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Effects of Edge-Width on Mammal Activity Patterns in Balsam Mountain Preserve

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Abstract

Balsam Mountain Preserve consists of 3,400 acres of protected land within a 4,400-acre property in Jackson County, North Carolina. These 3,400 acres form fragmented habitats throughout the property. In this project, we examined how these different fragments of habitats, and specifically the width of the edge between them, affected species' richness and the activity patterns of mammals. Sites were determined by their relative edge widths: large edge widths were sites along the golf course edge, medium edge widths were along road edges, and small edge widths were along trail edges. We had a total of six sites, two for each edge width. Data was collected via automated trail cameras, which took a picture and recorded the time and date of the photo. Data was then analyzed through RStudio to create three different models: species richness for each edge type, activity patterns for each mammal, and landscape of fear for each mammal, which is a measure of foraging time spent in front of a camera as a proxy for comfort level at that site. We found that species richness differed between large and small edge widths; this difference supported our predictions of species richness being lower in large edge widths, with a total of seven species compared to ten in small edge widths. Activity patterns revealed a variety of behaviors between carnivores and herbivores, with some showing diurnal and others showing nocturnal tendencies. Landscape of fear analyses revealed

differences between predator and prey and did not always align with our predictions. These findings are important in conveying how varied land use in Balsam Mountain Preserve affects mammal behaviors within the preserve.

Introduction

Balsam Mountain Trust consists of 3,400 acres of protected land within 4,400 acres of Balsam Mountain Preserve. This land is protected via a permanent conservation easement through NALT (North America Land Trust). The Trust is in Jackson County, North Carolina, spread throughout Balsam Mountain Preserve supporting many residential and community areas. These community areas consist of a golf course, an equestrian center, a camp site, all spread throughout the preserve fragmenting the Trust.

These patches of land protected by the Trust vary in patch edge width. Edges are the area that splits two or more habitats. Examples of edges would be hiking or game trails or the greenage of a golf course. Edges can affect the species inhabiting areas for different reasons. One example edge effect difference showed that bird communities in Australia had higher species richness and density in wooded edges compared to a shrubland edge (Baker et al. 2002). The number of edges is also another factor when determining edge effects. Bobolinks were found to avoid double edge patches of land four times more than a non-edge patch (Fletcher. 2005). A previous study conducted with automated cameras showed coyotes (*Canis latrans*) had differing activity patterns when coyotes had a forested edge or a grassland edge (Moll et al. 2024). These studies did not address variation in edge widths, which led to our research question: how does the size of an edge affect mammal diversity and behavior within the Preserve? We chose three edge width sizes: small edge width which is game/small hiking trails, medium edge widths are roads, and large edge widths are the golf course.

We hypothesized that edge width size will affect species richness. We predicted that small edge widths (trails) would have the highest species richness while large edge widths (golf courses) would have lower species richness. This is due to the species-area relationship, in which the loss of habitat results in loss of species (Ney-Nifle & Mangel. 2000). Larger edge widths will have the least amount of habitat or non-edge areas. We also predicted that predators would avoid large edge widths, limiting uncovered exposure. We hypothesized that edge widths will influence when mammals are active, and their activity levels observed. We predicted that White-tailed deer (*Odocoileus virginianus*) would be most active in the large edge widths during the day. This is due to the lack of predicted predators. We predicted that predators throughout edge widths would be active during the night. We hypothesized also that edge widths would show different landscapes of fear for observed species. Landscape of fear refers to the idea of predation risk a species is willing

to endure (Laundré et al. 2010). The more time spent being observed decreases the amount of fear understood. We predicted that the large edge widths would have low fear levels meaning longer foraging times, because we predicted that predators would avoid these areas and prey would be less fearful.

Methods

All sites chosen were within the Balsam Mountain Preserve. We had three types of sites: Small, medium, and large edge-widths. Each site had its own *Bushnell Trophy* motion-detected game camera installed so that photographs could be taken parallel to each edge when motion triggered. Each camera was set to the highest sensitivity and took three pictures per detected movement.

Data was collected from each camera and downloaded every two weeks from June 2025 to August 2025. After downloading pictures to an external hard drive, each camera's SD card was cleared to save space on the cameras to ensure all observational data was collected. Once the camera data was collected, each picture taken was analyzed and recorded into an Excel Spreadsheet. Data recorded for each photograph were as follows: Species common and scientific name, date of collection, time of collection, and the edge width category of the site.

After all data was collected and recorded, it was then analyzed through RStudio. Four analyses were conducted: one for the total number of occurrences of each species across all edge types, species richness for each edge type, activity pattern models for each species (showing the edge types for the species where they occurred), and Landscape of Fear models per edge width category per mammal. All model codes were written with the use of the *dplyr* package (Wickham et al. 2023). The activity patterns code was also written with the use of the *overlap* package (Meredith et al. 2024). The landscape of fear models was written with the use of the *luberidate* package (Grolemund and Wickham 2011).

Results

A total of 1,226 observations of mammals were taken within the two-month study period. Ten species were observed throughout the six sites combined, with coyote and deer dominating the photos (Figure 1a). Not all species were observed in each site type. The large edge width sites had a total of seven species observed. Medium edge width sites had the lowest species richness, with a total of six species observed. Small edge-width sites had the highest species richness, with ten species observed (Figure 1b).

