PRELIMINARY EVALUATION OF WILDLIFE USE OF SLASH WALLS IN HARDWOOD STANDS AT THE ARNOT FOREST IN SOUTHEASTERN NEW YORK STATE

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ABSTRACT

The browsing of white-tailed deer (*Odocoileus virginianus*) has caused many issues with the regeneration of hardwood forests in the northeastern US. Constructing perimeter slash walls has been successful for excluding deer and helping tree seedlings regenerate. However, little is understood about slash walls and the role they serve for other taxa. We examined how wildlife interacted with slash walls using infrared-triggered trail cameras. The study was conducted at Cornell University's Arnot Teaching and Research Forest in Van Etten, New York. Camera traps (*n*= 32) were placed at random locations both facing slash walls and in adjacent control plots for 3 months during April-July 2022. Several species were photographed interacting with slash walls, and sufficient data were recorded for white-tailed deer, red foxes (*Vulpes vulpes*), and coyotes (*Canus latrans*). These three species were significantly more likely to be observed near slash walls than at adjacent control plots in open forest stands. The species diversity recorded indicated that slash walls do serve a larger purpose and may have significant conservation implications for wildlife.

BIOGRAPHICAL SKETCH

The son of an American diplomat, Patrick McGee was born and raised overseas, living in Ukraine, the Philippines, Bangladesh, and Kenya. It was in Kenya that Patrick developed his interests in the outdoors, and wildlife conservation and management. He received his Bachelor of Science in Environmental Science at the Evergreen State College in Olympia, Washington in 2015. In the interim years between Evergreen and attending Cornell University, Patrick partook in wildlife conservation projects across Africa. He volunteered at an elephant orphanage in Zambia, participated in numerous wildlife research projects in South Africa, and collaborated with local wildlife authorities to resolve human-wildlife conflicts in Malawi. Upon completion of his master's degree, Patrick aspires to continue his passion of conserving and restoring the world's wildlife populations.

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INTRODUCTION

Hardwood forests of the northeastern US face great pressures from browsing by white-tailed deer (Curtis et al. 2021, McGill et al. 2019, Lesser et al. 2019, Blossey et al. 2019). Successful regeneration in forests may be impaired, resulting in a 'regeneration debt' (McGill et al. 2019), defined as an insufficient number of juvenile stems to replace older generations, or composition differences between adults and juveniles. Various strategies have been implemented to exclude deer from areas to enhance forest regeneration. They include recreational hunting, as well as wire fencing (Smallidge et al. 2021, Curtis et al. 1994). Regulated hunting has been used for decades to manage deer populations. However, subsequent studies have questioned the effectiveness of hunting (Williams et al. 2013, Kugeler et al. 2015). Williams et al. (2013) showed that hunting alone was not sufficient to reduce deer populations to desired management objectives of <10 deer/km^2 in New Jersey and Pennsylvania. Also, Kugeler et al. (2015) reported inconclusive evidence of hunting being an effective method to reduce human cases of Lyme disease (Kugeler et al. 2015). Wire fencing, while not frequently used in forest settings, can also effectively protect seedlings from deer, however it can be costly to construct, operate, and maintain (Curtis et al. 1994). The novel strategy of perimeter slash walls (Smallidge et al. 2021) has the potential to exclude deer from regeneration harvest while also being cost effective.

Slash is a term to describe the downed woody debris remaining after logging practices have concluded, and it has been observed as a natural barrier for deer. Grisez (1960) reported a 15% reduction of hardwood species browsed in slash compared to open plots (36% of seedlings in slash were browsed, compared to 51% of seedlings in open spaces). Manipulating slash into physical structures is perhaps a novel strategy. In 2017, a pilot study was initiated to see whether the construction of a slash wall around selected plots would be effective at excluding deer and allowing seedlings to regenerate at the Arnot Teaching and Research Forest near Van Etten, New York. After 4 years, Smallidge et al. (2021) found that tagged seedlings inside the slash wall were taller than seedlings in adjacent control plots.

