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The Impact of Human Traffic on Wildlife Abundance on a Recreational Trail System in Southeastern Tennessee

Katherine Hesler and Aaron Corbit, Ph.D.

Abstract - Humans impact wildlife in numerous ways. The most serious being direct habitat destruction due to the expansion of urban landscapes, farmland, logging, and other activities that consume natural resources. However, even outdoor recreation in relatively protected areas can exert an influence. While consumptive outdoor recreational activities, like hunting and fishing, directly impact wildlife populations, non-consumptive outdoor recreation, like hiking or mountain biking, can impact wildlife in less overt ways. Simply the presence of humans in a natural area can disrupt normal animal behavior and drive animals away from important resources. In this study we used trail cameras to examine the impact of human traffic on the rate of wildlife detection on a private trail system in southeastern Tennessee during the Fall mating season. 92.9% of total camera sightings were from humans or domestic animals (i.e. domestics dogs) while only 7.1% were from native wildlife with most of these sighting (55.9%) coming from white-tailed deer (*Odocoileus virginianus*). Analysis using Poisson generalized estimating equations (GEEs) suggested an inverse relationship between the intensity of human traffic and the rate of wildlife detection. Analysis also showed that the portion of the trail system that had been developed the longest (since 2001) had lower cumulative wildlife detection and species richness than the portion of the trails system developed more recently (2016). An analysis of the time of day sightings occurred showed that peak activity for wildlife did not overlap with human activity. Wildlife sightings peaked in the morning while human activity peaked in the later afternoon/evening. Overall, these results confirm previous research that suggests that non-consumptive outdoor recreation can have significant effects on the abundance and behavior of wildlife.

Introduction

Humans continue to have a heavy impact on the biosphere, with most recent estimates suggesting that humans have altered at least three quarters of the Earth's land area (Sanderson, 2002; Grimm, 2000; Vitousek et al., 1997). Human impact on the biosphere include global climate change, loss of biological diversity, and shrinking natural habitats as urban landscapes expand and natural resources are consumed (Vitousek et al., 1997; Grimm, 2000).

Humans not only impact the biosphere as they work, but also as they play. Human participation in outdoor activity has increased in recent years (Reed and Merenlender, 2008; White et al., 2014). This outdoor recreation falls into two general categories—consumptive, in which natural resources are consumed (e.g. fishing, hunting, insect collecting), and nonconsumptive, in which the participant does not take from nature (e.g. hiking, climbing, mountain biking, camping) (Knight and Gutzwiller, 1995). Because of its obvious direct impacts on wildlife populations, consumptive recreation is often regarded as having negative effects (Wood, 1993). However, though these kinds of activities must be regulated in order to make them sustainable, they can generate revenue for conservation purposes (Organ and Fritzell, 2000).

Here we focus on the impacts of nonconsumptive recreation, which is often assumed to have minimal effects on wildlife (Reed and Merenlender, 2008). However, despite the fact that nonconsumptive recreation does, overall, have less of an impact on wildlife, it is, by no means, completely benign. Negative effects, caused by nonconsumptive recreation, have been documented and are summarized in Table 1.

Table 1. Documented effects of nonconsumptive recreation on wildlife.

Human Effects on Wildlife	**Citation**
Decline in wildlife community composition when certain species leave an area in order to avoid humans	Reed and Merenlender, 2008
Increases in energy-expenditure when animals flee from humans	Miller and Knight, 2001; Blanc et al., 2006
Reductions in species ranges and populations when wildlife avoids part of its natural range	Ewert, 1999
Decrease in activity levels, such as cessation of foraging	Taylor and Knight, 2003; Knight and Cole, 1995
Simplification of wildlife habitats through an increase in sediment yield and erosion due to continual and regular human "trampling" of soil, which decreases plant species on and near the trail	Deluca et al., 1998; Jordan, 2000; Porter and Bright, 2003; Weri, 2000; Wright, 2000; Blanc et al., 2006

In this study, we sought to characterize the effect of nonconsumptive recreation on wildlife abundance and diversity within a private trail system in southeastern Tennessee. Our particular focus was on the effects of hiking and mountain biking, which are the two most common uses for this trail system. This location also allowed us to look at the differences in wildlife abundance and richness between a recently developed trail system and one developed fifteen years prior.