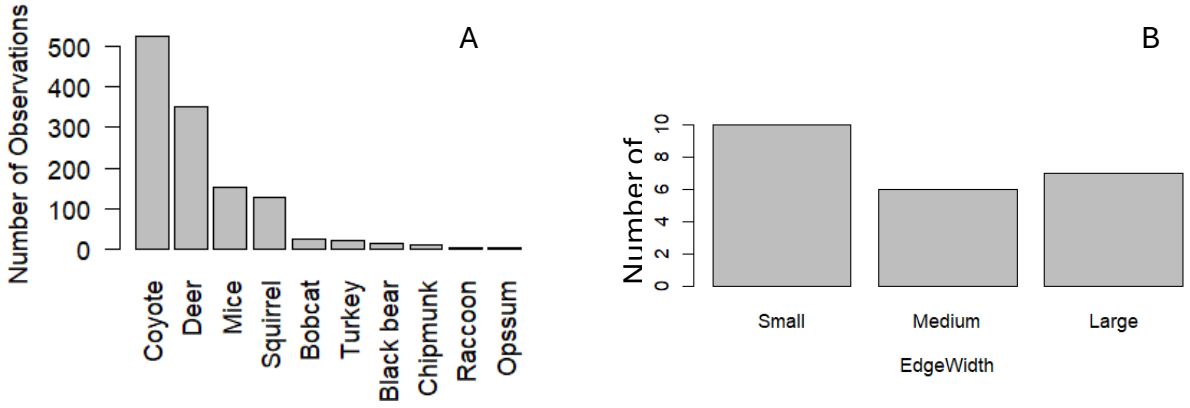

Figure 1. A. Total number of observations for each species from all sites combined. **B**. Total number of species observed at each edge width category.

Activity patterns were measured for seven of the species observed; the other three species were excluded due to low number of observations. Coyotes had activity patterns that showed high activity during the day at small edge widths, contrary to our expectation, while large edge widths had high activity during the night (Figure 2). White tailed deer throughout all sites had high activity during the day (Figure 3). White footed mice (*Peromyscus leucopus*) had high activity during the night, with none being observed during the day (Figure 4). Squirrels (*Sciurus carolinensis*) showed high activity in the morning and evening (Figure 5). Bobcats (*Lynx rufus*) were only found at one site and showed high activity in the morning, but the highest activity was during the evening (Figure 6). Turkeys (*Meleagris gallopavo*) showed high activity in both sites observed in the morning and evening (Figure 7). Black bears (*Ursus americanus*) only had enough observations at one site to create an activity pattern that showed low activity in the morning and high activity in the evening (Figure 8).

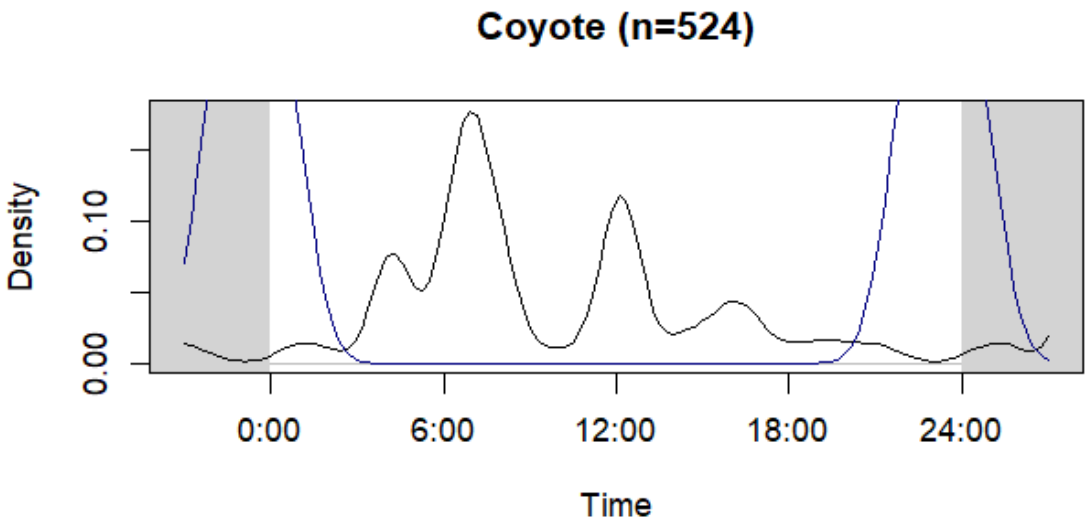

Figure 2. Coyotes activity within small and large edge widths. The black line represents the small edge widths combined and the blue line represents the large edge widths combined.

