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EFFECTS OF FOREST EDGE AND CANOPY COVER ON NON-WOODY PLANT SPECIES RICHNESS IN DECIDUOUS FORESTS

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ABSTRACT

The forest edge effect describes ecological changes at the boundary between forests and other habitats and how they influence species composition. This study investigates the spatial variation of plant species richness along a gradient from the edge of a forested area to its interior, measured at three different forested sites near Juniata College. We used transects to survey counts of non-woody plant species at systematically measured intervals (0 m, 10 m, 25 m, 50 m) starting at the forest edge and going inwards. We also recorded the canopy cover at each transect location. We assessed how species richness and composition change with increasing distance from the boundary. Results indicate a clear pattern of decreasing richness, with higher species richness in areas with less canopy cover near the forest edge and a gradual decline toward the interior where there is more canopy cover, likely due to changes in light availability, soil characteristics, and disturbance. These findings highlight the ecological importance of diverse forest edges and have implications for biodiversity conservation, particularly in fragmented landscapes.

Keywords: canopy cover, edge-effect, non-woody plants, species richness

INTRODUCTION

Recent decades have witnessed a growing interest in the dynamics of ecotones–transitional areas where two distinct ecosystems meet–as researchers seek to understand how environmental gradients shape biodiversity. Forest edges represent zones of marked change where light, moisture, wind, and nutrient availability fluctuate dramatically compared to the forest interior (Matlack 1993; Chen et al. 1999). Although much attention has been given to the woody species that dominate forest structure, non-woody plants, given their rapid responses to microenvironmental shifts, offer critical insights into how forest structure influences community assembly and ecosystem functioning (Brosofske et al. 2001).

Non-woody species, often overlooked in traditional forest inventories, provide essential functions such as nutrient cycling, soil stabilization, and early successional dynamics (Brosofske et al. 2001). Their distribution at forest edges versus interiors not only reflects inherent sensitivity to spatial microclimatic gradients but also underscores the broader implications for conservation and management. The interplay of abiotic stressors–such as increased light transmittance and temperature extremes–and biotic interactions at the edge creates both challenges and opportunities for these species, potentially leading to unique assemblages that differ markedly from those found deeper within the forest (Dormann et al. 2020).

This study aims to bridge the knowledge gap by examining non-woody plant species richness across a gradient from the forest edge to the interior. By employing systematic field surveys and advanced spatial analyses, we explore the hypothesis that the transition zone–the forest edge–harbors a higher diversity of non-woody species due to a combination of resource availability and disturbance-driven opportunities. Such insights are central not only for refining ecological theory on edge effects but also for

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informing practical strategies in conservation biology and forest management.

In what follows, we detail our rationale, methodological approach, and the underlying theoretical framework that positions non-woody plants as key indicators of ecological change. With global landscapes increasingly fragmented, understanding these patterns is more crucial than ever for crafting interventions that sustain biodiversity and ecosystem resilience.

FIELD SITES

We chose three separate areas to conduct our measurements. All three locations were deciduous forests located near Juniata College (Table 1). All three areas contained similar non-woody plant species. The sites were measured during various stages of yearly growth and weather conditions, due to the change of season throughout April.

Table 1. Sampling locations and details

Site	Transect	Direction	Lat	Long	Sample Date
Peace Chapel	1	180° S	40°30’21” N	77°59’36” W	4/8/25
Peace Chapel	2	194° S	40°30’20” N	77°59’32” W	4/15/25
Peace Chapel	3	54° NE	40°30’20” N	77°59’28” W	4/15/25
Gamelands	1	271° W	40°31’24” N	78°1’3” W	4/22/25
Gamelands	2	86° E	40°31’24” N	78°1’3” W	4/22/25
Gamelands	3	268° W	40°31’18” N	78°1’1” W	4/22/25
Field Station	1	113° SE	40°21’8” N	78°9’46” W	4/29/25
Field Station	2	100°E	40°21’8” N	78°9’46” W	4/29/25
Field Station	3	146° SE	40°21’60” N	78°8’44” W	4/29/25

METHODS AND MATERIALS

At each site, we selected transects based on reasonable accessibility. Sections of forest that were full of dense brush were avoided for safety reasons. All transects were located directly off a trail or road. At each transect, we used a measuring tape to measure 50 meters into the forest. Flags were placed at 0 m, 10 m, 25 m, and 50 m directly next to the measuring tape.1x1 meter quadrats were measured using each flag as the bottom left corner of the quadrat. Within each quadrat, the number of unique non-woody herbaceous species was counted to determine species richness in each quadrat. The app iNaturalist was used to help identify different species, using photos and recommended suggestions to determine the species of plants we saw and avoid counting a species twice. Canopy cover at each quadrat was collected using an app called Canopy Cover. This app uses a color gradient to estimate the total coverage based on a photo. Canopy Cover photos were taken from the middle of each quadrant facing straight upwards. All data was recorded in a field notebook before being input into an Excel file.

All statistical analysis was completed using jamovi computer software. All assumptions of normality and variance were met to complete an analysis of variance (ANOVA). All assumptions were met for linear regression.

