preserve, plant conservation, Virginia.

INTRODUCTION

Exotic plants are common in many habitats in the United States (Yahner, 1995), but are highly prevalent in temperate forests in the eastern U.S. that are fragmented due to agriculture, logging, and road building (Brothers & Spingarn, 1992). Fragmented forests can harbor relatively intact native plant communities, and are important reservoirs of native plant diversity. However, over time, exotic plants commonly invade fragmented forests. The exotic tree species Norway Maple (*Acer platanoides*) and Tree of Heaven (*Ailanthus altissima*), the shrubs Japanese Barberry (*Berberis thunbergii*) and Winged Burning Bush (*Euonymus alata*), the grass Japanese Stilt Grass (*Microstegium vimineum*), and the forb Japanese Knotweed (*Polygonum cuspidatum*), for example, are well established in Virginia forests (Virginia Department of Conservation and Recreation & Virginia Native Plant Society, 2003). Exotic plant encroachment can reduce native plant abundance and upset community structure (Claridge & Franklin, 2002) with cascading effects on native animals that depend on these plants for food, nests, and shelter (Yahner, 1995). Ultimately, effects from exotic plant invasion into fragmented forests are twofold: the potential loss of ecological stability in some native communities and of native plant species diversity.

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The success of exotic plant recruitment into fragmented forests is generally related to life history traits that may favor exotic species over native ones and to disturbance from fragmentation (Brothers & Spingarn, 1992; Worley & Tyser, 1992). Exotic plants often produce more seeds and grow faster than do many natives (Rejmanék & Richardson, 1996), which can lead to competitive exclusion of natives by exotics. Human disturbances are also influential, primarily because they can cause environmental changes. Forest fragmentation can increase light availability and disrupt soil along fragment edges, for example. The resulting "edge effects" can assist exotic recruitment along disturbed canopy edges (Brothers & Spingarn, 1992), though native species may also benefit. However, the degree to which fragmentation influences exotic distributions in many forests has not been fully investigated. This is especially true for mountain forests that, due to topography, are often less fragmented than forests found at lower elevations.

Although many surveys have documented exotic plants in Virginia forests in general, fewer have assessed exotics in Virginia mountain forests, especially those established to conserve important closed-canopy forest communities (e.g., Mountain Piedmont Acidic Woodlands) and open woodland and grassland communities (e.g., Piedmont Prairie). This study sought to survey exotic plants in the Grassy Hill Natural Area Preserve (Grassy Hill), a Blue Ridge Mountain sanctuary containing many important forest, open woodland, and grassland communities, but which has not been studied for exotic plant presence and invasion. Specifically, we surveyed exotic plants in the areas of the preserve most disturbed by human activity. Our primary goals were: (1) to identify and quantify exotic plant species richness and frequencies in plots located along disturbance corridors in the preserve and (2) to assess encroachment by exotic species into closed-canopy forest interiors adjoining the corridors. We also surveyed exotic species along the corridors, outside of the plots, to assess their presence along the corridors in general. We hypothesized that exotic species richness and frequencies would differ between corridor types and across transects. Specifically, we hypothesized that exotic plant richness and frequencies would be higher in the most disturbed plots (i.e., paved and gravel road plots) and in transects closest to corridor edges compared to those in forest interiors.

SITE DESCRIPTION

Grassy Hill is a 524-ha preserve located northwest of Rocky Mount, Franklin County, Virginia, 32 km south of Roanoke. The Virginia Department of Conservation and Recreation (VDCR) has managed the preserve since 1999 as part of its Natural Area Preserve system. Grassy Hill lies in the foothills of the Piedmont physiographic province (Roberts & Bailey, 2000), and contains magnesium-rich bedrock overlain with mafic soils (Virginia Department of Conservation and Recreation, 2003). The terrain is mountainous, with northwest-southeast oriented slopes ranging in elevation from 365-535 m asl (U. S. Geological Survey & Virginia Division of Mineral Resources, 1985). Annual precipitation averages 106 cm, and monthly average temperatures range from 3-24 ºC (Town of Rocky Mount, 2006). The preserve is in the southern oak-pine forest zone (Yahner, 1995), and is dominated by hickory (*Carya*), oak (*Quercus*), and pine (*Pinus*) species. Grassy Hill contains important ecological forest communities (i.e., Mountain Piedmont Acidic Woodland and Basic Oak-Hickory Forest) recovered from logging, and is likely named for grassland habitats that occurred on the mountain before logging and fire suppression altered pre-settlement conditions (Virginia Department of Conservation and Recreation, 2003). Today, the preserve is primarily composed of closed-canopy forest communities, with some open woodland and grassland habitats, as well as disturbed areas such as road corridors and power line right-of-ways. The xeric soils in some open woodland and disturbed areas provide habitats for rare grassland plants like Smooth Coneflower (*Echinacea laevigata*), a federally listed endangered species. The proximity of this and other rare native plants to disturbance corridors at Grassy Hill is a major reason why our study is of importance, since ironically, disturbed areas favoring some native plants can also act as conduits for exotic species invasion. There are no records of fire, logging, or other major disturbances (other than occasional pest outbreaks) since the mid-20th century at the preserve (J. Ebbert, Virginia Department of Forestry; pers. comm.). However, corridor fragmentation is a source of ongoing disturbance and forest management plans may include additional disturbances that will be needed to facilitate the restoration of some habitats to early successional conditions. Balancing these management goals while discouraging exotic recruitment is, thus, important.

