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The effect of seeds of exotic species transported via horse dung on vegetation along trail corridors

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Abstract

It has been suggested that exotic species will colonize within forests more frequently by the continual introduction of seeds through horse dung deposited along trails. Whether or not these exotic species have the ability to spread into and establish in the forest interior has been disputed. To address this, horse dung and soil samples were collected from trails during Autumn 1994 and Summer 1995 from three areas in southern Illinois, USA open to recreational horse travel. In addition, deer dung samples were collected from each of the study areas. Vegetation data were collected from each of the trail systems as well as from a trail along which horse travel was prohibited. The density of vascular plants in 0.25 m^2 quadrats placed at varying distances from the trail center to 5 m into the forest interior were recorded. Finally, dung samples were placed in situ along horse trails at one site to examine seedling germination in natural conditions. While 23 exotic species germinated from samples of horse dung placed out in a greenhouse, only one of these exotic species was also found in trail plots (*Kummerowia striata*). Similarly, while there were empirically more exotic species found along the trails allowing horse travel than there were on the trail lacking horse travel, the relative importance of those species was negligible along both trails. These results suggest that the emigration of exotic species via horse dung does not pose an immediate threat to the plant communities adjacent to trails in these forest systems. Nevertheless, the large number of exotic species in horse dung reflects the constant threat to any system from these species. Care must be taken, when allowing horseback use in areas, to anticipate invasion by exotic species from horse dung

Introduction

A community dominated by native vegetation is considered relatively desirable, or ‘healthy’ (Noss 1990). The primary concern with exotic, or non-native, species is their effect on this native vegetation. Exotic species often compete with native plant species for available resources, thus decreasing the number of native species and rendering the community ‘unhealthy’ (Mooney & Drake 1986; Meekins & McCarthy 1999; Davis et al. 2000). Williamson (1996) suggests that it is common for roughly 10% of non-native species to become established in a community and that 10% of those will become aggressively invasive species. Although Williamson’s (1996) ‘Tens Rule’ suggests that most invaders have little impact on communities, the cumulative effect of the unchecked spread of exotic species may be reduced heterogeneity and biological diversity (Mooney & Drake 1986; Soule 1990; Westman 1990).

Disturbance is a component of many natural plant communities (Pickett & White 1985; Holland & Olson 1989; Hobbs & Huenneke 1992). For example, fire greatly influences the species diversity and vegetative structure of both prairie (Kucera & Koelling 1964; Collins & Gibson 1990) and forest communities (Ohmann & Grigal 1981; Scheiner et al. 1988; Bartos et al. 1994). However, areas that experience frequent disturbance, particularly unnatural disturbance, are most susceptible to biological invasions (Elton 1958; Braithewaite et al. 1989; Binggeli 1996). All contemporary ecosystems are subject to some form of unnatural disturbance, therefore no system is free from the possibility of invasion by exotics (Hobbs & Huenneke 1992).

Horse travel is a source of frequent disturbance in many forest ecosystems. Horse trails normally contain a barren treadway and a trail edge community with both natural and exotic species; many of these trail edge species cannot survive within the forest interior (Bates 1935; Benninger-Truax 1992). The impact to trails and adjacent areas from erosion caused by horses and other users is also well documented (Burde & Renfro 1986; Hammit & Cole 1987; Wilson & Seney 1994). In addition to erosion, Bates (1935) suggests that horses also effect vegetation by grazing along and defecating on trails.

Studies of horse dung show that horses pass large numbers of seeds through their digestive tract. Harmon & Kiem (1934) fed horses seven different species of seeds and recovered 12.9% of those seeds in the resulting dung. Benninger (1989) reported 15 different plant species arising from horse manure in samples collected from the Rocky Mountain National Park, USA. In addition, Hammit & Cole (1987) state that horse manure is a major source for exotic seeds in wilderness recreation areas. Most seeds pass through a horse's digestive tract within 48 hours of consumption (Alexander 1946; Vander Noot et al. 1967). However, Janzen (1981) showed that guanacaste seeds (*Enterolobium cyclocarpun*) may remain viable in the horses' digestive tract for up to two months, and deduced that horses could contribute to establishing local as well as distant populations.

Dung can be a source of viable seed for taxa not otherwise present in a community. The role of herbivores in dispersing seeds is well established (Ridley 1930; Harmon & Kiem 1934; Heady 1954; Janzen 1982; Fenner 1985; Hammit & Cole 1987): seeds can be spread from one location to another by attachment to the body of animals (epizoochory) or by being ingested and later excreted (endozoochory). In some cases, the seed coat of seeds moving through the digestive system of herbivores may become scarified, enhancing germination (e.g., legumes). Many native herbivores such as deer (Heady 1954; Gonzalez-Spinosa & Quintana-Ascencio 1986), wild boar (Middleton & Mason 1992), and emus (Brunner et al. 1976), have proven effective seed dispersers. In addition, stock animals such as cattle (McCully 1951; Harper 1977; Janzen 1982; Welch 1985), sheep (Harmon & Kiem 1934; Heady 1954; Piggin 1978), and pigs (Harmon & Kiem 1934) have all been shown to pass viable seeds through their intestinal tract.

The fear that exotic species may be spread into pristine or relatively undisturbed natural areas via the dung from recreational horse travel has led to an acute debate between environmental groups and equestrian groups. Natural Areas have been established by federal agencies (wilderness or scientific areas) and state bureaus (nature preserves or reserves) to protect high quality natural communities. In some federal areas, multiple use, including recreation, is allowed. Recreation and preservation are not always compatible (Cole 1993).

