The Impact of Hiking Trails on Invasive Shrub Species Dispersal in Temperate Deciduous Forests

Rachel Hoffman and Lindsey Sestak

Introduction

Invasive species are a concerning threat to native biodiversity. They present a significant impairment to global biodiversity, secondary only to habitat loss (Simberloff et al. 2013). Invasive species have been a decisive force in recent species extinctions, acting as a contributing factor for 54% and the sole factor of 21% of recent extinctions (Simberloff et al. 2013). Studies frequently discuss the impact invasive plants can have on the environment. For recent plant extinctions that can be attributed to a single cause, invasive species were responsible for 17% of those extinctions (Bellard et al. 2016).

Invasive species can have a negative impact on ecosystems for a myriad of reasons. Many invasive species are characterized by early germination, rapid growth and effective dispersal mechanisms (Holl 2020). These traits facilitate their ability to reproduce at rates that outpace their native counterparts and influence community composition and enable them to thrive in highly disturbed areas (Holl 2020).

Scientists are beginning to evaluate the effect of human infrastructure on invasive species dispersal. Many elements of human infrastructure often create a highly disturbed habitat that is ideal for the establishment of invasive plant species. For example, studies have found a higher abundance of invasive species along roads and within utility corridors than in the surrounding ecosystem (Tyser and Worley 1992; Flory and Clay 2006).

Recreational trails are another form of human infrastructure that encroach into undisturbed natural spaces. Studies have noted an increased abundance of invasive species at the beginning of these trails relative to surrounding areas (Weiss et al. 2016). The act of creating and maintaining trails often disturbs the vegetation directly surrounding the trail. As a result, there is growing concern that invasive species could disperse from the highly disturbed area at the trailhead to the microhabitat present at the trail edges (Bella 2011; Liedtke et al. 2020; Wells et al. 2012).

The objective of this study is to investigate and understand the interactions that can occur between hiking trails and invasive shrub species in order to prevent their spread in temperate deciduous forests. Several studies have analyzed the relationship between hiking trails and invasive species, but few have considered the ability of invasive species to diffuse along trails (Bella 2008; Liedtke et al. 2020; Wells et al. 2012). Additionally, very few studies have addressed the potential for invasive species to diffuse along trails within the context of temperate deciduous forest ecosystems. In this study, we analyzed the abundance of invasive shrub species at transects along several recreational trails in these ecosystems. We hypothesized that invasive shrub species have the potential to use the hiking trails as a means of dispersing deeper into temperate deciduous forests due to the edge habitats created by the trail. Therefore, we predicted to observe invasive shrubs at all measured distances along the trail, with a decrease in abundance as distance increases from the trailhead. We also expected to observe a higher abundance of invasive shrub species along the trail when compared to abundances 30 meters into the interior of the forest.

Methods

Site Selection

This study was conducted at three recreational trails in Southwest Virginia during October and November, 2021. The trails selected for this study met the following criteria. First, each trail was unpaved and predominantly utilized for hiking or mountain biking. Second, the trails possessed a single trailhead and limited connections to other trails to minimize dispersal from other sources. Third, each trail was located in an area that is dominated by temperate deciduous forest. The trails employed in this study were the Royale Trail of the Poverty Creek Trail System in Blacksburg (37.2792, -80.4839), Virginia, Ellett Valley Nature Trail in Blacksburg (37.1883, -80.3773), Virginia, and Rice Fields Shelter Trail in Narrows, Virginia (37.3663, -80.7484) as shown in Figure 1.