RESULTS

Species richness declined with distance from the forest edge (Figure 1). A drop in the number of plant species was observed from the forest edge (0 m) compared to the interior points (Figure 1). The highest species counts were recorded at the forest edge (0 m), with a mean of 6.44 species, while the forest interior (50 m) exhibited the lowest counts, with a mean of 1.44 species (Table 1). A one-way ANOVA test revealed that plant species richness differed significantly across distances from the forest edge ($F = 12.7$, $p < 0.001$). Tukey’s post hoc tests showed that species richness was statistically significantly higher

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at the forest edge (0 m) compared to all interior distances: 10 m ($p = 0.004$), 25 m ($p < 0.001$), and 50 m ($p < 0.001$). Differences among the interior distances (10 m, 25 m, and 50 m) were not statistically significant ($p > 0.19$ in all cases), which indicates that the decline in richness occurred mostly between the forest edge and forest interior, rather than gradually across the interior.

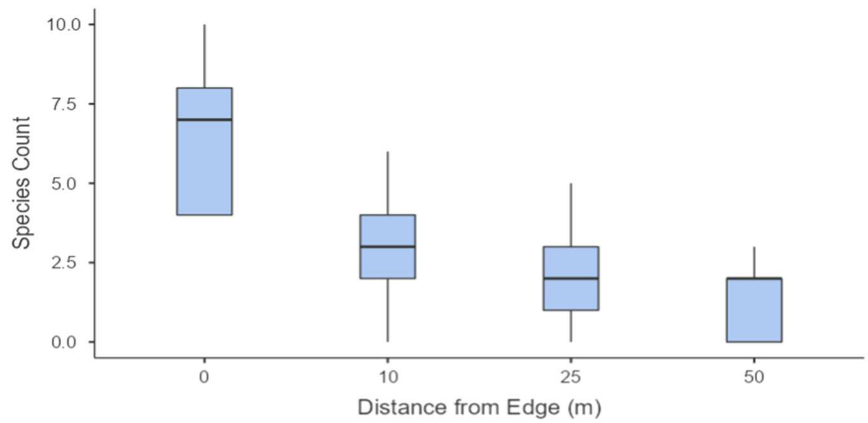

Figure 1. Box and whisker plots displaying the distributions of Species Count across each distance from the forest edge (n=9 for each distance).

Table 2. Summary statistics for Species Count across each distance (n=9).

Distance (m)	Mean	Median	SD	Min	Max
0	6.44	7	2.30	4	10
10	3.22	3	1.79	0	6
25	2.33	2	1.87	0	5
50	1.44	2	1.24	0	3

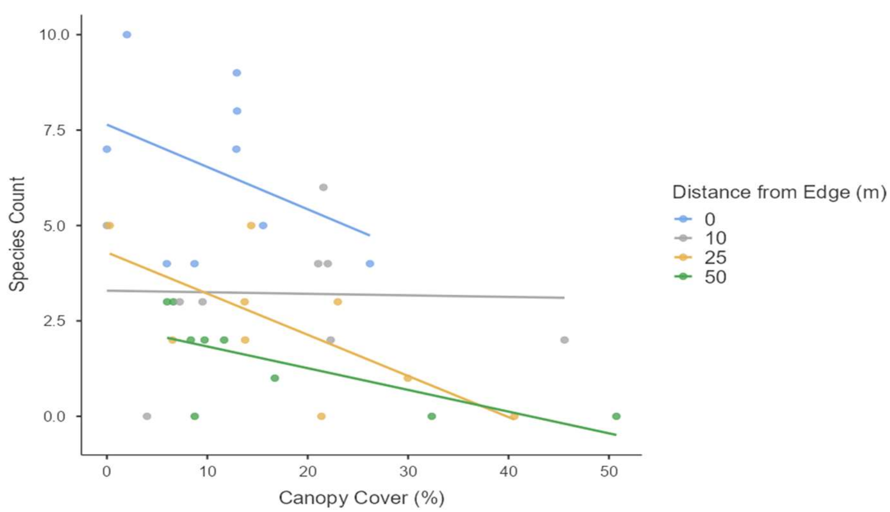

Figure 2. Relationship between plant species richness and canopy cover (%) at different distances from the forest edge (0 m, 10 m, 25 m, 50 m; n=9 for each distance). Lines represent linear trends within each distance group. Species richness declines more steeply with canopy cover at the forest edge (0 m) and at interior distances, with the strongest decline at 50 m.

A multiple linear regression was also conducted to see the effects of both canopy cover and distance from the forest edge on species richness. The model was statistically significant and explained 61.5% of the variation in the species count ($R^2 = 0.615$,

$p < 0.001$). Canopy cover had a significant negative relationship with species richness ($p = 0.022$). The linear regression model indicated that every 1% increase in canopy cover was associated with a decrease of approximately 0.06 species. Relative to the forest edge (0 m), species richness decreased by 2.86 species at 10 m ($p = 0.002$), 3.68 species at 25 m ($p < 0.001$), and 4.65 species at 50 m ($p < 0.001$). These findings demonstrate a strong edge effect, with species richness highest at the forest margin and declining sharply with distance into the interior, influenced by both distance and increasing canopy cover.