Land owners, land managers, and environmentalists in southern Illinois are concerned about exotic seed dispersal via horse dung (Faulkner 1993; Blackorby 1994a,b, Land 1994). The Shawnee National Forest contains over 1000 km of horse trails (Shawnee National Forest 1992) as well as a number of exotic plant species. Among the aggressive exotics present in the Shawnee National Forest are Japanese honeysuckle (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellata*, kudzu-vine (*Pueraria lobata*, and sweet clover (*Melilotus* spp.) (Evans 1981). Some agencies, such as the Illinois Nature Preserve Commission (INPC) and environmental groups like the Illinois Native Plant Society (INPS), expect land managers to primarily concern themselves with the preservation of 'natural' conditions, and believe that natural areas are threatened by horse travel (Faulkner 1993). Conversely, The Illinois Federation of Outdoor Recreation (IFOR), an equestrian group, feels that natural areas should continue to be multiple use lands, available for recreational users (Blackorby 1994a). IFOR also believes that suggestions that horses are responsible for the influx of exotic species are unsupported.

This research is designed to determine whether there is a relationship between the spread of exotic species into forest systems and recreational horse riding: (1) Does horse dung transport seeds of exotic species, (2) Can seeds transported via horse dung germinate *in situ*? (3) Can seedlings emerging from horse dung alter the vegetative composition on or around trails?

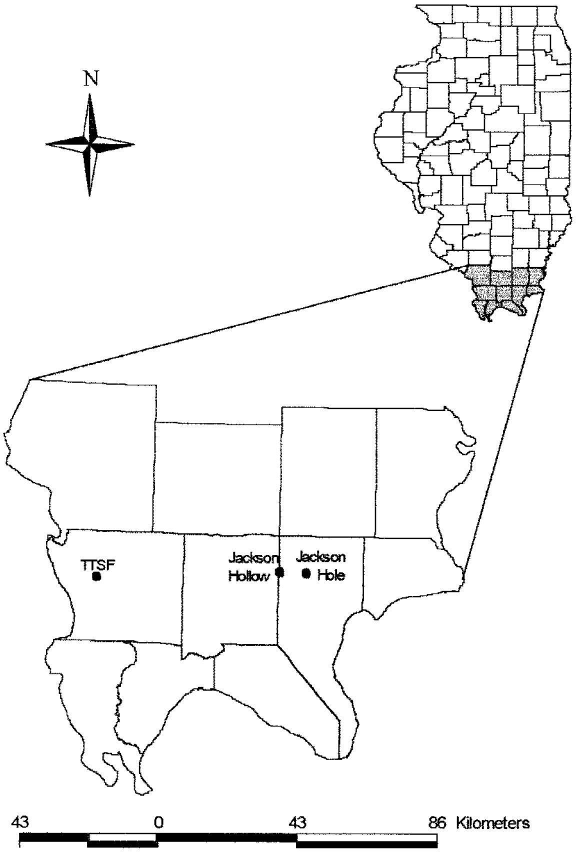

Figure 1. Location of the three study sites for the study of seed dispersal along horse trails in southern Illinois. A fourth trail that was free from horse travel was studied as TTSF (Trail of Tears State Forest).

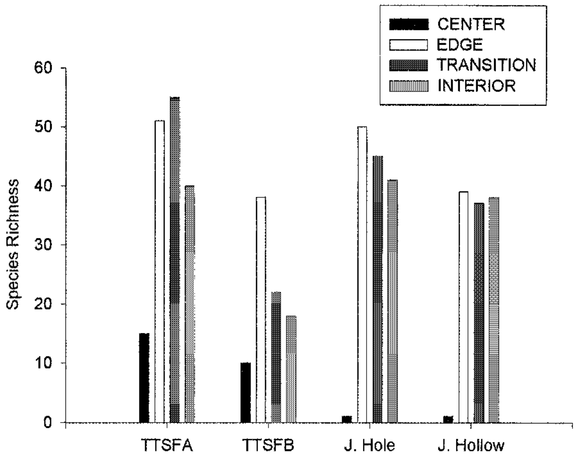

Figure 2. Total number of species at each of the four trail systems. (TTSF-A = trails subject to horse travel at Trail of Tears State Forest, TTSF-B = trails free from horse travel at Trail of Tears State Forest, J. Hole = Jackson Hole, J. Hollow = Jackson Hollow).

Materials and methods

Study sites

This study was conducted in three forest areas in southern Illinois, USA; Trail of Tears State Forest, Jackson Hole Ecological Area, and Jackson Hollow Ecological Area (Figure 1). In all, three horse trails and one hiking trail were examined. Unfortunately, the Jackson Hole and Jackson Hollow Ecological Areas did not contain trails restricting horse travel. Nevertheless, the hiking trail at Trail of Tears State Forest was incorporated into this study to allow us to compare and contrast hiking trails with horse trials.

The Trail of Tears State Forest (TTSF), located in west-central Union County, Illinois, comprises 2070 ha. There are approximately 29 km of horse trails in addition to hiking trails. The forest, located in the southern section of the Ozark Natural Division, is on the eastern edge of the Salem Plateau (Leighton et al. 1948). Purchased by the State of Illinois in 1929, Trail of Tears State Forest is managed by the Illinois Department of Natural Resources. Ninety percent of the forest is Oak-Hickory forest, while the remaining 10% is pine plantations (Anonymous 1972). Two trail systems were studied at TTSF, one which is open to horse travel (TTSF-A) and one in which horse travel is prohibited (TTSF-B). Horse trails receive light to moderate use at TTSF and are open from May 1 until the second weekend in November (K.A. West, pers. commun.).