Methods and Materials

Location

This study was conducted on a series of private recreational hiking and mountain biking trails located in Collegedale Tennessee (near Chattanooga). The trails, collectively known as the Biology Trails, are owned and managed by Southern Adventist University and are adjacent to the main campus. The trail area lies within the Southern Shale Valleys, a part of the Ridge and Valley ecoregion (ecoregion 67; EPA, 2013). This area is also known as the Great Valley of Tennessee, which falls between the Blue Ridge Mountains to the east and the Cumberland Plateau to the west (Griffith et al., 1999; Arnwine et al., 2000). The climate is temperate and the habitat is characterized by a mix of oak-hickory- pine forests (The Nature Conservancy, 2003; Amick, 1934; Braun, 1947).

The Biology Trails comprise two separate trail systems that together include a total of 32 miles of trails. The White Oak Mountain trails, west of campus, began to be used by the community approximately ninety years ago. However, major development of these trails began in 2001 when the Biology Department at Southern Adventist University took on the responsibility of organizing the trails for use by hikers and bikers (Foster and Cammack, 2011). Since that time, new trails have been added, and currently there are about 20 miles of trails on White Oak Mountain (Guth, 2015). The trails on Bauxite Ridge, east of the campus, are more recent. Development began in 2015 and they opened officially in 2016 (Hankins, 2013). Currently, there are 12 miles of hiking and biking trails on this system ("Sabbath", 2016).

Figure 1: Placement of trail cameras (two per site) in Collegedale, TN. The circle shows the location of Southern Adventist University's campus. Sites 1-5 were located on the older White Oak Mountain trails system while sites 6-10 were located on the newer Bauxite Ridge trail system.

Survey Method

The study was conducted in the Fall of 2016 (16 October–27 November) so as to coincide with the breeding season of the white-tailed deer (*Odocoileus virginianus*), which are known to be abundant in this area (Clement et al., 2011; Nixon et al. 1991).

We distributed trail cameras at ten different sites throughout the trail systems. Five sites were located on the White Oak Mountain trail system and five sites on the Bauxite Ridge system. At each site two cameras were posted, both attached to the same tree but facing opposite directions; one camera was set to face the trail and other set to face away from the trail. This was done to increase the field of view for each site so as to document both human and wildlife traffic at each site.

The cameras used in this study were Browning Strike Force BTC-5 Trail Cameras (Browning, Morgan, UT) featuring infrared LED illumination to make them effective at night. The trail cameras were set to take three pictures when they were motion-triggered in order to increase the chances of capturing images that allowed animal identification. These images were used to establish the dates, times, and types of animals (both human and wildlife) visiting each site.

Statistical Analysis

We calculated wildlife abundance and human traffic for each site by counting each animal or person observed in photographs from each camera site during the 6-week study period. We categorized sightings as either a human or other domestic animal (domestic dog or cat), or as wildlife. The species richness was determined by tallying up the number of different species observed at each site. In order to examine the time of day sightings occurred, we also calculated the number of sightings for each hour of the day across all days in the study for both humans/domestic animals and wildlife.

We used a Poisson generalized estimating equation (GEE) with an “exchangeable” correlational structure and grouped by camera site to test if there was a significant relationship between the number of sightings of human/domestic animals and number of sightings of wildlife per camera site per day. Statistical calculations were made using R 3.2.3 (R Core Team, 2016) with the alpha value set to 0.05. Our independent variables were human/domestic animal sightings per camera per day (log transformed), trail system (White Oak Mountain vs. Bauxite Ridge), number of days since the beginning of the year, the mean daily temperature (obtained from the Southern Adventist University weather station accessed on wunderground.com), and the presence or absence of daily precipitation. Our dependent variable was wildlife sightings per camera per day.