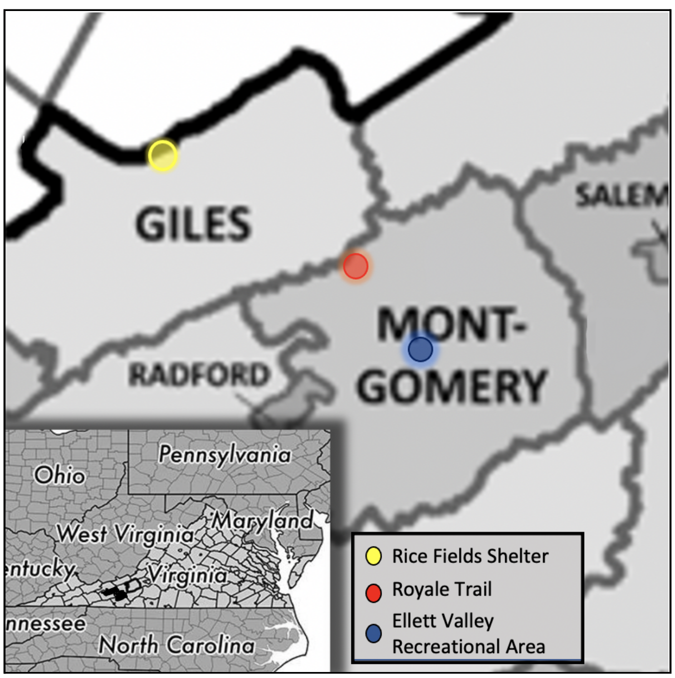

Figure 1. Geographical location of the study in Southwest Virginia. All sites were located within Giles County and Montgomery County. Each site location is depicted by a different color circle on the map.

Study Design

At each of the selected sites, we established transects at three benchmark distances along the trail: the trailhead, 0.32 kilometers and 0.64 kilometers (Figure 2). At each of the transects, we established two plots. Each plot was 15 meters in length and 1.5 meters in width. The "Trail Edge" plot was placed lengthwise directly along the edge of the trail. The "Forest Interior" plot was placed 30 meters from the boundary of the Trail Edge plot. Distance between the plots were measured with a 30 meter measuring tape. This ensured that the plots at each transect were parallel to one another, as illustrated in Figure 2. The plots were created by placing four stake flags at each corner of the transect after measuring out a 15 x 1.5 meter rectangle with the tape measure. Each stake flag was then connected with string to establish defined boundaries for the plot.

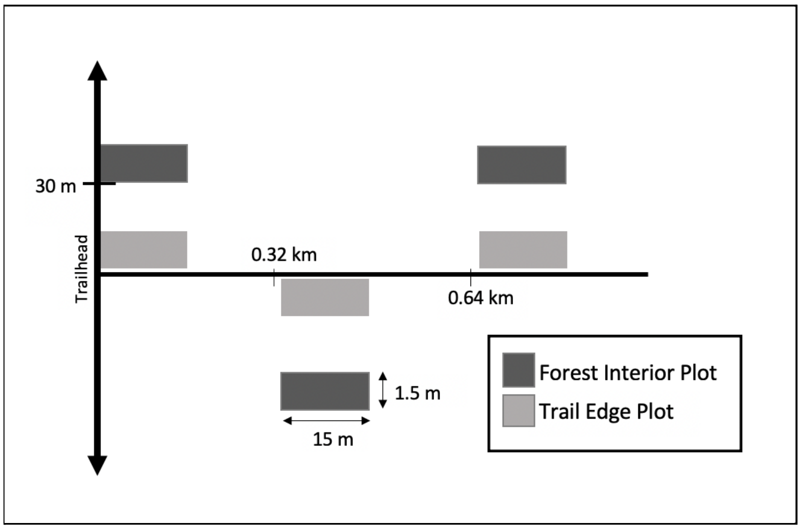

Figure 2. Example layout of transect methodology on a hiking trail.

We identified and recorded the abundance of all of the shrubs within each transect to a species level. We utilized iNaturalist software for an initial identification and confirmed this identification with the PLANTS database from the United States Department of Agriculture. We later classified each of the species we identified as "native" or "non-native" for further analysis (Le et al. 2018). During the time period of this study, many shrub species had already begun to lose their leaves due to the cold weather, therefore, making them unidentifiable. As a result, we were unable to identify 29 of the 604 individuals we recorded. When counting abundances, we defined an individual shrub as a group of stems that appeared to be connected to one another when examined under the leaf litter or when moved.

Statistical Analyses

To test the effects of hiking trails on invasive shrub abundance, we used a generalized linear mixed model with binomial distribution. Invasive species was the response variable, transect and plot were fixed effects and site was a random effect. Also, Non-metric multidimensional scaling (NMDS) was used to evaluate changes in shrub community composition along the trails and across the two plot types. A permutational multivariate analysis of variance (PERMANOVA) analysis was conducted to confirm each distance from the trailhead had a significant impact on the shrub community composition.

Results

A total of 17 different shrub species were observed across the plots, 7 of which were invasive species and 10 of which were native species. A variety of invasive shrubs were found at the trailhead transect at each of the selected sites. However, they were not always present in each subsequent transect or within both the Trail Edge and Forest Interior plots (Table 1). Ellett Valley is the only trail that contained invasive species at the final 0.64 km benchmark.