Jackson Hole Ecological Area (1942 ha) and Jackson Hollow Ecological Area (116 ha) are located within the Greater Shawnee Hills Section of the Shawnee Hills Natural Division (Leighton et al. 1948; Schwegman et al. 1973; Stritch 1982). These areas are dominated by mesic oak-hickory forest, although much of the forest on Wellston-Berk soils has succeeded to beech-maple. Horse trails at both Jackson Hole and Jackson Hollow receive heavy use and are open year round (Beth Shimp, personal communication).

Sampling

To determine the dominant flora found along horse trails, 100 sample sites were located randomly along each of the three trail system (TTSF-A, Jackson Hole, Jackson Hollow). In addition, to determine the difference between trails subject to and trails free from horse travel, 100 sample sites were placed out on trails at Trail of Tears State Forest (TTSF-B) that were free from horse travel. To attain 100 sample sites, five transects, containing 20 sample sites each, were placed on each trail system. The 20 sample sites were placed out along the trail in 5 m intervals. All transects were randomly located by placing a numbered grid over a map of the study site and picking and x- and y-coordinate from a random number table. When this random point did not fall directly onto the trail, the transect was placed at the location on the trail closest to this point. The determination of the direction that the 20 sample sites were placed from the original random location and which side of the trail the transect was placed were determined by a coin toss. Sample sites were comprised of a series of four 0.5 × 1 m plots oriented perpendicular to the trail. The first plot was placed in the center of the of the trail (CENTER), the second was placed adjacent to the edge of the trail (EDGE), the third was placed 1 m from the trail center into the forest (TRANSITION), and the fourth plot was placed 5 m into the forest interior (INTERIOR). Density of all plant species less than one meter in height was recorded for each plot during summer 1995. Nomenclature and determination of whether or not a species was exotic to the sites followed Mohlenbrock (1986).

To determine the germinable seed bank in horse dung, 40 dung samples (400 ml each) were collected from each TTSF-A, Jackson Hole, and Jackson Hollow during Summer (June and July) 1995. TTSF-A samples were supplemented with collections from the nearby Black Diamond Ranch, located approximately 1 km from TTSF-A, with direct trail connections onto the TTSF horse trail system. Forty dung samples were also collected during Autumn (August and September) 1994 from TTSF-A. All dung samples collected in the field (both summer and autumn samples) were approximately 0–2 days old. Soil samples were taken from each of the three trail systems adjacent to each summer dung sample in the center of the trail to a depth of approximately 5 cm. In addition, 22 deer dung samples were collected during Summer (June and July) 1995 from the three study sites (5 from TTSF-A, 10 from Jackson Hole, and 7 from Jackson Hollow).

To identify the germinable seeds in the dung and soil, each sample was spread evenly over vermiculite in a 12.7 × 17.8 cm tray. The trays were then placed in the greenhouse. Seedlings germinating in the greenhouse trays from Autumn 1994 were identified and recorded until May 1995, while seedlings germinating from greenhouse trays from Summer 1995 were identified and recorded until November 1995. Seedlings were removed from the trays upon identification; some were preserved as voucher specimens. Some species with dormancy-breaking requirements (i.e., cold, scarification, etc.) may have escaped our screening process.

To quantify the seedlings arising in situ, five grids, each consisting of 32 plots, were placed along the horse trails at TTSF-A. The placement of grids used the same randomization method used to locate transects along the trail. Each of the plots were 12.7 × 17.8 cm, corresponding to the size of the greenhouse trays. Four hundred ml of horse dung was spread evenly over 80 of the 160 plots. Forty of those 80 treated plots received horse dung collected from TTSF-A during August and September of 1994, while the other 40 were treated with horse dung collected from TTSF-A during June and July of 1995. The remaining 80 plots in each grid remained untreated. Each of the five grids contained 8 plots treated with dung collected in the fall, 8 plots treated with dung collected in the summer, and 16 untreated plots. All treatments were randomly placed within each grid. Stem densities of all herbaceous species were recorded monthly in all plots during Autumn 1994 (August–November) and 1995 (March–November).

Data analysis

Normality of all data sets was tested using SigmaStat 2.0 (Jandel Corporation, San Rafael, CA). In most cases, non-parametric statistics were used to analyze the data in this study because of their highly non-normal distribution. Absolute and relative densities of all species were calculated for each data set. Relative density was calculated by dividing the density of each species by the total density of all species in each respective data set.

Detrended Correspondence Analysis (DCA: Hill 1979; Hill & Gauch 1980) was used to describe the species composition at each of the trail sites. The DCA was conducted by detrending via 26 segments using CANOCO for Windows Version 4.02. For each plot, distance from trail was assigned a rank of 1 (CENTER), 2 (EDGE), 3 (TRANSITION), or 4 (INTERIOR). These ranks were then compared with sample scores along the first DCA axis using a one-way Kruskal-Wallace Analysis of Variance (ANOVA) on Ranks, followed by a Dunn's Test for all pairwise comparisons, to see if species composition in trail sites varied with distance from trail.

An ANOVA on Ranks extended for factorial designs (Zar 1998), followed by a Tukey Test for multiple comparisons, was employed to determine if stem density values at different distance differed between trails subject to horse travel and trails free from horse travel at Trail of Tears State Forest (TTSF-A and TTSF-B). All ANOVAs were calculated using SigmaStat for Windows Version 2.0 (Jandel corporation, San Rafael, CA).