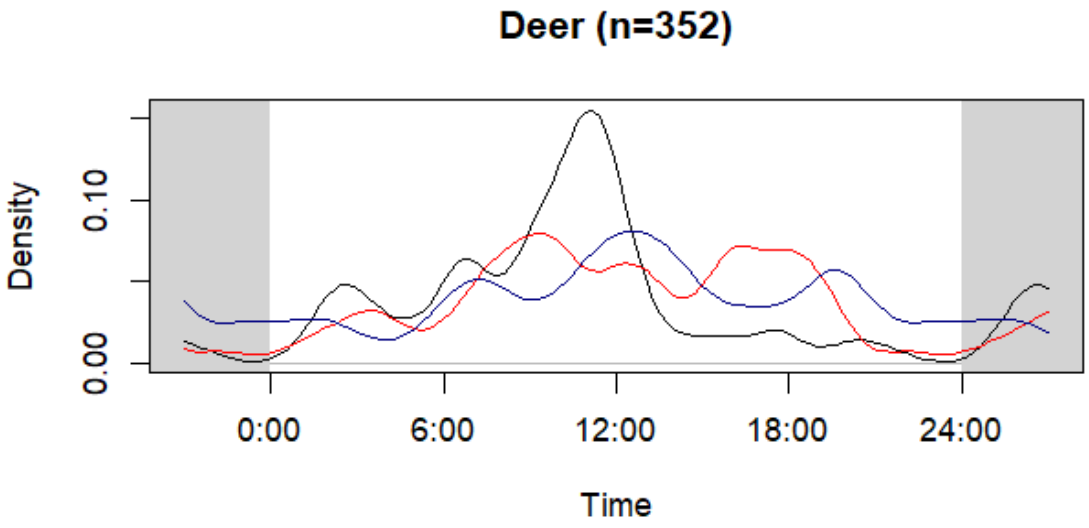

Figure 3. White tail deer activity in all edge sizes. The black line represents the small edge widths combined. The red line represents the medium edge width combined, and the blue line represents the large edge widths combined.

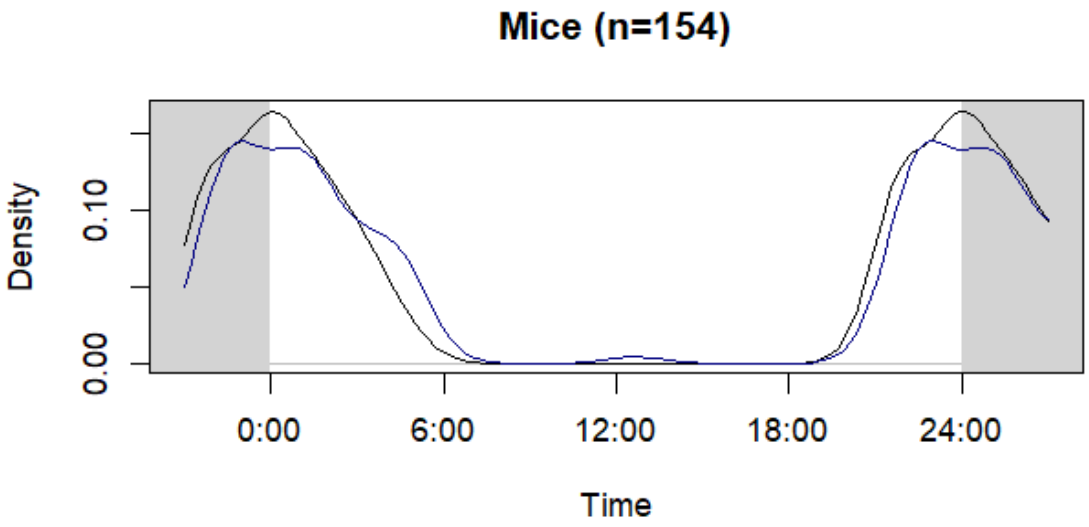

Figure 4. Mouse activity in small and large edge widths. The black line represents the small edge widths combined and the blue line represents the large edge widths combined.

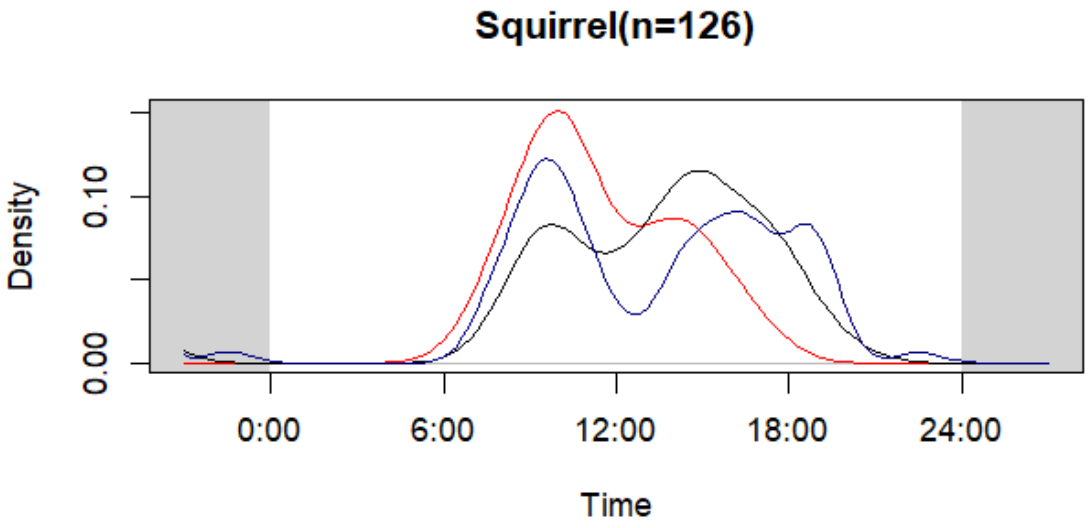

Figure 5. Squirrel activity in all edge sizes. The black line represents the small edge widths combined. The red line represents the medium edge width combined, and the blue line represents the large edge widths combined.