METHODS

In the summer of 2005, nine 0.25-ha plots were randomly established at Grassy Hill along three corridors: (1) a heavily traveled paved road (VA Route 919), (2) a rarely used gravel access road, and (3) an old abandoned dirt logging road. No plot was located within 500 m of another, and all but two plots were more than 750 m apart. All plots were within 100 m in elevation and had a northwest aspect. Plots were similar in tree composition, and were dominated by hickories and oaks. Within each plot, five 50 x 4 m belt transects, each subdivided into 4 x 5 m quadrats, were established using the procedures of Brothers & Spingarn (1992) to create a transect gradient based on proximity to corridor edge. Transects were placed parallel to corridors beginning at (-2) - 2 m, and then 2 - 6, 10 - 14, 20 - 24 and 45 - 49 m into the forest from corridor edges. Transects were labeled T(-2), T2, T10, T20, and T45 accordingly. T(-2) was established 2 m outside of the forest edge to account for irregularities in edge linearity. However, no T(-2) transect overlapped the corridor area, since corridor edges included dirt shoulders.

Sampling was conducted from June to August 2005, and exotic plants were identified following Harrar & Harrar (1962), Petrides (1986), and Huebner et al. (2005). Identified plants were considered exotic and invasive if listed in the Invasive Alien Plant Species of Virginia (Virginia Department of Conservation and Recreation & Virginia Native Plant Society, 2003). In each transect quadrat, exotic shrubs, tree seedlings, tree saplings, and canopy trees were counted, as were stems of forbs. Grasses were counted by ramet. Native tree species were also identified and marked as present, but were not counted. Additionally, exotic species were identified along each corridor outside of the plots, and noted as present during foot walking surveys consisting of visual examinations of ca. 10 m of forest interior beyond corridor edges.

Canopy cover and leaf litter depth were measured in mid-July in the center of each transect quadrat to evaluate if they might influence exotic presence. Canopy cover was measured 1.5 m above ground level, using a hand-held mirror densiometer. Litter depth was measured with a metric ruler as the distance from the bottom duff layer to the top of the leaf layer.

CALCULATIONS AND ANALYSES

Exotic species richness was calculated as the number of exotic species encountered per corridor type and transect, while exotic species frequencies were calculated as the percentage of quadrats in which exotic species were encountered. Frequencies were determined for all exotic species. Log-linear analyses were conducted to test for effects of (1) corridor type on *Ailanthus altissima* and *Microstegium vimineum* frequencies because they were the only exotic species found across corridor types and (2) proximity to corridor on *A. altissima* frequencies, because it was the only exotic species found beyond T2 transects at relatively high frequencies. Tests were considered significant if $P \leq 0.05$.

RESULTS

Six exotic plant species were identified in our plots (Table 1). The most commonly encountered were *A. altissima* and *M. vimineum*, both of which were established in plots along each corridor. *Ailanthus altissima* occurred primarily as sparsely dispersed saplings, whereas *M. vimineum* occurred in patchy clusters. The other four species were much less common, and were observed as saplings, small trees, bushes, or vines. Eleven other exotic species were found along corridors, outside of plots, suggesting that exotic encroachment in the preserve may be greater than that represented by the plots. Most of these species were found along paved and gravel road shoulders, and included the following forbs: Wild Garlic (*Allium vineale*), Canada Thistle (*Cirsium arvense*), Bull Thistle (*Cirsium vulgare*), Crown Vetch (*Coronilla varia*), White Sweet Clover (*Melilotus alba*), Curly Dock (*Rumex crispus*) and Common Chickweed (*Stellaria media*). Three grasses, Orchard Grass (*Dactylis*

Table 1. Exotic plant species presence across corridors and transects at Grassy Hill Natural Area Preserve, Franklin County, Virginia. The numbers -2, 2, 10, 20, and 45 represent transect distance (in m) from the corridor edge. X indicates species presence in transects.