The RAREFRAC procedure from the Statistical Ecology software package (Ludwig & Reynolds 1988) was used to calculate rarefraction curves on horse dung and soil samples in the greenhouse germination study (Autumn, $n = 40$; Summer, $n = 120$, respectively) and field grid experiment ($n = 40$). Rarefraction analyses are used to create richness curves which illustrate the expected number of species over an array of theoretical sample sizes (Simberloff 1978; Simberloff 1979; Gotelli & Graves 1996). *Juncus tenuis* was excluded from the rarefraction analyses on the summer horse dung samples because of its overwhelming dominance (>90% relative density) in those plots.

Mann–Whitney Rank Sum Tests were used to determine if field grids treated with horse dung had significantly different stem density values than untreated field grids.

Results

Trail vegetation

The Kruskal-Wallace Analysis of Variance (ANOVA) on Ranks showed that the principal gradient of vegetation composition from the Detrended Correspondence Analysis (DCA) (eigenvalue = 0.679; percentage variance of species data = 3.8) was related to distance from the trail center ($H = 120.777$, df = 3 $p < 0.001$). A Dunn's Test on all pairwise comparisons further showed that species composition on all four trial distances were significantly different ($p < 0.05$), with the exception of the CENTER and EDGE positions ($Q = 2.559$, $p > 0.05$). Indeed, several species on the four trail systems were identified only at one or two distances; e.g., the exotic *Poa pratensis* was limited to the edge and transition plots. Species richness was always highest in the one of two plots adjacent to the trails (EDGE and TRANSITION), while the CENTER plot maintained the lowest species richness values at all sites (Figure 2). The density of graminoids, as well as exotic species, was consistently higher near the trail than in the forest interior, whereas the density of vines was lower (Figures 3a–d). Total relative density of exotic species found on the trail systems was low (TTSF-A = 4.15%; TTSF-B = 1.23%; Jackson Hole = 0.65%; Jackson Hollow = 1.06%). In all 1600 trail plots, 5 exotic species were identified on the four trail systems (Table 1). In addition, an ANOVA on Ranks extended for factorial designs showed that overall stem density values at Trail of Tears State Forest were significantly different ($F = 5.861$, df = 3, $p = 0.003$) between trails subject to (TTSF-A, 34.25 stems m^{-2}) and trails free from horse travel (TTSF-B, 26.35 stems m^{-2}). The multiple comparison Tukey test showed that all four distances exhibited significantly higher stem density values at TTSF-A (CENTER: q=2.905, $p < 0.05$; EDGE: $q = 10.814$, $p < 0.05$; TRANSITION: $q = 10.451$, $p < 0.05$; INTERIOR: $q = 8.379$, $p < 0.05$).

Greenhouse trays

A wide variety of species, many of which are exotic and not normally present in the forest interior, can survive passage through the horses' digestive tract: *Digitaria* spp., *Festuca arundinacea*, *Melilotus* spp., *Poa annua*, *Trifolium repens*, *Chenopodium ambrosioides*, *Eleusine indica*, *Kummerowia striata*, *Amaranthus spinosa*, and *Plantago* spp. are some of the exotic species that germinated abundantly from dung in the greenhouse (Appendix 1). *Kummerowia striata* and *Prunella vulgaris* were the only exotic species found both growing along the trail systems and germinating from the horse dung in the greenhouse trays. *Kummerowia striata* was found in horse dung samples collected during Autumn 1994 at TTSF-A and in horse dung samples collected during summer 1995 at Jackson Hole. However, along the four trail systems, it was found only at TTSF-A and with a relative density of 0.2%. Another exotic species, *P. vulgaris*, was also found in horse dung samples collected during summer 1995. Several native species also occurred frequently in greenhouse trays; e.g., *Juncus tenuis*, *Callitriche terrestris*, *Erigeron* spp., *Lobelia intraya*, and *Leersia virginica*.

Horse dung samples collected in the Autumn from TTSF-A and placed out in the greenhouse yielded a total of 43 identifiable (4 unidentifiable) taxa, 19 (44.2%) of which were exotic (Figure 4a). Soil samples collected from TTSF-A, Jackson Hole, and Jackson Hollow yielded 40, 25, and 38 species, re-

Table 1. Relative densities of exotic species identified in trail vegetation plots at each study site. Origin for each species is taken from Mohlenbrock (1986). (TTSF-A = trails subject to horse travel at Trail of Tears State Forest, TTSF-B = trails free from horse travel at Trail of Tears State Forest).