In additions the construction of slash walls was less expensive than wire fencing. On average, slash wall construction cost $4.82 per m, compared to wire fencing at $6.50-$12.20 per m (Smallidge et al. 2021, Curtis et al. 1994). Also, because these walls were made of natural materials, the original wall height (*n*= 3 m) decreased by 8-14% per year (Smallidge et al. 2021). Although slash walls were effective at excluding deer from forest regeneration plots, little is known about their impact on the environment and other wildlife.

While little research has been done specifically on slash walls, several studies have been conducted on brush piles and coarse woody debris (CWD). Many taxa use brush piles and CWD, including mammals, birds, invertebrates, and fungi (Loeb 1996, Sullivan et al. 2012), and CWD provides important habitat for many mammals. Mammals such as red foxes (*Vulpes vulpes*) and American martens (*Martes americana*) have placed their dens under logs (Loeb 1996, Sullivan et al. 2012). A Pennsylvania study showed that cottontail rabbits (*Sylvilagus floridanus*), mice (*Peromyscus* spp.), voles (*Microtus* spp.), and birds used brush piles as winter refuge (Goguen et al. 2011).

Rodents play an important function in the ecosystem, including seed dispersal (Fritts et al. 2016). In the southeastern U.S., CWD is a major habitat component for rodents. Cotton mice (*Peromyscus gossypinus*) used rotting stumps, root boles, and logs as refuges and burrows when predators were nearby (Loeb 1996, Fritts et al. 2016). Rodents may also use CWD as navigational landmarks for their intricate travel routes (Loeb 1996, Fritts et al. 2016). CWD may also provide a food source for insects and fungi. The fungi that grow on decaying logs may be eaten by rodents, and therefore lead to an important factor in recycling woody debris (Loeb 1996). Invertebrates also use CWD for food, refuge from extreme temperatures, refuge from moisture, and shelter (Grodsky. 2016, Grodsky et al. 2017). CWD provides important habitat for invertebrates. A study in South Carolina showed that CWD removal for biofuel usage decreased invertebrate diversity and greatly affected community composition of those species (Grodsky et al. 2017). Brush piles and CWD serve pivotal roles in the environment, serving as shelter, refuge from predators, and a food resource.

Sullivan et al. (2012) looked at the species diversity of small mammals (voles, mice, and shrews [*Blarina brevicauta*]) between forest clear cuts, and clear cuts with woody debris piles in British Columbia, Canada. The overall abundance of mammals in clear cuts was unaffected, however, species richness and diversity were either similar or higher (Sullivan et al. 2012) in sites with woody debris. There was a noticeable increase in generalist species and decrease in specialist species associated with woody debris. The constructed debris piles had more species and activity with winter mammals, but this turned out to be species-specific (Sullivan. 2012).

While previous literature on brush piles and CWD may provide some hints as to how wildlife might respond to slash walls, actively studying wildlife interactions with slash walls is needed. The primary objective for this study was to understand how wildlife respond to and interacted with slash walls. We hypothesized that some species, (e.g., red fox), might use slash walls for shelter and denning purposes, while other species, (e.g., white-tailed deer) would perceive slash walls as a significant barrier to movements.

METHODS

Study Area

This research project was conducted at Cornell University's Arnot Teaching and Research Forest in Van Etten, approximately 25 km south of Ithaca, New York. The Arnot Forest is managed by the Department of Natural Resources and the Environment in the College of Agricultural and Life Sciences. It covers an area of 1,700 hectares (4,200 acres) and is comprised of mainly mixed hardwoods over hilly terrain. Common overstory tree species included red maple (*Acer rubrum*), red oak (*Quercus rubra*), American beech (*Fagus grandifolia*), aspen (*Populus tremuloides*), and sweet birch (*Betula lenta*).

Stand characteristics included the entire field site covering an area of 69.55 hectares (Figure 1). Plots 4-7 included 27.01 hectares, and plots 3, 8, 9, and 10 were 42.54 hectares. Tree species in these plots were primarily red oak (*Quercus rubra*) and other northern hardwoods. Plots 3, 4, 5, and 6 contained the slash wall treatments. Plots 7, 8, 9, and 10 had no slash walls and were designated as controls. Plot 7 was an open plot with scattered slash covering much of the area. Plots 8, 9, and 10 had more mature trees and were situated on steep terrain.