DISCUSSION

Our results show a clear decline in plant species richness with increasing distance from the forest edge, with the highest richness observed at 0 m and the lowest at 50 m. This pattern is consistent with the "edge effect," where conditions at the boundary between forest and more open areas create favorable environments for a wider variety of plant species (Driscoll et al. 2013). The ANOVA indicated a significant effect of distance from edge on species count where the forest edge had significantly fewer species compared to interior points ($p < 0.001$). There were no significant differences in species count between any of the interior distances. This result could be explained due to a lack of data points or sampling bias, since transects were selected based on our ability to safely access them. We avoided making transects through thick, impassable brush, but they may have potentially changed our results.

These results were further supported by our linear regression model, which explained 61.5% of the variation in species count. In this model, both canopy cover and distance from the edge were significant predictors, with species count decreasing with increasing canopy cover ($p = 0.022$). It should be noted that canopy cover readings were taken over the course of April, with us visiting each site on a different date (Table 1). There was much less foliation at the beginning of our sampling compared to the end, so this may have skewed our canopy cover values.

Our findings agree with previous research showing higher species richness at forest edges than interiors. A global analysis found that forest edges support greater biodiversity, particularly at higher latitudes, due to increased light availability and microclimatic variability (Pfeifer et al. 2017). From an ecological standpoint, forest edges are typically characterized by greater light penetration, higher temperatures, and increased disturbance, all of which can promote colonization and growth of a diverse array of plant species (Harper et al. 2005).

In conclusion, our study adds to the literature that forest edges promote greater species richness. These results highlight the need to consider edge effects in forest conservation and management, especially in fragmented landscapes where edge habitats are becoming increasingly common.

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LITERATURE CITED

Brosofske, K. D., J. Chen, and T. R. Crow. 2001. Understory vegetation and site factors: implications for a managed Wisconsin landscape. Forest Ecology and Management **146**: 75–87.

Chen, J., S. C. Saunders, T. R. Crow, R. J. Naiman, K. D. Brosofske, G. D. Mroz, B. L. Brookshire, and J. F. Franklin. 1999. Microclimate in Forest Ecosystem and Landscape Ecology: Variations in local climate can be used to monitor and compare the effects of different management regimes. BioScience **49**: 288–297.

Dormann, C. F., M. Bagnara, S. Boch, J. Hinderling, A. Janeiro-Otero, D. Schäfer, P. Schall, and F. Hartig. 2020. Plant species richness increases with light availability, but not variability, in temperate forests understorey. BMC ecology **20**: 43.

Driscoll, D. A., S. C. Banks, P. S. Barton, D. B. Lindenmayer, and A. L. Smith. 2013. Conceptual domain of the matrix in fragmented landscapes. Trends in Ecology & Evolution **28**: 605–613.

Govaert, S., C. Meeussen, T. Vanneste, K. Bollmann, J. Brunet, S. A. O. Cousins, M. Diekmann, B. J. Graae, P.-O. Hedwall, T. Heinken, G. Iacopetti, J. Lenoir, S. Lindmo, A. Orczewska, M. P. Perring, Q. Ponette, J. Plue, F. Selvi, F. Spicher, M. Tolosano, P. Vermeir, F. Zellweger, K. Verheyen, P.

Vangansbeke, and P. De Frenne. 2020. Edge influence on understorey plant communities depends on forest management. Journal of Vegetation Science **31**: 281–292.

Harper, K. A., S. E. Macdonald, P. J. Burton, J. Chen, K. D. Brosofske, S. C. Saunders, E. S. Euskirchen, D. Roberts, M. S. Jaiteh, and P. Esseen. 2005. Edge Influence on Forest Structure and Composition in Fragmented Landscapes. Conservation Biology **19**: 768–782.

iNaturalist. Available from https://www.inaturalist.org.

Matlack, G. R. 1993. Microenvironment variation within and among forest edge sites in the eastern United States. Biological Conservation **66**: 185–194.

Pfeifer, M., V. Lefebvre, C. A. Peres, C. Banks-Leite, O. R. Wearn, C. J. Marsh, S. H. M. Butchart, V. Arroyo-Rodríguez, J. Barlow, A. Cerezo, L. Cisneros, N. D’Cruze, D. Faria, A. Hadley, S. M. Harris, B. T. Klingbeil, U. Kormann, L. Lens, G. F. Medina-Rangel, J. C. Morante-Filho, P. Olivier, S. L. Peters, A. Pidgeon, D. B. Ribeiro, C. Scherber, L. Schneider-Maunoury, M. Struebig, N. Urbina-Cardona, J. I. Watling, M. R. Willig, E. M. Wood, and R. M. Ewers. 2017. Creation of forest edges has a global impact on forest vertebrates. Nature **551**: 187–191.

The jamovi project (2022). *jamovi*. (Version 2.3) [Computer Software]. Retrieved from https://www.jamovi.org.