	Species	Origin	Density (stems m^{-2})	Rel. density (%)
TTSF-A	*Kummerowia striata*	Asia	0.10	0.2
	Lonicera japonica	Asia	0.85	2.2
	Poa pratensis	Europe and Asia	0.18	0.5
	Prunella vulgaris	Europe	0.28	0.7
	Rosa multiflora	China and Japan	0.03	0.6
TTSF-B	*Prunella vulgaris*	Europe	0.10	0.3
	Rosa multiflora	China and Japan	0.23	0.8
Jackson Hole	*Lonicera japonica*	Asia	0.08	0.3
	Prunella vulgaris	Europe	0.05	0.2
	Rosa multiflora	China & Japan	0.03	0.1
Jackson Hollow	*Lonicera japonica*	Asia	0.05	0.2
	Prunella vulgaris	Europe	0.13	0.6

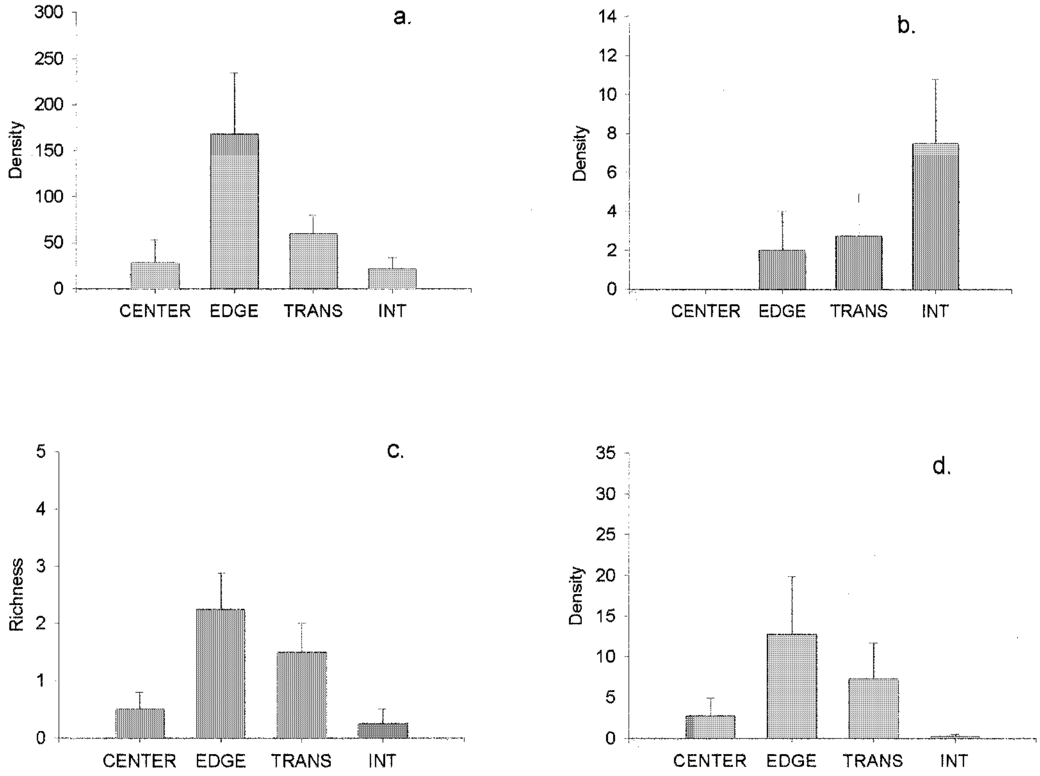

Figure 3. (a) Mean density (± 1) standard error) of graminoid taxa. (b) Mean density of vine taxa (excluding *Parthenocissus quinquefolia*). (c) Mean richness of exotic taxes (d) Mean density of exotic taxa identified at each distance from horse trails.

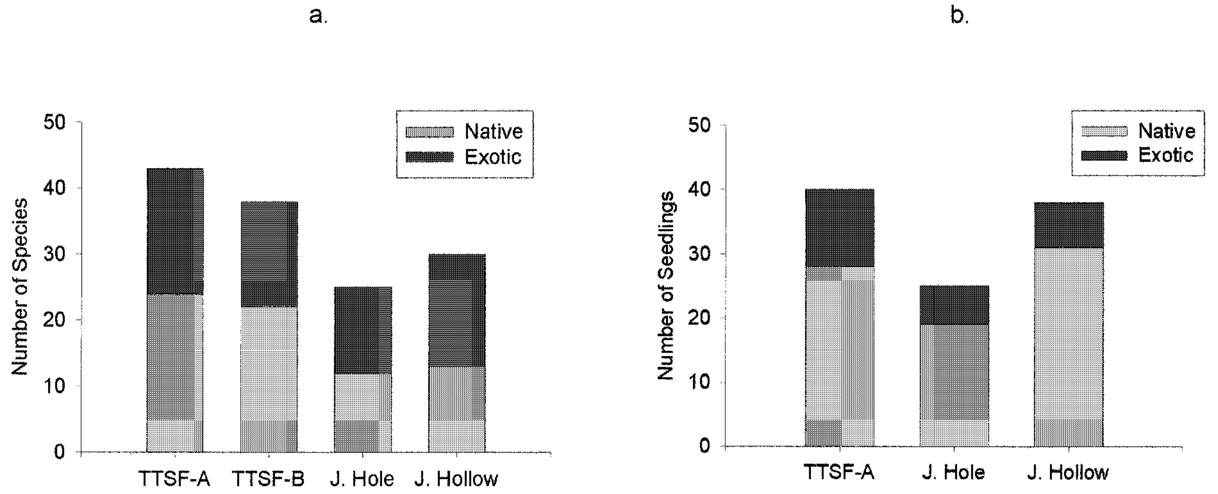

Figure 4. Richness of exotic versus native seedlings germinating from (a.) horse dung samples and (b.) soil samples. (TTSF-A = trails subject to horse travel at Trail of Tears State Forest, J. Hole = Jackson Hole, J. Hollow = Jackson Hollow).