Field Design

We selected 8 study plots, 4 adjacent to slash walls, and 4 control plots away from the walls (Figure 1). Trail cameras were placed randomly both along the slash walls and within the control areas. Slash walls were divided into 45-m segments to randomly assign camera locations. These 45-meter sections were measured using a Garmin 66i GPS unit (Garmin Ltd., Kansas) that contained coordinates of the corners and midpoints of the slash walls. Treatment cameras were placed between 5-10 m away from and facing the slash walls at heights between 30-110 cm

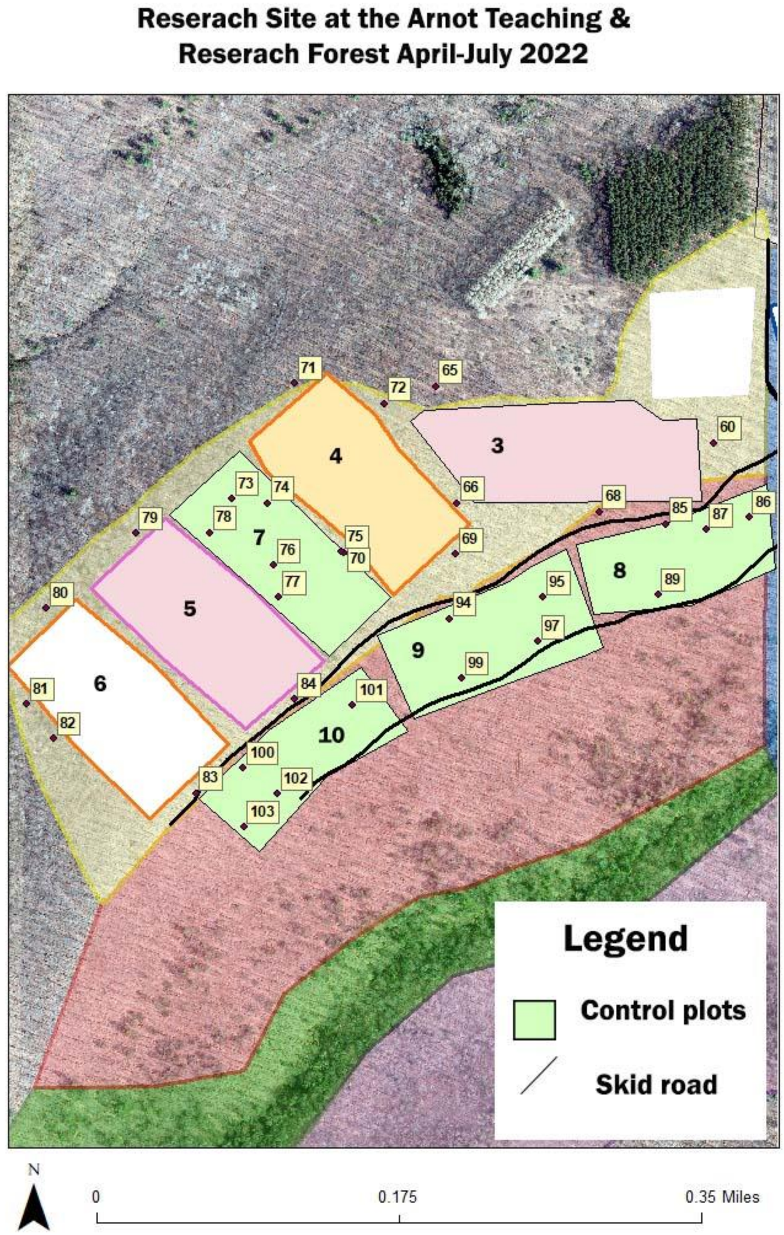

Figure 1. Locations of trail cameras (numbered boxes) in Stands 3-10 at the Arnot Teaching and Research Forest, Van Etten, New York, during April through July 2022.

above ground. We usually mounted cameras on the nearest tree or tree stump that would provide the most unobstructed view to monitor wildlife movements. Control cameras were placed at random points and orientations outside the slash walls in adjacent forest stands. In total, 32 cameras were placed across the 8 plots (4 cameras per plot).