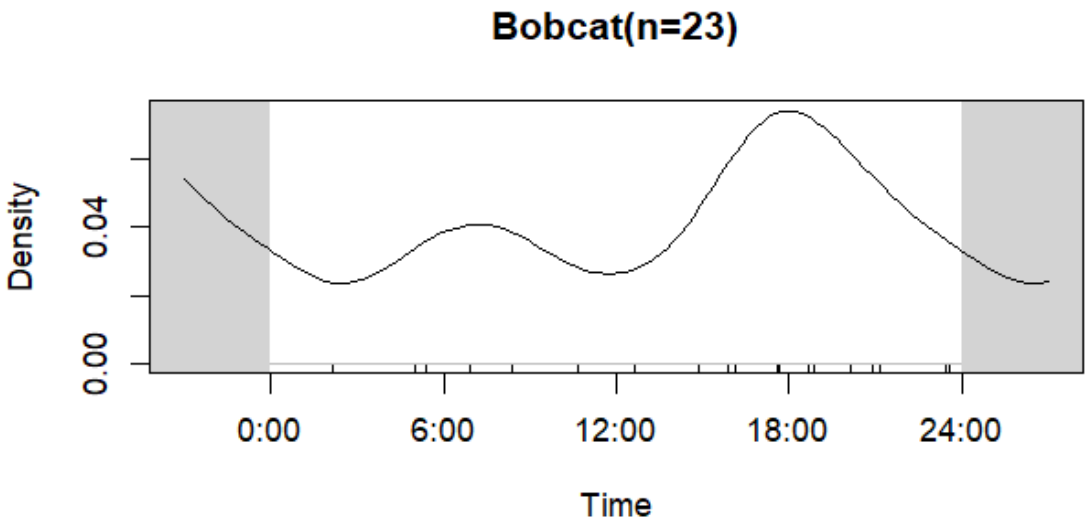

Figure 6. Bobcat activity in small edge width sites.

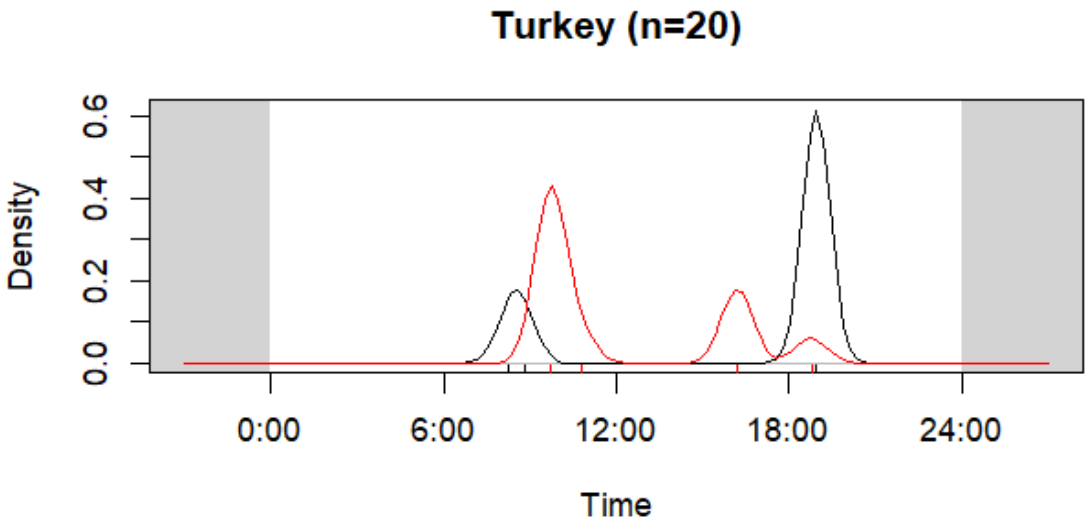

Figure 7. Turkey activity in small and medium edge widths. The black line represents small edge widths combined, and the red line represents medium edge width combined.

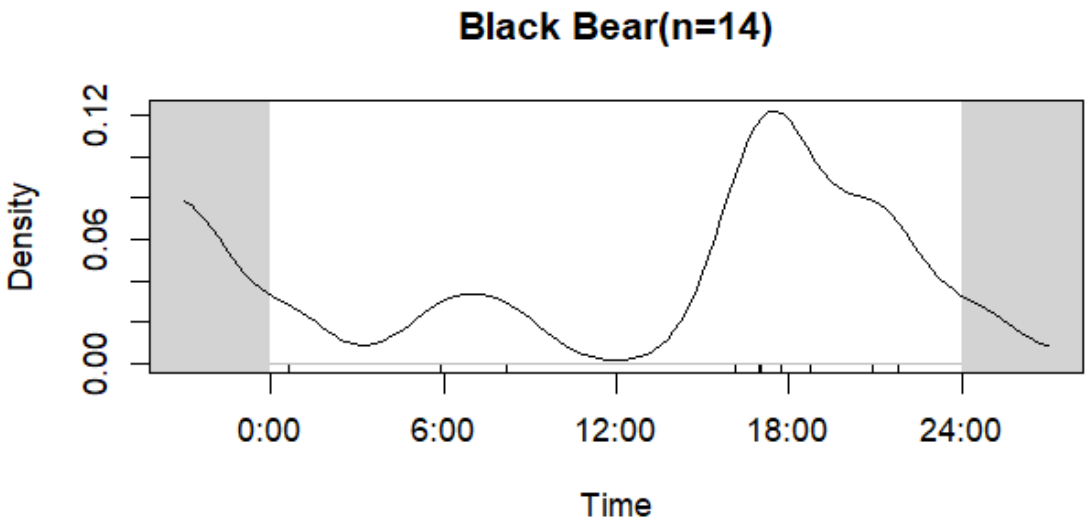

Figure 8. Black bear activity in small edge widths sites.