Road Corridor / **Species**	**Paved**					**Gravel**					**Logging**				
	-2	2	10	20	45	-2	2	10	20	45	-2	2	10	20	45
Ailanthus altissima	x	x	x	x	x	x	x	x	x	x	x			x	x
Albizia julibrissin	x	x				x	x								
Crataegus sp.						x									
Ligustrum sinense						x	x								
Lonicera japonica						x									
Microstegium vimineum	x					x	x				x				

Table 2. Total exotic plant species richness and frequency between corridors and across transects. The numbers -2, 2, 10, 20, and 45 represent transect distance (in m) from the corridor edge.

Variable \ Road Corridor	Paved	Gravel	Logging
Exotic species richness	2	4	2
Exotic species frequency (%)	26	23	11

Variable \ Transect	-2	2	10	20	45
Exotic species richness	6	4	1	1	1
Exotic species frequency (%)	72	14	8	9	9

Table 3. Mean percent canopy cover and leaf litter depth across corridor transects. The numbers -2, 2, 10, 20, and 45 represent transect distance (in m) from the corridor edge.

Variable \ Transect	-2	2	10	20	45
Mean canopy cover (%)	82.2	91.0	94.6	98.0	98.4
Mean leaf litter depth (cm)	0.9	3.9	3.6	4.1	4.6

glomerata), Tall Fescue (*Festuca arundinacea*), and Timothy (*Phleum pratense*) were common along the paved road. White Mulberry (*Morus alba*) also occurred along the paved road.

Consistent with our hypotheses, exotic species richness differed among corridors, being higher in gravel road plots than in paved or logging road plots (Table 2). Two species were found in plots along all three corridors (*M. vimineum* and *A. altissima*), one was found in plots along paved and gravel roads (*Albizia julibrissin*), and three were found only in gravel road plots (an exotic *Crataegus* species, *Ligustrum sinense*, and *Lonicera japonica*; Table 1). Frequencies of exotic species were similar between the paved and gravel road plots, and were more than twice the frequencies found in the logging road plots (Table 2). However, a log-linear analysis of both species found in all three corridors found no effect of corridor type ($P < 0.05$) on their frequencies. Also consistent with our hypotheses, exotic species richness was highest in transects located closest to corridors, with species richness per transect declining from six in T(-2) transects to one in T45 transects (Table 2). Similarly, exotic species frequencies declined from 72% in T(-2) transect quadrats to 9% in the T20 and T45 transects. Mean *A. altissima* frequency also conformed to this pattern, falling from 37% in T(-2) quadrats to 12% in T45 quadrats (Fig. 1). Not surprisingly, a log-linear analysis found a significant effect of proximity to corridor on *A. altissima* frequency ($P < 0.05$), indicating that the frequencies of this species were significantly higher in transects closest to corridors compared to those located farther into the forest interior. *Microstegium vimineum* had the highest frequency of any exotic in any transect, occurring in 58% of T(-2) quadrats, but it was virtually absent from all other transects across corridors, as were the other exotic species. *Albizia julibrissin*, *Crataegus* sp., *L. sinense*, and *L. japonica* occurred in 12, 2, 1, and 1% of T(-2) transect quadrats on average, respectively. Due to the very low frequencies of all exotic species except *A. altissima* beyond the T(-2) transects, log-linear analyses of the effect of proximity to corridor were not conducted for any of those species.

The forest environment also differed between exterior and interior transects across corridors (Table

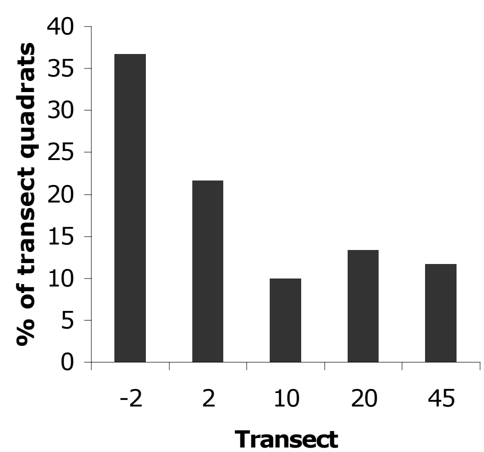

Fig. 1. *Ailanthus altissima* frequency across corridor transects.