Photographic data were collected during mid-April to mid-July 2022. The Cuddeback X-Change™ Color Modal 1279 (Cuddeback Digital, Wisconsin) digital trail cameras were used to obtain photos of wildlife use. They were set to take a 3-photo burst during daytime and single night-time picture. Once weekly, cameras were checked to change memory cards, inspect batteries, and tend to other maintenance issues. Two cameras were replaced early in the study due to the images having some discoloration. As spring temperatures warmed and the plants began to grow, some vegetation in front of the cameras had to be trimmed because of many accidental triggers that occurred from wind movement of foliage.

Photo Images

Pictures of wildlife using the stands were collected 24-h per day (Illustration 1). Each camera had two, 16 GB SanDisk Ultra SD memory cards. Each memory card was labeled with the camera number on it, and was colored coded; one in green and the other in red. This was done to avoid confusion during the weekly camera checks when SD cards were exchanged. The SD cards were transported using the Elephant waterproof memory card case (Elephant Cases, Italy). After the weekly camera checks, the SD cards would be analyzed. Any photos containing wildlife were sorted into files with the corresponding camera number and uploaded to Cornell University's Box cloud storage service. All the files were also backed up onto an external hard drive.

Illustration 1. Wildlife species observed at camera sites in Stands 3-10 at the Arnot Teaching and Research Forest, Van Etten, New York, during April through July 2022.

ANALYSIS

After collecting and sorting through the photos, they were then recorded into a spreadsheet using Microsoft Excel. This spreadsheet contained the camera number, GPS coordinates, the camera position relative to a slash wall, month, time the picture was taken, and species recorded. Multiple individuals in the same picture were counted as a single event. Individuals that made multiple visits to the camera in the span of less than 10 minutes were considered as one event. Multiple visits to camera sites beyond the 10-minute threshold were considered as multiple events. Analysis was performed using the statistical software JMP from SAS (JMP Statistical Discovery LLC, 2021). The Excel spreadsheet was imported into JMP to analyze the results.

RESULTS

During the 3-month study, one camera recorded no pictures, even though it was operating correctly. By far, white-tailed deer was the most common species recorded during the study (Table 1). Cameras 60, 65, 66, 71, 74, 75, and 83 recorded the most sightings (Figure 2). Cameras 60, 65, 66, 71, and 83 were placed facing slash walls, and cameras 74 and 75 were not.

A Chi-Square test was completed in JMP to test the likelihood of wildlife being observed more frequently near slash walls (Table 2) than control sites. However, sample sizes were too low (cell numbers <5) for several species for this test to be valid. We performed the test again for the three species (coyote [*Canus latrans*], red fox, and white-tailed deer) that had sufficient data for analysis (Table 3), and these species were observed significantly more near slash walls than adjacent control sites (Pearson Chi-square = 8.933, $P = 0.0115$). In addition, for all other species except grey squirrels (*Sciurus carolinensis*), more images were observed on cameras facing slash walls than on control cameras. With a longer-term study and larger sample sizes, it appeared that more species would have shown significant results.

The total number of photographs observed increased as the study progressed into summer (Figures 3, 4, and 5), particularly for white-tailed deer, red foxes, and coyotes. However, the greatest species diversity was recorded in April and May. No fishers (*Pekania pennanti*), grey squirrels, porcupines (*Erethizon dorsatum*), or wild turkeys (*Meleagris gallopavo*) were seen on cameras in July, and grey squirrels and porcupines were also missing in June. There was a greater species diversity at slash walls than in the control plots (Figure 4). No black bears (*Ursus americanus*), porcupines, or wild turkeys were recorded in control plots (Figure 5).

Along with the increase in species diversity at slash walls, there were significantly more images taken from cameras facing slash walls than for control cameras (Figure 6, Table 3). A total 433 images were taken from cameras facing slash walls, and only 252 images from the control plots. Most sightings were of white-tailed deer for both control and treatment cameras.