Every species for which activity patterns were created also had landscape of fear models created. Coyotes only had enough observation to create a violin plot for small edge widths. Coyotes had upwards of 30 minutes spent at the site (Figure 9). Deer had landscape of fear models created for all three edge widths. Deer spent the longest time in the small edge widths at ten minutes, contrary to expectations. Deer spent the least amount of time at the medium edge width with approximately five minutes spent (Figure 10). Mice were only observed at small and large edge widths; they spent six minutes at the large edge widths and five minutes at small edge widths (Figure 11). Squirrels spent the most time in large edge widths at three minutes spent. Squirrels spent the least amount of time in small edge widths at one minute spent (Figure 12). Bobcats only spent a maximum of one minute at one small edge width site (Figure 13).

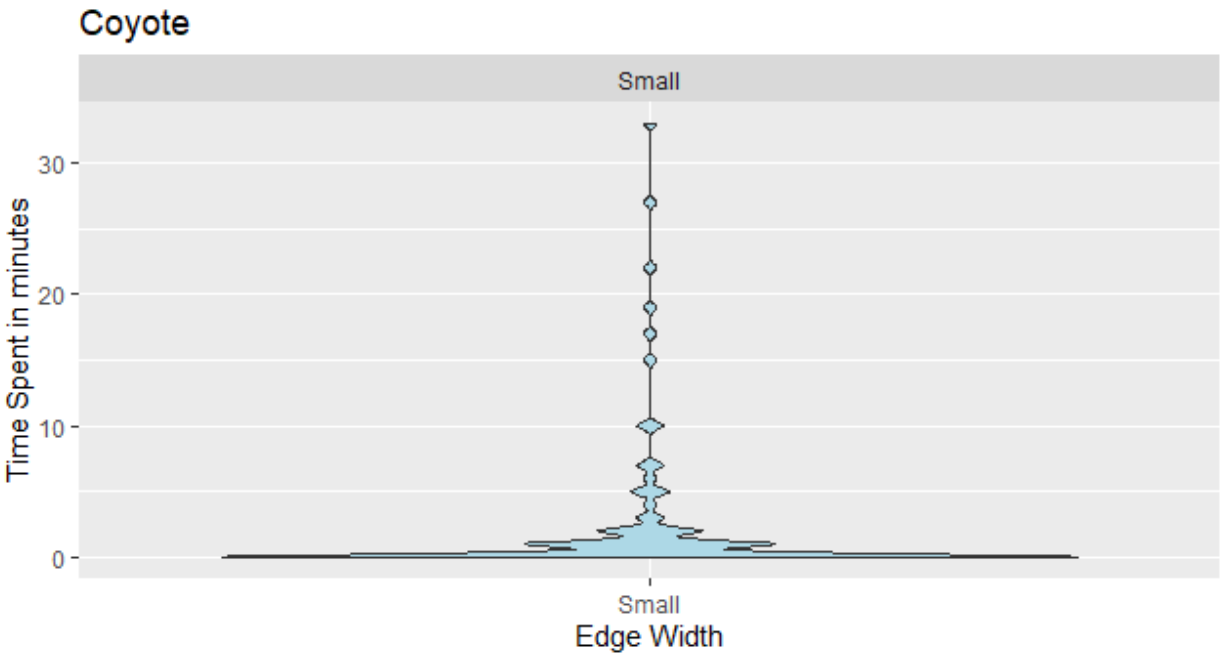

Figure 9. Coyotes time spent in front of cameras at small edge width sites. Coyotes spend a maximum time of 30 minutes in front a camera, while most observations were less than five minutes.

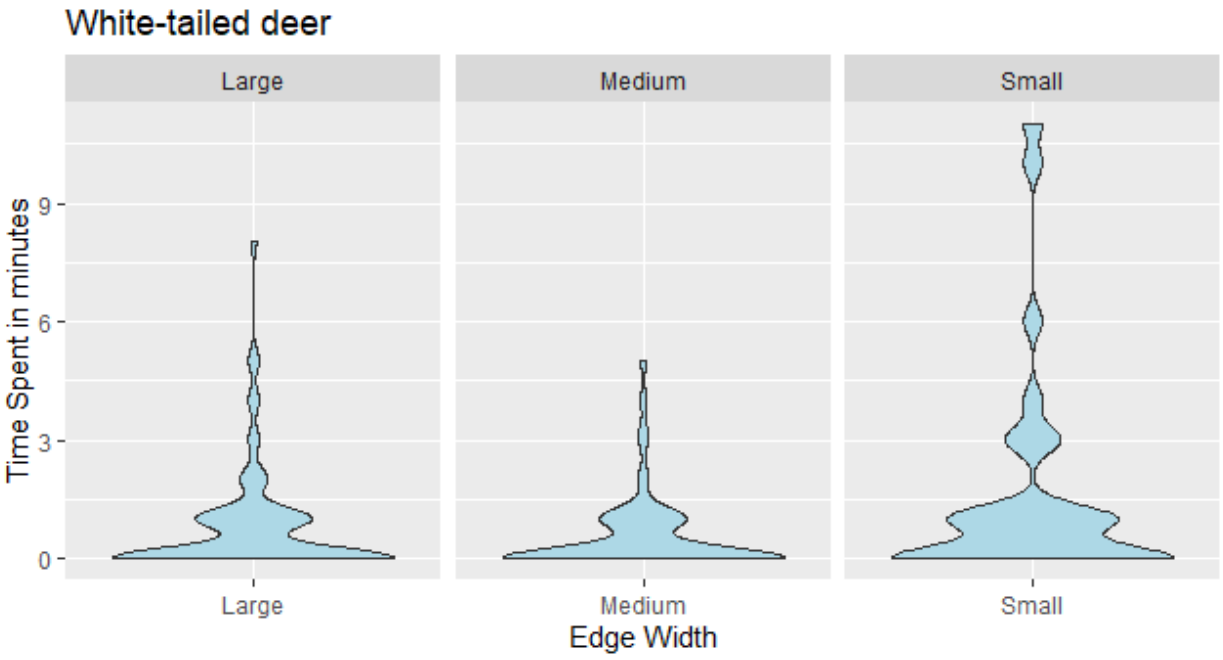

Figure 10. White tail deer's time spent at each edge width. Deer spent a maximum of ten minutes in small edge widths, with most observations being less than five minutes.