Results

In total, the cameras were triggered 3092 times. Of these, 2008 (64.9%) provided useful images that allowed for animal identification. These images yielded a total of 2833 sightings of humans, domestic animals, and wildlife (some images showed more than one animal). Human/domestic animals comprised a majority of these with 2629 observations (92.8% of total sightings). These included 2,471 human sightings (94.0% of domestic sightings), 157 domestic dog sightings (6.0%), and 1 domestic cat sighting (0.04%; Table 2). There were a total of 204 sightings (7.2% of total sightings) of wildlife. Deer were the most common sighting (113 sightings; 55.4% of wildlife sightings), followed by raccoon (35 observations; 17.2%), and other species (56 observations; 27.4%; Table 2).

The majority of human and domestic animal sightings occurred at site 1 and site 2 located on White Oak Mountain (see Figure 1). Wildlife sightings were highest at sites 10 and 6, which were both located on the trails on Bauxite Ridge (see Figure 2). Species richness was greater on the Bauxite Ridge trails than on the White Oak Mountain Trails (see Figure 3). On White Oak Mountain, wildlife sightings included three species: the white-tailed deer (*Odocoileus virginianus*), common raccoon (*Procyon lotor*), and eastern gray squirrel (*Sciurus carolinensis*). On Bauxite Ridge, wildlife sightings included ten species: the white-tailed deer (*Odocoileus virginianus*), common raccoon (*Procyon lotor*), eastern gray squirrel (*Sciurus carolinensis*), eastern fox squirrel (*Sciurus niger*), eastern chipmunk (*Tamias striatus*), groundhog (*Marmota monax*), Virginia opossum (*Didelphis virginiana*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), and wild turkey (*Meleagris gallopavo*).

We found distinct differences between the times when wildlife were detected versus when humans and domestic animals were detected (see Figure 4). Wildlife sightings began to increase between 6 and 7 a.m., peaking and 8 a.m., and declining between 9 and 11 a.m. (most of the sightings were of deer). This sharp decline in wildlife sightings was associated with an increase in human and domestic animal sightings. Human and domestic animal activity was highest between 12 p.m. and 7 p.m., and peaked between 6 and 7 p.m. After 7 p.m., these sightings decreased dramatically.

Our GEE analysis revealed that increased amounts of human and domestic animal traffic per camera per day was associated with declines in the amount of wildlife detected per camera per day (Parameter estimate = -0.29, SE = 3.21, Rate ratio = 0.75, $p = 0.034$; See Figure 3). The trail system (White Oak vs. Bauxite) also affected the amount of wildlife detected (Parameter estimate = -1.49, SE = 0.50, Rate ratio = 0.22, $p = 0.003$) with the statistical model suggesting that the rate of wildlife sightings on Bauxite Ridge was 4.55 times greater than the rate of wildlife sightings on White Oak Mountain (See Figure 4). Somewhat unexpectedly, our analysis also revealed a slight increase (about 3% per day) in wildlife sightings per day as the study progressed (Parameter estimate = 0.03, SE = 0.01, Rate ratio = 1.03, $p < 0.001$).

Table 2. The number of animal sightings by species on a private trail system in Collegedale, TN. Total sightings, sightings on the older White Oak Mountain trails, and sightings on the newer Bauxite Ridge trials are shown. The study period was from 16 Oct – 27 Nov, 2016.