It was interesting that most of the photos taken in April were associated with slash walls (Figure 4). However, in May, just the opposite was true with most images being recorded at control sites. Too few images were recorded in June and July to discern any patterns associated with slash walls. As the study progressed, the species diversity decreased, and primarily white-tailed deer were observed.

Table 1. Total number of photographs recorded on trail cameras by species at the Arnot Teaching and Research Forest in Van Etten, New York, during mid-April to mid-July 2022.

Total Observations of each Species Recorded		
Common Name	**Scientific Name**	**Total Observations**
Black bear	*Ursus Americanus*	3
Coyote	*Canus latrans*	22
Fisher	*Pekania pennanti*	6
Grey Squirrel	*Sciurus carolinensis*	3
Porcupine	*Erethizon dorsatum*	2
Raccoon	*Procyon lotor*	12
Red fox	*Vulpes vulpes*	36
White-tailed deer	*Odocoileus virginianus*	472
Wild turkey	*Meleagris gallopavo*	5

Table 2. Results of the Chi-square test conducted for each species recorded to determine likelihood of being observed near slash walls vs. control sites at the Arnot Teaching and Research Forest, Van Etten, New York during mid-April to mid-July 2022.

		Species									
	Count Total % Col % Row %	black bear	coyote	fisher	grey squirrel	porcupine	raccoon	red fox	white-tailed deer	wild turkey	Total
Slash Wall	N	0	6	2	2	0	1	6	235	0	252
		0.00	0.88	0.29	0.29	0.00	0.15	0.88	34.31	0.00	36.79
		0.00	26.09	33.33	66.67	0.00	8.33	16.67	39.50	0.00	
		0.00	2.38	0.79	0.79	0.00	0.40	2.38	93.25	0.00	
	Y	3	17	4	1	2	11	30	360	5	433
		0.44	2.48	0.58	0.15	0.29	1.61	4.38	52.55	0.73	63.21
		100.00	73.91	66.67	33.33	100.00	91.67	83.33	60.50	100.00	
		0.69	3.93	0.92	0.23	0.46	2.54	6.93	83.14	1.15	
	Total	3	23	6	3	2	12	36	595	5	685
		0.44	3.36	0.88	0.44	0.29	1.75	5.26	86.86	0.73	

Tests

N	DF	-LogLike	RSquare (U)
685	8	12.820303	0.0310

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	25.641	0.0012*
Pearson	20.457	0.0087*

Warning: 20% of cells have expected count less than 5, ChiSquare suspect.

Table 3. Chi-square test for coyote (*Canus latrans*), red fox (*Vulpes vulpes*), and white-tailed deer (*Odocoileus virginianus*) to determine likelihood of being observed near slash walls vs. control sites at the Arnot Teaching and Research Forest, Van Etten, New York mid-April to mid-July 2022.

		Species			
Slash Wall	Count Total % Col % Row %	coyote	red fox	white-tailed deer	Total
N	Count	6	6	234	246
	Total %	0.92	0.92	35.94	37.79
	Col %	26.09	16.67	39.53	
	Row %	2.44	2.44	95.12	
Y	Count	17	30	358	405
	Total %	2.61	4.61	54.99	62.21
	Col %	73.91	83.33	60.47	
	Row %	4.20	7.41	88.40	
Total	Count	23	36	592	651
	Total %	3.53	5.53	90.94	

Tests

N	DF	-LogLike	RSquare (U)
651	2	4.9425925	0.0208

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	9.885	0.0071*
Pearson	8.933	0.0115*