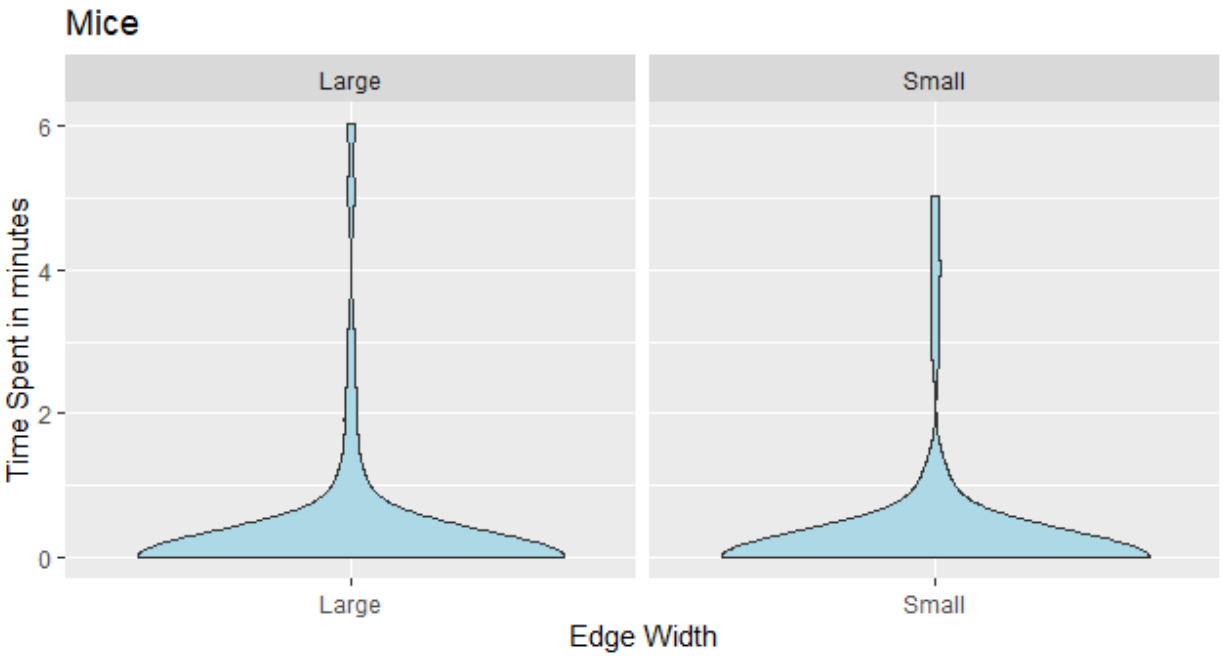

Figure 11. Mice time spent in small and large edge widths. Mice spent a maximum of six minutes in large edge widths, with most observations being less than two minutes.