spectively (Figure 4b). The number of unidentifiable species in each of the soil samples at each site was 3, 1, 2, respectively. Overall, the percentage of exotic species in the summer dung and soil samples ranged from 6.7 to 34.4%. The mean % exotic species, however, was similar between the dung (15%) and soil samples (13.9%) at the three study sites. Rarefraction analysis suggested estimated species richness was lowest in the autumn dung samples (11 species) and highest in summer dung samples (18 species) (Figure 5). Rarefraction analysis was also run on exotic species in the different samples, however exotic species richness was not high enough in all cases to yield interpretable rarefraction curves. Nevertheless, the richness of exotic species in comparison with native species was higher in fall and summer dung samples (40.4 and 26.5%, respectively) than they were in summer soil samples, trail plots, or field grids (15, 5.5, and 13.3%, respectively). In addition, 14 of the 17 exotic species found in the summer soil samples were also found in one or more horse dung samples. These results show that the exotic seeds transported via horse dung to contribute to and remain viable in the soil seed bank. However, of the 30 exotic species found in the dung and soil samples, *Kummerowia striata* was the only one found in trail survey plots; and it occurred only at TTSF-A with a relative density of only 0.1%.

Two species germinated from the 22 deer dung samples. Six individuals of *Rubus* sp. germinated out of three different greenhouse trays. A fourth tray contained one individual of *Ranunculus sceleratus*.

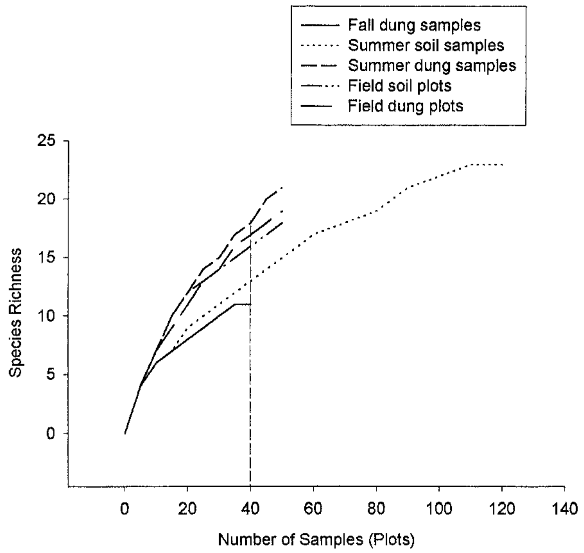

Figure 5. Results of rarefaction analysis examining the difference between species richness in fall and summer dung samples, summer soil samples and field soil and dung plots. The vertical dashed line indicates where valid comparisons of species richness can be made among samples and plots.

Field grids

Field grid plots treated with dung and untreated plots at TTSF-A yielded 25 and 20 species, respectively. Three of the species from treated plots and two species from untreated plots were exotic. The three exotic species that emerged from the treated plots were *Digitaria ischaemum* (relative density = 0.8%), *K. striata* (39.2%), and *Trifolium repens* (0.8%). The two exotic species emerging from the untreated plots were *K. striata* (9.0%) and *Poa pratensis* (3.3%). Of these species, only one individual of *K. striata* and two individuals of *P. pratensis* were found in quadrats placed along the trials at TTSF-A. These species were not found on trails at Jackson Hole or Jackson Hollow. Stem densities in treated and untreated plots were statistically indistinguishable ($T = 932$, $p = 0.807$). Rarefraction analysis showed both untreated grid plots and plots treated with horse dung resulted in relatively similar estimated species richness (16 and 17 species, respectively) (Figure 5).

Discussion

Vegetation along horse trails

Horse trails act as conduits for species dispersal through the forest matrix. Our study shows that the vegetation along horse trails is significantly related to the distance from the trail center. These findings support the results of Adkison & Jackson (1996); i.e., the density of graminoids is higher along trail corridors than in the forest interior, while the density of vines is lower. These trends in the vegetation along trail corridors are partially due to the fact that the perennating tissue in graminoids is located at ground level allowing some defense against trampling, but vines are not so protected. The one vine species that did not follow this trend was *Parthenocissus quinquefolia*: it can successfully regrow from severed portions of the shoot (Adkison & Jackson 1996). These findings are consistent with those of Benninger-Truax et al. (1992) who found that the number of exotic species is higher along trail corridors than in the forest interior. Compared to the forest interior, trails are sites of significantly higher soil density (Bates 1935; Weaver & Dale 1978), lower soil moisture (Dale & Weaver 1974; Liddle 1975), higher light intensity (Cole 1978; Hall & Kuss 1989), and greater trampling pressure (Dale & Weaver 1974; Hammit & Cole 1987). Trails are sites where compositional shifts in the vegetation are to be expected (Adkison & Jackson 1996).

The exotic species found along trails during this study are comparable to those reported in previous studies. We have found 5 exotic species at Trail of Tears State Forest (TTSF), three at Jackson Hole, and two at Jackson Hollow (Table 1). Evans' (1981) recorded each of the 5 exotic species at TTSF found along trails in this study as growing primarily in human-disturbed communities. In addition, he identified additional invasive exotics such as *Pueraria lobata* and *Melilotus alba*. Smith (1992) also noted the occurrence of both of the exotic species recorded in this study at Jackson Hollow. However, Stritch (1982) did not identify *Rosa multiflora* growing in any of the communities he sampled. While only comprising a relative density of 0.12% along trails at Jackson Hole in our study, the presence suggests that this species is currently invading these communities.