Species	Total Sightings	White Oak Mountain	Bauxite Ridge
Humans/Domestic Animals			
Human (*Homo sapiens*)	2,471	1,758	713
Domestic Dog (*Canis familiaris*)	157	101	56
Domestic Cat (*Felis catus*)	1	0	1
Total	2,629	1,859	770
Wildlife			
White-tailed Deer (*Odocoileus virginianus*)	113	34	79
Common Raccoon (*Procyon lotor*)	35	1	34
Eastern Gray Squirrel (*Sciurus carolinensis*)	17	1	16
Bobcat (*Lynx rufus*)	10	0	10
Red Fox (*Vulpes vulpes*)	8	0	8
Wild Turkey (*Melegaris gallopavo*)	6	0	6
Coyote (*Canis latrans*)	4	0	4
Virginia Possum (*Didelphis virginiana*)	4	0	4
Eastern Fox Squirrel (*Sciurus niger*)	2	0	2
Woodchuck, Groundhog (*Marmota monax*)	2	0	2
Eastern Chipmunk (*Tamias striatus*)	1	0	1
Unknown	2	1	1
Total	204	36	166

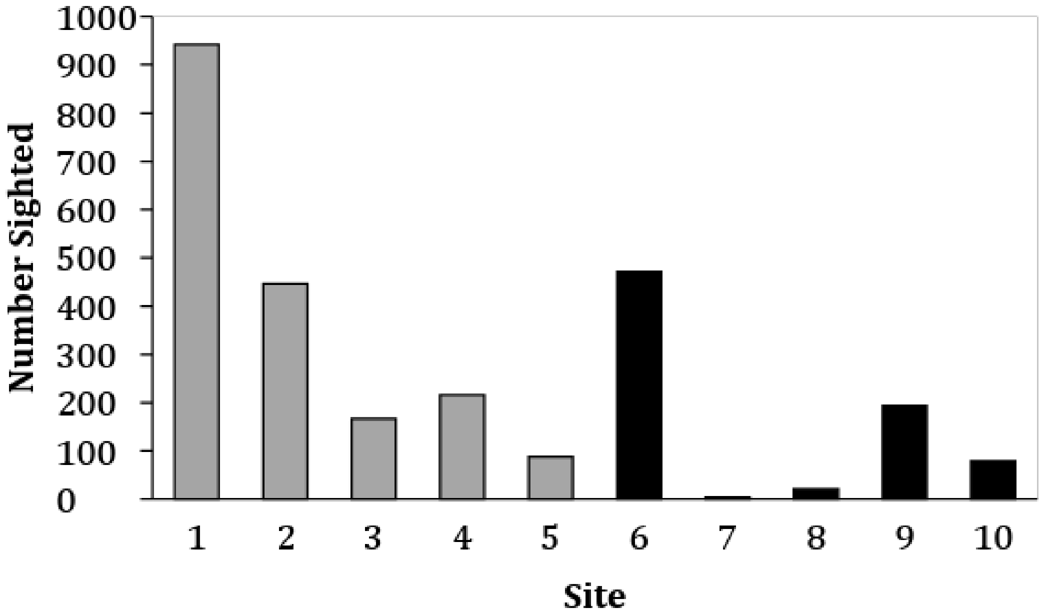

Figure 1. Total number of human/domestic animal sightings at each trail camera site during the 6-week study period (16 Oct – 27 Nov, 2016) in Collegedale, TN. Sites 1-5, indicated by the grey bars, were located on older White Oak Mountain trail system. Sites 6-10, indicated by the black bars, were located on newer Bauxite Ridge trail system.