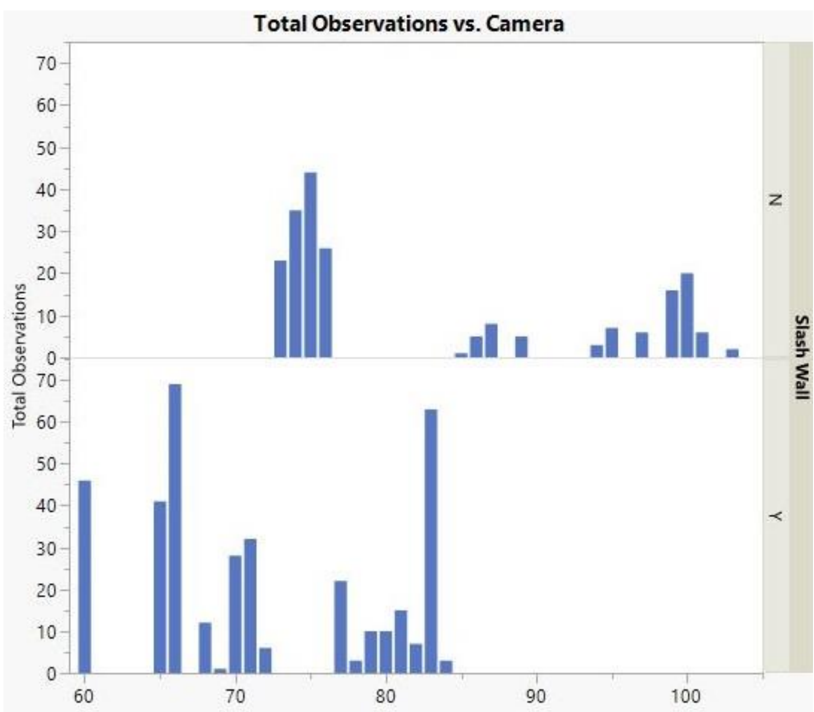

Figure 2. Total number of images recorded for each camera site in Stands 3-10 at the Arnot Teaching and Research Forest, Van Etten, New York, during April through July 2022.

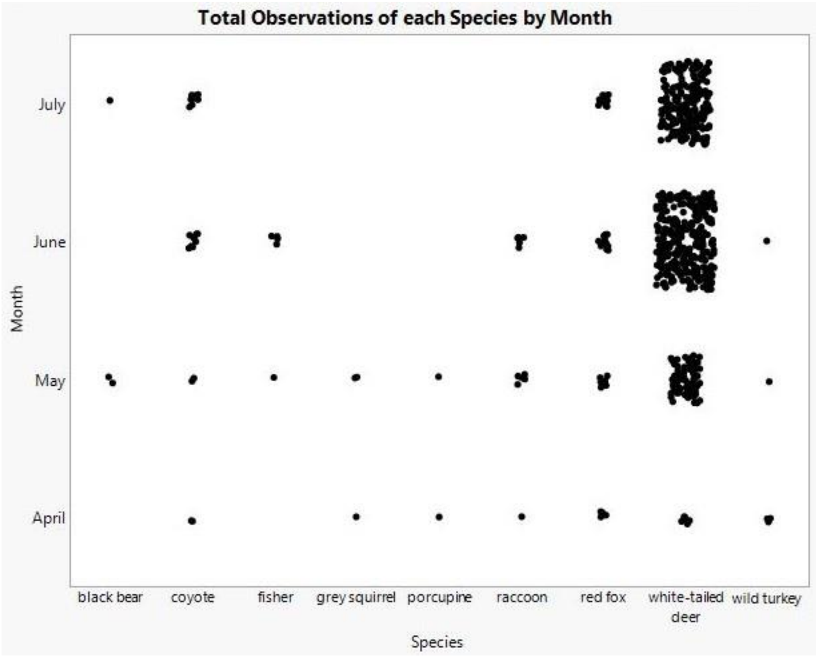

Figure 3. Total number of images for each species by month in Stands 3-10 at the Arnot Teaching and Research Forest, Van Etten, New York, during April through July 2022.