The occurrence of exotic species in our study, when compared to other studies, was relatively low. Of the eleven U.S. National Parks reviewed by Vitousek (1988), Sequoia-Kings Canyon had the lowest percentage of exotic species (6–9%), while the Hawaiian Volcanoes had the greatest percentage (64%). Of the four sites we studied, the percentage of exotic species ranged from 3.9% at Jackson Hollow to 6.9% at TTSF-A. Similarly, Shimp (1996) examined three Research Natural Areas in southern Illinois (Dennison Hollow, Panther Hollow, and Barker Bluff) and also found 26 exotic species (3.8% of total species richness). *Lonicera japonica*, *Rosa multiflora*, *Microstegium viminium*, and *Lespedeza cuneata* are exotic species found both in our study and Shimp's study. Both *L. japonica* and *R. multiflora* were found in the trail vegetation plots at sites in this study. In addition, although *M. viminium* and *L. cuneata* were not found in any of the plots in this study, they were observed growing elsewhere along the horse trails at Trail of Tears State Forest.

Horses as vectors for exotic seeds

A large number of germinable seeds representing a whole variety of native and exotic species are present in horse dung. Nevertheless, *Kummerowia striata* was the only exotic of seven species that was identified both in the dung samples and found growing on the horse trails. The other six species, *Callitriche terrestris*, *Dichanthelium dichotomum*, *Juncus tenuis*, *Leersia virginica*, *Lobelia intraya*, and *Verbena urticifolia* were not found in trails free from horse travel at TTSF. These species may have entered the trail system via horse dung. While only *K. striata* is an exotic, the presence of these seven species demonstrates that seeds transported via horse dung can become established on trail systems.

Deer dung samples produced many fewer germinating seeds than did the horse dung. *Rubus* sp. and *Ranunculus sceleratus* both germinated from samples of deer dung placed in the greenhouse. While other studies found the related congener, *Rubus procerus* (e.g., Brunner et al. 1974), to be dispersed by animals, the species that we found did not occur along the trails or germinate from horse dung or soil samples. This suggests that recruitment from deer dung may not influence vegetation composition along the trail corridors. Other studies have observed deer to be important dispersers of seed (Malo & Suarez 1998).

The field grids yielded similar results to the greenhouse trays. There was not a significant difference between the controls and the horse dung grids. Nevertheless, *Digitaria ischaemum*, *T. repens* and *K. striata* were found growing out of the horse dung treated plots. *Digitaria ischaemum* is an agricultural weed, whereas *T. repens* is widely planted in pastures. *Kummerowia striata* is also an agricultural weed, however, prior to the 1990's it was planted in some areas in southern Illinois (although not at our study sites) as a food source for quail and other wildlife. It was noted earlier that neither *D. ischaemum* nor *T. repens* were found in any of the trail plots, which suggests that they may not be colonizing and establishing along the trails despite germinating from the horse dung. Such species probably do not constitute a serious threat to the forest around the trail system. However, some exotic species from horse dung, though not found in the trail plots, may yet have the capacity to germinate *in situ*. Indeed, Kowarik (1995) points out that a long period of time often exists between importation and establishment of exotics, often over 100 years.

We have shown that a number of the native and exotic species, which can germinate *in situ*, are transported via horse dung. However, few of these species were found growing along the trails. This suggests that while erosion and soil compaction due to trampling are still considerable concerns along horse trails, the exotic species present in horse dung constitute only a limited threat to plant communities, at least in these forested ecosystems. Perhaps high light intensities required by these exotic species for germination and growth are not present within the forested trail corridor. This could contribute to the inability of many species to germinate *in situ*, become established, and persist in the trail corridor. Nevertheless, one must recognize the noxious potential of some exotic species (Bratton 1982). Their spread is possible within more open communities, some of which may be found within forests containing horse trails (e.g., glades, hill prairies, or barrens). For these reasons, it is important to try and reduce the number of potential invading plant species in a nature preserve. Care must be taken to balance the needs of the recreational community against the possibility of establishment of an invasive plant species.

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Appendix 1. Absolute (seedlings m^2) and relative densities of species identified in dung samples.