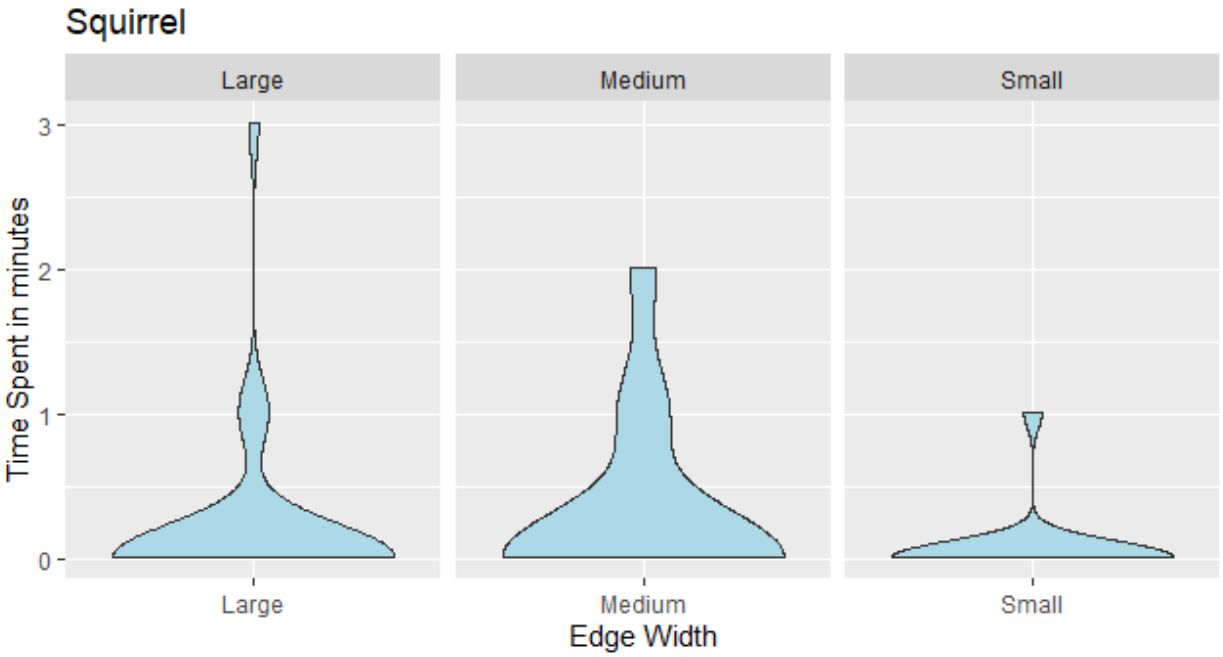

Figure 12. Squirrels time spent in all edge widths. Squirrels spent a maximum of three minutes in large edge widths, with most observations being less than one minute.

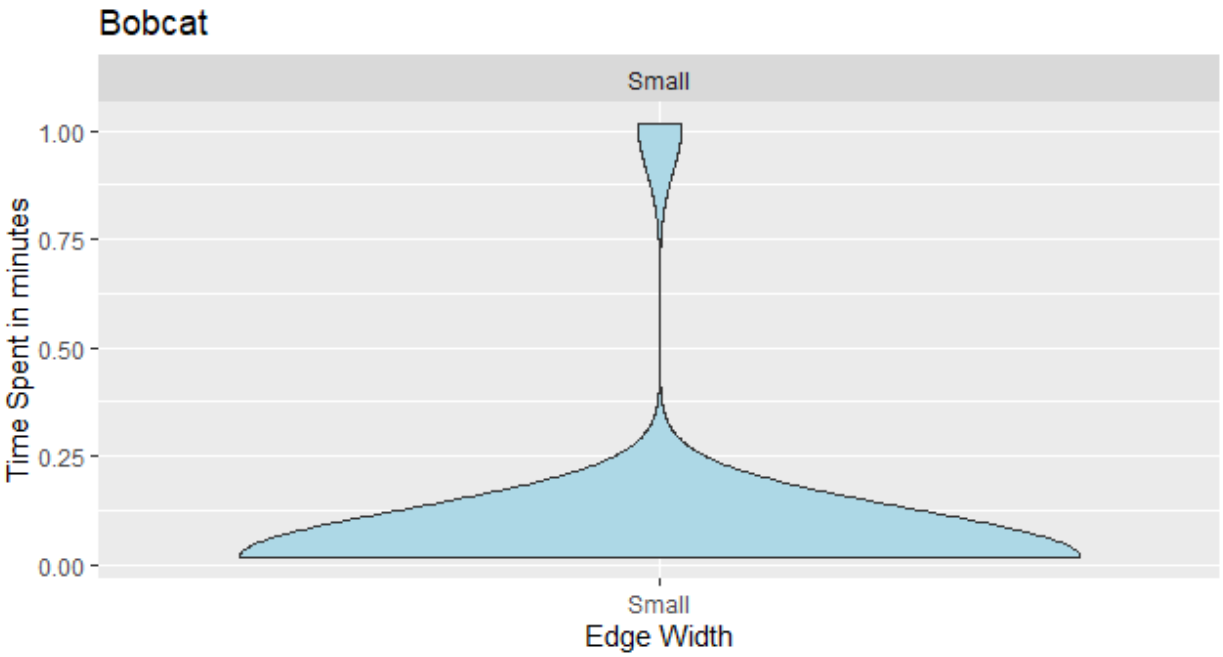

Figure 13. Bobcats time spent in small edge widths. Bobcats spent a maximum of one minute, with most observations being only one photograph.

Discussion

The results supported some of our hypotheses. The results (Figure 1b) showed a higher species richness in our smallest edge width. Small edge widths also saw species that were not detected at other sites, like the bobcat. This could be due to the distance of the small edge width sites to human activity (Mendes et al. 2020). Results for species richness did have an unexpected outcome of medium edge widths having the lowest species richness. This result could be from what we chose to be the medium edge width. The road could have been a determining factor in why some species would avoid these areas due to higher mortality rates from associations with the roadway (Adams. 1983) rather than the size of the edge created by the road.

Activity patterns as expected varied across species and site types. Black bear and bobcat activity patterns could only be generated for small edge width sites due to lack of observations at other sites. Surprisingly neither predator showed a nocturnal activity pattern: both models suggest a more crepuscular activity pattern for both species. Coyote activity patterns suggest diurnal activity in the small edge width sites where in large edge width sites they suggest a nocturnal activity pattern. This switch to nocturnal behaviors could be caused by human avoidance reasons (Mendes et al. 2020). On the other hand, diurnal activity could be caused by the age range of the coyotes observed. Coyotes observed at our small edge width sites appeared to be juveniles (Appendix A-B). Juveniles

spend time outside of the den exploring and gaining survival skills around the den which could be causing increased observations. With juveniles being in the pack there is also an increase in need for foraging.

Mice were the only species that models suggest being truly nocturnal, only being observed in the night or very early morning in both small and large edge width sites. Turkey activity patterns were analyzed for both small and medium edge widths. It suggests that turkeys are observed at both sites at the same time but have an inverse relationship in peak activity levels. Turkeys in small edge width sites have higher activity levels in the evening, while medium edge-width sites have higher activity levels in the morning. With medium edge widths, having a road at an edge could explain why turkeys are not using the area in the evening, avoiding post work traffic. Deer and squirrels were both suggested to be diurnal species based on the activity patterns created for all three site widths.