3). Mean canopy cover increased from 82.2% in T(-2) transects, which is relatively high for forest edges, to almost complete cover (98.4%) in T45 transects. Mean leaf litter depth varied greatly between transects, being 3.7 cm more in T45 than in T(-2) transects (Table 3). Thus, across corridors, light availability and litter depth both decreased with distance from corridor edge.

DISCUSSION

The presence of 17 exotic plant species along disturbance corridors at Grassy Hill is evidence that exotic plant species have recruited there. While only six species were found in our plots, four are highly invasive in Virginia mountain communities (i.e., *Ailanthus altissima*, *Ligustrum sinense*, *Lonicera japonica* and *Microstegium vimineum*; Virginia Department of Conservation and Recreation & Virginia Native Plant Society, 2003), as is *Cirsium arvense*, which was found along corridors outside of our plots. *Microstegium vimineum* in particular has been found to be highly invasive in Appalachian mountain forests, replacing most native ground vegetation within a few years of encroachment in areas where it establishes (Gibson et al., 2002). Given the goal of the VDCR Natural Heritage program to conserve natural communities, encroachment by *M. vimineum* and other exotics into important forest communities at the preserve could occur over time with potentially negative consequences for community integrity and native plant diversity.

Exotic encroachment beyond corridor edges was not extensive as of this study, however, since most exotic species were only prevalent in T(-2) transects. Furthermore, encroachment by *A. altissima*, the only species found at frequencies greater than 10% beyond T(-2) transects, was still significantly greater in T(-2) transects than in forest interior transects. These results are consistent with similar studies examining exotic invasion along disturbance corridors in low elevation habitats (Brothers & Spingarn, 1992; Tyser & Worley, 1992). The maximum exotic species richness and frequencies along roadside transects likely reflect recruitment success following accidental and purposeful human disturbance (Tyser & Worley, 1992). For example, vehicles carrying gravel or soil can accidentally introduce exotic seeds along roads, which can then germinate and colonize (Schmidt, 1989). Road plowing also aids exotic colonization via soil disruption, which is correlated with exotic establishment and population growth (Tyser & Key, 1988; Tyser & Worley, 1992). This may explain why total exotic richness was greatest in the gravel road plots in our study; this road was more recently disturbed by soil disruption than were the other corridors.

High *M. vimineum* frequencies along gravel road T(-2) transects, for example, likely reflect recent disturbance there, because extensive plowing was evident and extended to forest edges where grass frequency was highest. It is possible that *M. vimineum* seed was accidentally introduced in imported gravel and colonized disturbed soil alongside the gravel roadbed. Similarly, high *M. vimineum* frequencies in T(-2) transects along the paved road may reflect disturbance from shoulder maintenance that includes periodic plowing and gravel application. Furthermore, in mixed-use preserves such as Grassy Hill, recreational pursuits, such as horseback riding can introduce and assist exotic grass colonization through manure droppings and by soil trampling (Cole, 1987; Hall & Kuss, 1989). Horseback riding was documented at Grassy Hill before this study began (G. Turner, pers. obs.), especially on the gravel road, although it is now restricted. However, seed introduction and soil trampling from horses in the recent past on this road, as well as the logging road, which has experienced little other recent soil disturbance, may have assisted *M. vimineum* colonization.

Other exotic species, like *L. sinense* and a *Crataegus* species, which are only present in one plot along the gravel road, probably recruited from seeds dispersed from plants found at homes located near this road. The presence of species along corridors, outside of plots, such as *Cirsium* species, *Dactylis glomerata*, *Festuca arundinacea*, and *Melilotus alba* may reflect their escape from local pastures, which are located along the paved road less than 1.6 km west of the preserve. Conversely, *Coronilla varia and F. arundinacea*, common along the paved road, are present due to purposeful seeding by the Virginia Department of Transportation (C. B. Reynolds, Virginia Department of Transportation; pers. comm.) for erosion control, a common practice documented as a cause of exotic introduction (Tyser & Worley, 1992).

Although factors such as human soil disturbance and seed dispersal may have favored exotic recruitment on corridor edges at Grassy Hill, low encroachment into the forest interior by *C. varia* and most of the other exotic species likely reflects unfavorable environmental conditions, such as shade, that restrict invasion. For example, growth of *C. varia* is generally inhibited by high shade (National Biological Information Infrastructure & Invasive Species Specialist Group, 2005), a condition found across most transects in this study. However, the other exotic species found in our plots (except *A. altissima*), are relatively shade tolerant, and *M. vimineum* is a moderately shade tolerant plant (Barden, 1987; Cole & Weltzin, 2005; National

Biological Information Infrastructure & Invasive Species Specialist Group, 2005) whose establishment is restricted only by dense midstory canopy. Thus, other factors, perhaps including leaf litter, are likely restricting encroachment by these species.