Date	Site	Distance (km)	Plot Type	Number of Invasive Shrubs	Number of Native Shrubs	Proportion of Invasive Shrubs
10-24-21	Royale	0	Edge	4	1	0.80
10-24-21	Royale	0	Interior	2	0	1
10-27-21	Royale	0.32	Edge	2	26	0.07
10-27-21	Royale	0.32	Interior	1	13	0.07
10-31-21	Royale	0.64	Edge	0	25	0
10-31-21	Royale	0.64	Interior	0	65	0
11-7-21	Ellett Valley	0	Edge	2	10	0.17
11-7-21	Ellett Valley	0	Interior	0	5	0
11-7-21	Ellett Valley	0.32	Edge	31	2	0.94
11-7-21	Ellett Valley	0.32	Interior	59	18	0.77
11/21/21	Ellett Valley	0.64	Edge	1	0	1
11-12-21	Ellett Valley	0.64	Interior	74	53	0.58
11-17-21	Rice Fields	0	Edge	0	12	0
11-17-21	Rice Fields	0	Interior	3	6	0.33
11-16-21	Rice Fields	0.32	Edge	0	49	0
11-16-21	Rice Fields	0.32	Interior	0	16	0
11-16-21	Rice Fields	0.64	Edge	0	43	0
11-16-21	Rice Fields	0.64	Interior	0	53	0

Table 1. Table of the proportion of invasive to native shrub species found at each plot type, distance from the trailhead and site.

We found there is a decrease in the proportion of invasive shrubs to native shrubs as there is an increase in distance from the trailhead to 0.64 km (Figure 3). The two regression lines for the plot types demonstrate that the Trail Edge plots and Forest Interior plots experience different relationships in regards to distance from the trailhead and the proportion of invasive shrub species present (Figure 3).

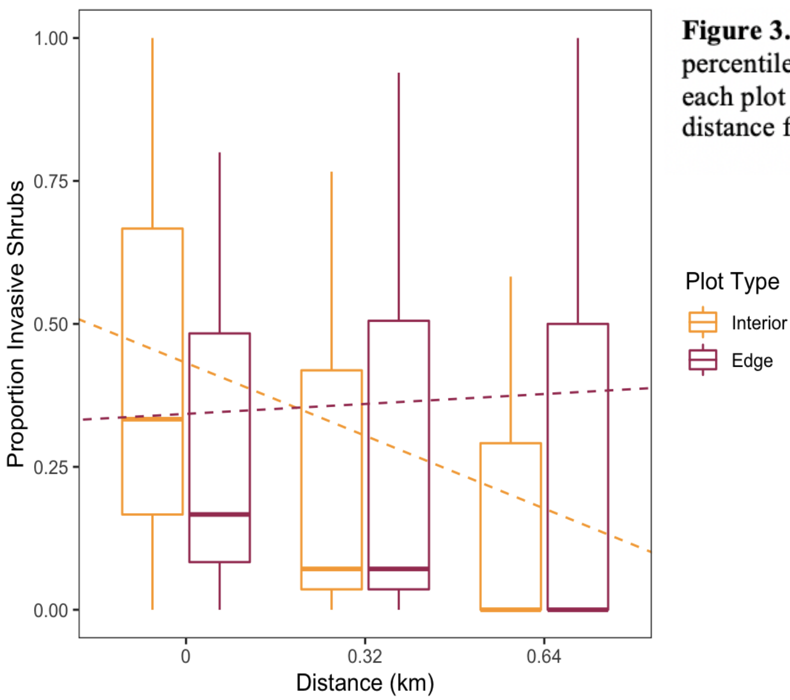

Figure 3. Boxes show the median, 25th and 75th percentiles for the proportion of invasive shrubs for each plot type (Forest Interior and Trail Edge) at each distance from the trailhead.

Our generalized linear mixed model suggested that the proportion of invasive shrubs was strongly impacted by distance from trailhead ($z = -3.29$, $p = 0.000998$), marginally impacted by proximity to edge ($z = -1.86$, $p = 0.0626$) and marginally impacted by the interaction of the distance from the trailhead and proximity to the edge ($z = 1.93$, $p = 0.0534$). Overall, the proportion of invasive shrubs decreased as distance from the trailhead increased. However, while distance from the trailhead had no significant effect on the proportion of invasives in the Trail Edge plots ($z = 0.388$, $p = 0.698$), there was a significant reduction in the invasives in the interior plots as distance from the trailhead increased ($z = -3.308$, $p = 0.000939$).