When looking at deer activity patterns the deer appeared to be the most active in small edge width sites, suggesting our prediction of low activity of deer in small edge widths due to predator presence to be untrue. Deer having this trend at small edge widths was surprising. Deer choosing these sites means that they are in higher threat of competition and predation. There are a couple of factors that could be leading to this decision despite competition and predation. One could still be human avoidance (Mendes et al. 2020) since both medium and large edge widths are anthropogenic edges. Another reason could be diet. Large edge widths, i.e. golf course edges are monocrop grasses that are not their preferred grass type (Chamrad & Box. 1968) and small edge widths would contain more varied vegetation. Squirrels had their highest peak of activity in the medium edge width sites. Squirrels could be using the medium edge width the most due to the lack of competition from other species.

The landscape of fear models suggested evidence against our predictions. The models did support our hypothesis that different edge widths would reveal different landscapes of fear. Predator average length of time detected by the camera was all focused on small edge widths. Bobcat and bear models showed the two species ether passing through, spending less than a quarter of a minute at a site or showed relatively low time spent, spending one minute at site. There was little variation besides those two options for these two species. Coyotes in small edge width sites spend a large average amount of time in the site. Coyotes spent the longest amount of time out of all species and all sites with a maximum of 30 minutes spent at a site. This could be due to the age range of coyotes observed and the number of coyotes in the area. Another reason coyotes could have high average time spent is proximity to their den. These juvenile coyotes would not travel far from their dens or territory.

Deer had the highest foraging time in small edge width contrary to our predictions. Deer also had the lowest foraging time in medium edge width sites, also suggesting evidence

against our prediction. Deer could be more fearful of medium edge width sites due to the road edge and increased mortality from car incidents. To decrease mortality, they would spend less time in areas where the edge is a road (Bellis & Graves. 1971). Reasoning for deer being less fearful and spending more foraging time in small edge width could be due to more vegetation cover. The edge being smaller allows for more areas of habitat to exist and decreases the time it takes to get to a patch of habitat suitable for grazing and browsing. Squirrels on the other hand showed the highest foraging times in large edge width sites. They had the lowest foraging time in small edge widths. This does follow our previous prediction and could be due to the presence of predators in small-edged widths. Mice foraging time was similar between small and large edge width sites. Mice did spend two minutes more in the large edge width supporting our predictions of larger edge widths having higher foraging times.

Mammals in Balsam Mountain Preserve varied in activity throughout edge width categories. In this project we highlighted what those differences in activity are. We found that edge widths do influence mammal activity depending on the species being observed. Most of our predictions were supported by our findings. More research is needed in the future to determine the reason behind these activity patterns. This project did not look for reasons behind the differences experimentally and further research will only reinforce the theories of edge effects. In the field this project will inform Balsam Mountain Trust about the effects future construction and the expansion of these larger anthropomorphic edges.

Acknowledgements

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References

Adams LW. 1983. Effects of roads on small mammals.

Baker J, French K, Whelan RJ. 2002. The edge effect and ecotonal species: bird communities across a natural edge in southeastern Australia. Ecology. 83(11):3048. https://doi.org/10.2307/3071841

Bellis ED, Graves HB. 1971. Deer mortality on a Pennsylvania interstate highway. The Journal of Wildlife Management. 35(2):232. https://doi.org/10.2307/3799596

Chamrad AD, Box TW. 1968. Food habits of white-tailed deer in south Texas. Journal of Range Management. 21(3):158. https://doi.org/10.2307/3896137

Fletcher RJ. 2005. Multiple edge effects and their implications in fragmented landscapes. Journal of Animal Ecology. 74(2):342-352. https://doi.org/10.1111/j.1365-2656.2005.00930.x

Grolemund G, Wickham H. 2011. Dates and times made easy with lubridate. Journal of Statistical Software. 40(3):1-25. https://www.jstatsoft.org/v40/i03/.

Laundré J, Hernández L, Ripple W. 2010. The landscape of fear: ecological implications of being afraid. The Open Ecology Journal. 3:1-7. https://www.predatordefense.org/agencies/docs/research_LandscapeOfFear_Laundre_2010.pdf

Mendes CP, Carreira D, Pedrosa F, Beca G, Lautenschlager L, Akkawi P, Bercê W, Ferraz KMPMB, Galetti M. 2020. Landscape of human fear in Neotropical rainforest mammals. Biological Conservation. 241:108257. https://doi.org/10.1016/j.biocon.2019.108257

Meredith M, Ridout M, Campbell LA. 2024. Overlap: estimates of coefficient of overlapping for animal activity patterns. R package version 0.3.9. Available from: https://CRAN.R-project.org/package=overlap.

Moll RJ, Green AM, Allen ML, Kays R. 2024. People or predators? comparing habitat-dependent effects of hunting and large carnivores on the abundance of North America's top mesocarnivore. Ecography. https://doi.org/10.1111/ecog.07390

Ney-Nifle M, Mangel M. 2000. Habitat loss and changes in the species-area relationship. Conservation Biology. 14(3):893-898. https://doi.org/10.1046/j.1523-1739.2000.98163.x

Wickham H, François R, Henry L, Müller K, Vaughan D. 2023. Dplyr: a grammar of data manipulation. R package version 1.1.4. Available from: https://CRAN.R-project.org/package=dplyr.

Appendix

Appendix A

Appendix B