We found a large increase in mean leaf litter depth from the T(-2) transects (0.9 cm) to the T2 transects (3.9 cm), and a further increase in depth into the forest interior (Table 3). It is possible that the deeper leaf litter found beyond corridor edges acts as a barrier to exotic encroachment for most of the species that we documented, because many exotics need bare soil for successful establishment (Harper, 1977). Perhaps other soil factors restrict exotic encroachment. For example, *M. vimineum*, prefers mesic soils (Barden, 1987; National Biological Information Infrastructure & Invasive Species Specialist Group, 2005) such as those found along corridor edges where water can pool in depressions, and may be restricted by lower soil moisture conditions that may be found in forest interiors. It is also possible that exotic invasion into forest interiors in this study was restricted by low disturbance in those habitats, which has been suggested as a factor restricting exotics (Brothers & Spingarn, 1992).

Finally, and perhaps most interesting, was the widespread encroachment of *A. altissima* into forest interiors, even though it was significantly greater in T(-2) transects compared to forest interior transects. As the only exotic species found beyond T2 transects, its distribution follows models of exotic invasion (Rejmanék, 1989; Rejmanék & Richardson, 1996), but based on its low frequencies in interior transects, its diffusion is minor. *Ailanthus altissima* may be a more successful invader of forest interiors than the other exotic species found in our study plots because of its prolific seed set (Virginia Department of Conservation and Recreation & Virginia Native Plant Society, 1999), airborne seed dispersal, and shade tolerance plasticity (Kowarik, 1995). In fact, *A. altissima* saplings found in T20 and T45 transects along the logging road were growing in highly shaded rock outcrops far from canopy trees that likely serve as seed sources.

CONCLUSIONS

Results from this study indicate that exotic plant species occur along disturbance corridors at Grassy Hill, but that encroachment off of corridors into the preserve's intact forest communities was not extensive, probably due to high shade and deep leaf litter found in forest interiors. While a lack of exotic species invasion may be good news in terms of managing closed-canopy forest communities, long-term management practices including modification of some closed-canopy stands in order to restore open woodland and grassland habitats, for example, might be considered with caution, since these methods could potentially promote recruitment into "opened" stands by exotic species currently found only along preserve corridors.

Proposed harvesting methods such as canopy thinning, for example, used to reduce forest stand density and promote open woodland habitats, could promote recruitment by desired native woodland and grassland species. However, this method has also been shown to promote exotic recruitment (Bartuska 1994; Cook 1998). Proposed prescribed burning and fireline construction, meant to restore and maintain native grassland habitats, could also promote exotic invasion if a "targeted native restoration" seed bank is absent or reduced (Huebner 2003), which is likely at the preserve given its post-settlement alteration to closed-canopy forest for many years (Virginia Department of Conservation and Recreation, 2003). Therefore, thinning and burning to promote new open canopy habitats to assist native plant recruitment and diversity could inadvertently promote exotic recruitment as well, because exotic species already present along preserve corridors could colonize the mineral soils of prescribed burn areas and firelines. While restoring open woodlands and grasslands at the preserve is desirable, and could return some habitats to a semblance of pre-settlement conditions, it should be done so with plans to restrict exotics, especially if native recruitment is not initially successful.

In addition to monitoring exotics in areas targeted for open woodland restoration, monitoring and managing exotics in important closed-canopy forest communities not targeted for restoration should also be made, since exotics found along preserve corridors could eventually invade into these forest communities. *Microstegium vimineum*, for example, has been shown in some studies to exhibit little forest invasion after establishing along forest edges, only to later invade forest interiors (Barden, 1987). Further, other shade tolerant exotics such as the herb *Alliaria petiolata* and the shrub *Euonymus alata*, both documented as "highly invasive" in Virginia mountains (Virginia Department of Conservation and Recreation & Virginia Native Plant Society, 2003) besides Grassy Hill, could potentially recruit into forest communities at the preserve. Ultimately, the management of native communities and the restoration of open woodland and grassland communities should incorporate careful monitoring of present and potential exotic species to ensure that they do not threaten restoration and long-term management of natural communities at this preserve.

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