	TTSFA-Summer		TTSFA - Autumn		Jack. Hole		Jack. Hollow	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Exotic species								
Amaranthus spinosus	4.20	0.11	86.10	4.75	1.05	0.13	2.10	0.26
Avena sp.	11.55	0.29	0.00	0.00	1.05	0.13	4.20	0.53
Cardimine hirsuta	1.05	0.03	5.25	0.29	0.00	0.00	0.00	0.00
Cerastium glomeratum	2.10	0.05	0.00	0.00	1.05	0.13	2.10	0.26
Chenopodium ambrosioides	0.00	0.00	264.60	14.58	0.00	0.00	0.00	0.00
Daucus carota	0.00	0.00	1.05	0.06	0.00	0.00	0.00	0.00
Digitaria ischaemum	27.30	0.69	613.20	33.80	2.10	0.25	2.10	0.26
Digitaria sanguinalis	2.10	0.05	119.70	6.60	0.00	0.00	1.05	0.13
Eleusine indica	2.10	0.05	130.20	7.18	1.05	0.13	0.00	0.00
Festuca arundinacea	11.55	0.29	12.60	0.69	9.45	1.14	21.00	2.64
Kummerowia striata	0.00	0.00	191.10	10.53	1.05	0.13	0.00	0.00
Matricaria chamomilla	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.13
Melilotus sp.	15.75	0.40	1.05	0.06	25.20	3.04	13.65	1.71
Mollugo verticillatus	1.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Plantago lanceolata	1.05	0.03	5.25	0.29	0.00	0.00	0.00	0.00
Plantago major	0.00	0.00	89.25	4.92	0.00	0.00	0.00	0.00
Poa annua	30.45	0.77	2.10	0.12	9.45	1.14	48.30	6.06
Polygonum aviculare	0.00	0.00	1.05	0.06	0.00	0.00	0.00	0.00
Polygonum cespitosum	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.13
Polygonum convolvus	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.13
Portulaca oleracea	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.13
Prunella vulgaris	0.00	0.00	0.00	0.00	1.05	0.13	0.00	0.00
Rumex crispus	1.05	0.03	4.20	0.23	0.00	0.00	5.25	0.66
Rumex obtusifolius	1.05	0.03	0.00	0.00	2.10	0.25	3.15	0.40
Taraxacum officinale	0.00	0.00	1.05	0.06	0.00	0.00	1.05	0.13
Trifolium pratense	5.25	0.29	0.00	0.00	0.00	0.00	0.00	0.00
Trifolium repens	118.65	3.02	16.80	0.93	35.70	4.31	77.70	9.75
Verbascum thapsus	0.00	0.00	0.00	0.00	1.05	0.13	1.05	0.13
Veronica perigrina	30.45	0.77	2.10	0.12	1.05	0.13	4.20	0.53
Native species								
Agrimonia sp.	0.00	0.00	1.05	0.06	0.00	0.00	0.00	0.00
Ambrosia artemisiifolia	0.00	0.00	2.10	0.12	0.00	0.00	0.00	0.00
Aster pilosus	0.00	0.00	1.05	0.06	0.00	0.00	0.00	0.00
Boehmeria cylindrica	0.00	0.00	4.20	0.23	0.00	0.00	0.00	0.00
Bromus sp.	1.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Callitriche heterophylla	0.00	0.00	3.15	0.17	0.00	0.00	1.05	0.13
Carex blanda	0.00	0.00	0.00	0.00	0.00	0.00	7.35	0.92
Carex cephalophora	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.13
Carex spp.	2.10	0.05	0.00	0.00	1.05	0.13	3.15	0.40
Cyperus ovularis	0.00	0.00	2.10	0.12	0.00	0.00	0.00	0.00
Dichanthelium boscii	0.00	0.00	10.50	0.58	0.00	0.00	0.00	0.00
Dichanthelium dichotomum	0.00	0.00	2.10	0.12	0.00	0.00	1.05	0.13
Eclipta prostrata	0.00	0.00	4.20	0.23	0.00	0.00	0.00	0.00
Eleocharis obtusa	2.10	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Erigeron anuus	0.00	0.00	6.30	0.35	0.00	0.00	0.00	0.00
Erigeron philadelphicus	3.15	0.08	0.00	0.00	0.00	0.00	0.00	0.00
Erigeron spp.	1.05	0.03	19.95	1.10	0.00	0.00	0.00	0.00
Erigeron strigosus	0.00	0.00	1.05	0.06	0.00	0.00	0.00	0.00
Iva annua	0.00	0.00	1.05	0.06	0.00	0.00	0.00	0.00

Appendix 1. Continued.

	TTSFA-Summer		TTSFA - Autumn		Jack. Hole		Jack. Hollow	
	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.	Abs.	Rel.
Juncus marginatus	0.00	0.00	0.00	0.00	1.05	0.13	0.00	0.00
Juncus tenuis	3593.10	91.35	152.25	8.39	642.6	77.57	535.50	67.19
Leersia virginica	2.10	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Lepidium virginicum	2.10	0.05	0.00	0.00	0.00	0.00	1.05	0.13
Leucospora multifida	0.00	0.00	0.00	0.00	1.05	0.13	0.00	0.00
Lindernia dubia	0.00	0.00	0.00	0.00	2.10	0.25	0.00	0.00
Lobelia inflata	0.00	0.00	1.05	0.06	2.10	0.25	0.00	0.00
Ludwigia altermifolia	0.00	0.00	0.00	0.00	0.00	0.00	1.05	0.13
Myosurus minimus	2.10	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Oxalis stricta	3.15	0.08	1.05	0.06	1.05	0.13	0.00	0.00
Panicum sp.	0.00	0.00	6.30	0.35	1.05	0.13	0.00	0.00
Penthorum sedoides	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.26
Pilea pumila	0.00	0.00	1.05	0.06	0.00	0.00	1.05	0.13
Plantago rugelii	0.00	0.00	1.05	0.06	0.00	0.00	0.00	0.00
Plantago virginica	11.55	0.29	0.00	0.00	0.00	0.00	5.25	0.66
Poa sp.	0.00	0.00	7.35	0.41	0.00	0.00	0.00	0.00
Ranunculus abortivus	4.20	0.11	0.00	0.00	0.00	0.00	0.00	0.00
Ranunculus sceleratus	28.35	0.72	0.00	0.00	2.10	0.25	46.20	5.80
Salix nigra	0.00	0.00	6.30	0.35	0.00	0.00	0.00	0.00
Senecio glabellus	1.05	0.03	0.00	0.00	1.05	0.13	0.00	0.00
Solidago canadensis	3.15	0.08	6.30	0.35	0.00	0.00	0.00	0.00
Solidago ulmifolia	1.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Verbena urticifolia	0.00	0.00	19.95	1.10	0.00	0.00	0.00	0.00
Veronica arvensis	8.40	0.21	1.05	0.06	0.00	0.00	0.00	0.00
Woodsia obtusa	0.00	0.00	0.00	0.00	80.85	9.76	0.00	0.00