Figure 4 demonstrates there was a difference in shrub community composition between each distance from the trailhead due to the lack of overlap between each ellipses of the NMDS plot. A permutational multivariate analysis of variance (PERMANOVA) permanova analysis was conducted to confirm each distance from the trailhead had a significant impact on the observed shrub community composition ($p = 0.026$). Additionally, Figure 4 shows that there was no difference in shrub community composition when comparing proximity to the trail which is represented by the Forest Interior and Trail Edge plots ($p = 0.821$).

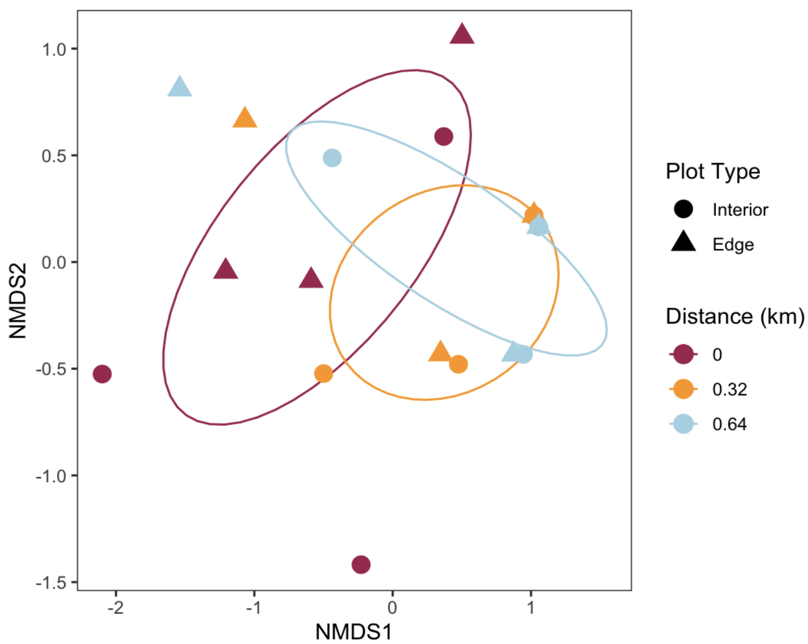

Figure 4. Non-metric multidimensional scaling (NMDS) analysis of the community composition of shrub species at each benchmark distance and plot type across all sites. As demonstrated, low overlap between ellipses and increased distance between points is equivalent to a lower similarity in shrub community composition.

Discussion

Hiking trails can play an important ecological role in the distribution of invasive species. The objective of our study was to determine if invasive species can use hiking trails as a means of dispersing deeper into temperate deciduous forest. The shrub distribution data indicated that the highest proportion of invasive species were present at the trailhead transect. The data suggested invasive species abundance decreased in the forest interior as distance increased from the trailhead and stayed relatively the same along the trail edge. Invasive shrub species abundances also, in most cases, stayed relatively constant between Trail Edge and Forest Interior plots. However, based on our NMDS analysis we found there is possibly lower shrub dispersal between each distance on the trail than originally expected. This is a strong indication that our data is not entirely in support of our hypothesis.

We initially predicted that the proportion of invasive shrub species would be present but decrease as distance from the trailhead or 0.0 km transect increased. Our results showed this was only true at the Ellett Valley site. The other two sites lost all invasive shrub species by the final benchmark distance of 0.64 km. We found that the trailhead had the highest abundance of invasive species. This increased proportion relative to the other transects could be attributed to their proximity to roads. Numerous studies have evaluated the ability of roads to serve as introduction mechanisms for invasive species (Tyser and Worley 2002; Flory and Clay 2006). All of our trailhead transects bordered or were in close proximity to moderately or frequently trafficked roads, the increased presence of invasive shrubs could be a result of dispersal from nearby roads. Overall, our data shows there was a decrease in invasive shrub abundance as distance from the trailhead increases. We speculate this could be attributed to a matter of time. Studies have shown many invasive plant species have an incubation or lag period where they experience slow population growth when spread to a new area (Larkin 2012). Therefore, these species could be capable of moving farther up the trail. It is possible they have not had the opportunity to disperse that far into the forest yet after being introduced at the trailheads of the sites. Information regarding the trail and plant history of each of our sites could be beneficial in making any concrete conclusions.