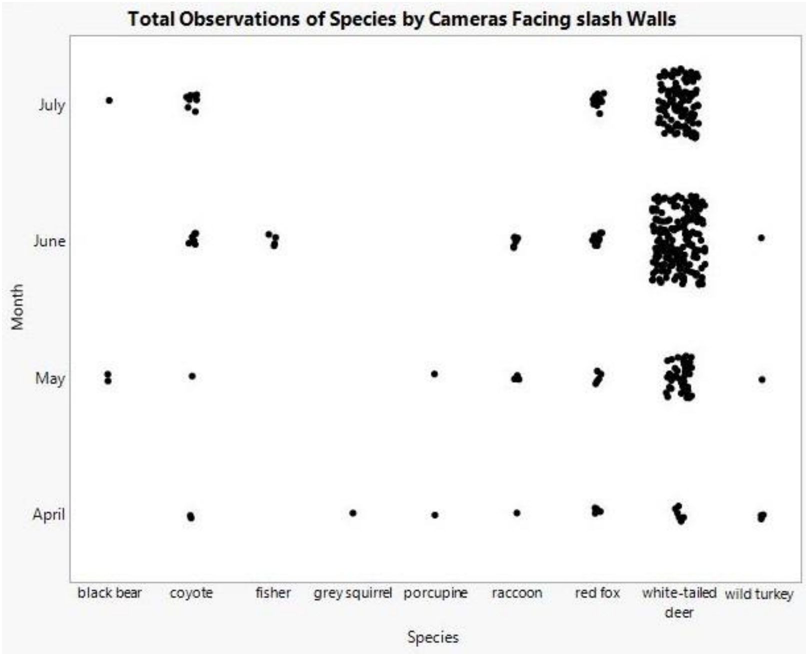

Figure 4. Total number of images for each species by month at cameras facing slash walls at the Arnot Teaching and Research Forest, Van Etten, New York, during April through July 2022.

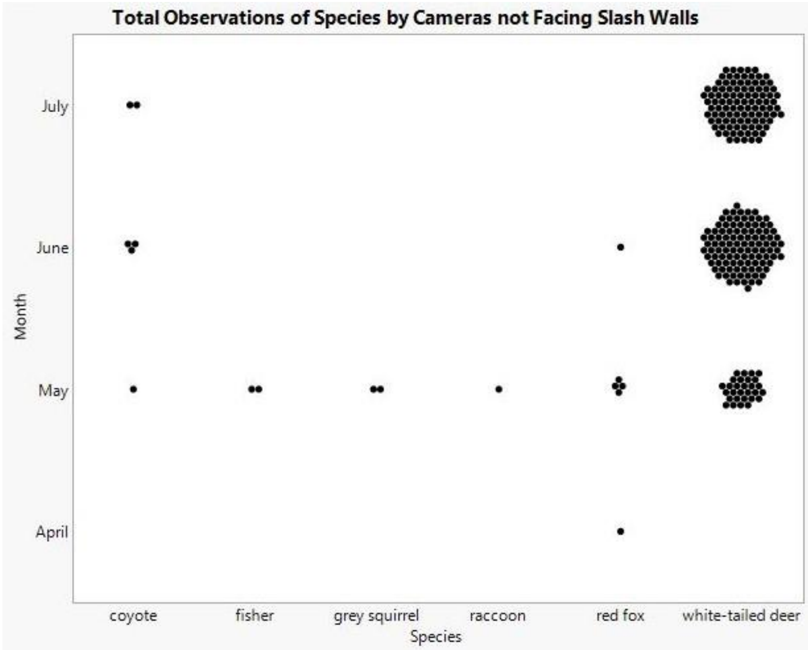

Figure 5. Total number of images for each species by month at cameras not facing slash walls at the Arnot Teaching and Research Forest, Van Etten, New York during April through July 2022.