However, this observed decrease in invasive species abundance was more complicated than it first appeared. A decrease in invasive species abundance was only prevalent in the Forest Interior plots which display a negative relationship (Figure 3). The Trail Edge plots did not follow a similar trend. These plots actually depicted a slightly positive relationship. This means that the Forest Interior plots followed our original predictions while the Trail Edge plots did not. This could indicate stronger dispersal was occurring along the trail edge rather than in the forest interior.

Finally, in our initial predictions we expected to observe a higher abundance of invasive shrub species in plots along the trail edge when compared to plots 30 m into the forest. Foremost, we found the Trail Edge and Forest Interior plots demonstrated a difference in the distribution of invasive shrubs when compared with the plots at the trailhead. As mentioned previously, the trailhead had the highest abundance of invasive shrubs in both the Trail Edge and Forest Interior plots. However, contrary to what we expected to observe, there was a higher distribution of invasive shrubs in the Forest Interior plots than in the Trail Edge plots. At the second and third benchmark distances, we found there to be almost equal proportions of invasive shrub species in plots adjacent to the trail edge as well as 30 m into the forest interior. We believe this data has the potential to show dispersal is occurring from the edge of the trail into the interior of the forest.

The NMDS plot and permanova analysis provided valuable information regarding shrub community composition between each of the benchmark distances and plot types for each site that could help further explain the results we have collected. This plot demonstrates that there was a significant difference in shrub community composition between each distance benchmark of a trail ($p = 0.026$). These results were not in support of our hypothesis and indicated that lower levels of dispersal were occuring between each of the benchmark distances and each plot type than we initially predicted.

Based on the results of our study, hiking trails do not facilitate the spread of invasive shrub species into deciduous forest. However, it is important to address the limitations of our study. It was composed of three sites. It is nearly impossible to make conjectures about landscape level mechanisms using such limited data. In order to make accurate conclusions about the relationship between invasive species and hiking trails, we need more data.

However, these findings can be used to inform future conservation efforts. Our data indicated that the highest proportion of invasive species were found at the 0.0 km transect. These trailheads, which are often along roadsides, frequently provide suitable conditions for the establishment of invasive species (Weiss et al. 2016). This information is valuable to consider when determining the future efforts for the mitigation of invasive shrub species. Conservation efforts are often limited by available resources. Focusing on the removal of invasive species along trailheads, which are far more accessible than further up the trail, could help reduce the time, resources and work required for these efforts.

Literature Cited

Bella, E. M. 2011. Invasion prediction on Alaska trails: distribution, habitat, and trail use. Invasive Plant Science and Management 4:296–305.

Bellard, C., P. Cassey, and T. M. Blackburn. 2016. Alien species as a driver of recent extinctions. Biology Letters 12:20150623.

Flory, S. L., and K. Clay. 2006. Invasive shrub distribution varies with distance to roads and stand age in eastern deciduous forests in Indiana, USA. Plant Ecology 184:131–141.

Holl, K. 2020. Primer of Ecological Restoration. Island Press, Washington, D.C., USA.

Larkin, D. J. 2012. Lengths and correlates of lag phases in upper-Midwest plant invasions. Biological Invasions 14:827–838.

Le, C., K. Fukumori, T. Hosaka, S. Numata, M. Hashim, and T. Kosaki. 2018. The distribution of an invasive species, *Clidemia hirta* along roads and trails in Endau Rompin National Park, Malaysia. Tropical Conservation Science 11:1-9.

Liedtke, R., A. Barros, F. Essl, J. J. Lembrechts, R. E. M. Wedegärtner, A. Pauchard, and S. Dullinger. 2020. Hiking trails as conduits for the spread of non-native species in mountain areas. Biological Invasions 22:1121–1134.

Simberloff, D., J.-L. Martin, P. Genovesi, V. Maris, D. A. Wardle, J. Aronson, F. Courchamp, B. Galil, E. García-Berthou, M. Pascal, P. Pyšek, R. Sousa, E. Tabacchi, and M. Vilà. 2013. Impacts of biological invasions: what's what and the way forward. Trends in Ecology & Evolution 28:58–66.

Tyser, R.W., and C.A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (USA). Conservation Biology 6:253-262.

Weiss, F., T. J. Brummer, and G. Pufal. 2016. Mountain bikes as seed dispersers and their potential socio-ecological consequences. Journal of Environmental Management 181:326–332.

Wells, F. H., W. K. Lauenroth, and J. B. Bradford. 2012. Recreational trails as corridors for alien plants in the Rocky Mountains, USA. Western North American Naturalist 72:507–533.