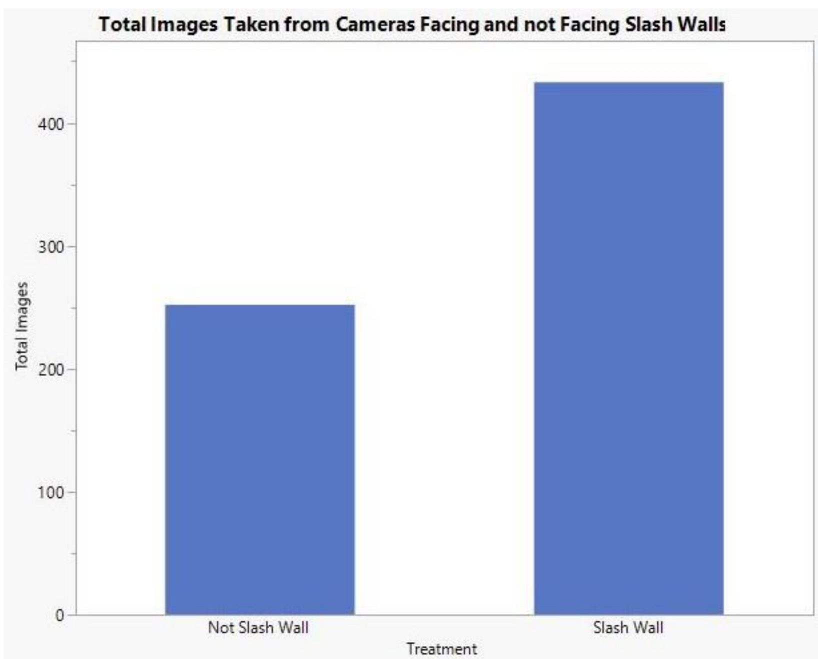

Figure 6. Total images taken from cameras facing and not facing slash walls at the Arnot Teaching and Research Forest, Van Etten, New York during April through July 2022.

DISCUSSION

We observed a greater diversity of species near slash walls than for control sites, but we only had sufficient data for coyote, red fox, and white-tailed deer to determine if they were significantly more likely to be seen near slash walls. Additional data, such as habitat availability data and species home ranges, would have been needed to show species use or a preference for slash walls.

Camera location likely contributed to the number of photos recorded, and the concentration of wildlife observations around cameras 60-75 may be associated with several factors. Cameras 60-75 were located around plots 3, 4, and 7, while camera 83 was located on the edge of a road between plots 6 and 10, an easy path for wildlife to follow. Also, Cameras 60-75, and 83 were on less steep terrain compared to plots 8, 9, and 10.

Plots 8, 9, and 10, as well as the outer perimeters of plots 5 and 6, contained more mature hardwoods contributing to shading and possibly less vegetation at ground level. There could have been more food resources (i.e., growing shoots and seedlings) in plots 3, 4, and 7, which would be especially attractive for white-tailed deer.

As the study progressed, there were increased observations of deer. The peak of fawn births occurred during late May and early June (Hewitt. 2011, Williams et al. 2016) in New York State. Females separate from their social groups to give birth, and fawns move less during their first few weeks of life so they can hide from predators (e.g., coyotes). By late June, fawns are much more mobile and spending time foraging with their mother. This could contribute to the increased number of deer observations in June and July (Figure 3) versus April and May.

White-tailed deer, red foxes, and coyotes were significantly more likely to be observed near slash walls than in the adjacent control plots (Table 3). We captured multiple images of red foxes and fishers crawling in and around the slash walls during April. For coyotes and red foxes, perhaps slash walls provided good foraging and denning opportunities. Prey species, such as rabbits, mice, voles, and shrews all use brush piles or CWD for shelter (Goguen et al. 2011, Sullivan et al. 2012). Coyotes may also be passing through the area in search of prey, such as deer or rodents. Another possibility could be the placement of these slash walls influenced a species' daily movements. Deer for example, may perceive slash walls as a large barrier. However other species, such as fisher, foxes, and bears, easily climbed over or through the woody debris.

The greatest species richness was observed in April and May. However, as the study progressed into June and July, species diversity declined and the photos were dominated by white-tailed deer. Perhaps a longer-term study would have produced more conclusive results. Previous studies observed how small mammals and invertebrates interacted with brush piles and CWD, while in this study, the cameras photographed mostly medium- and larger-sized mammals. In future studies, it would be helpful to capture and tag small mammals and monitor their movements (Sullivan et al. 2012).

Based on the literature and our results, slash walls may have important benefits for forest management in addition to protecting regeneration. As Smallidge et al. (2021) reported, slash walls were a cost-effective approach for excluding deer from regeneration harvests. They may also provide shelter and food resources for mammals, birds, and other species. This is a novel and unique management strategy that should be studied further. Slash walls and other large CWD structures are used by many taxa, and provide habitat structure for wildlife species.

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