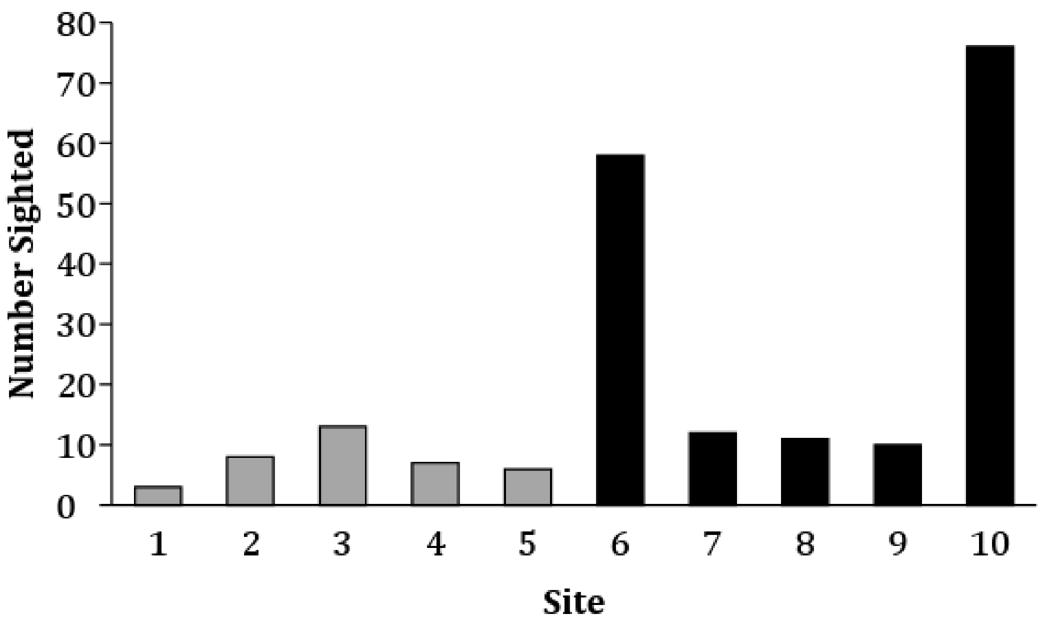

Figure 2. Total number of wildlife sightings at each trail camera site during the 6-week study period (16 Oct – 27 Nov, 2016) in Collegedale, TN. Sites 1-5, indicated by the grey bars, were located on the older White Oak Mountain trail system. Sites 6-10, indicated by the black bars, were located on the newer Bauxite Ridge trail system.

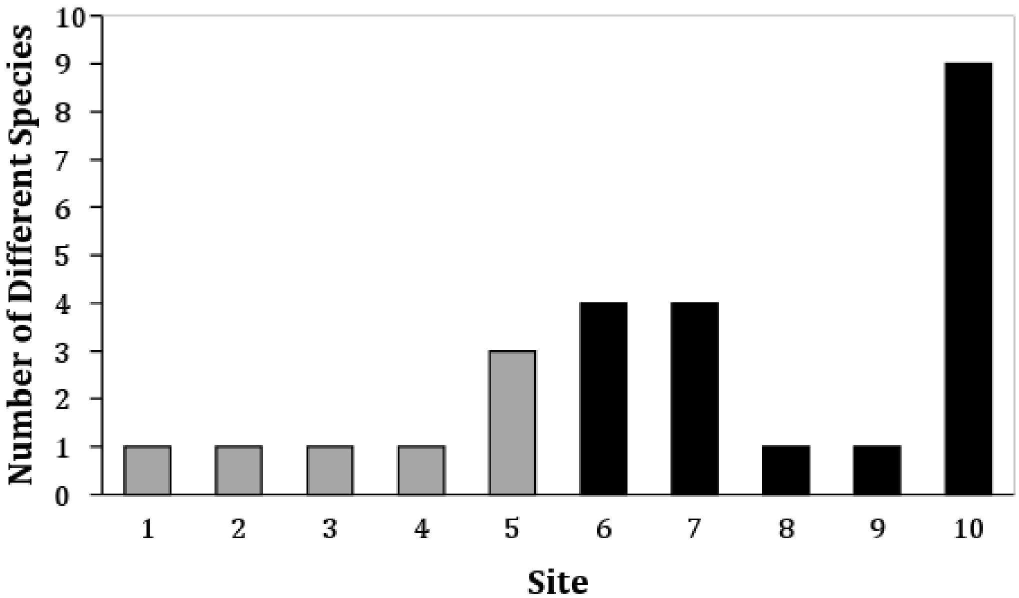

Figure 3. Species riches at each trail camera site during the 6-week period of study (16 Oct – 27 Nov, 2016) in Collegedale, TN. Sites 1-5, indicated by the grey bars, were located on the older White Oak Mountain trail system. Sites 6-10, indicated by the black bars, were located on newer Bauxite Ridge trail system.

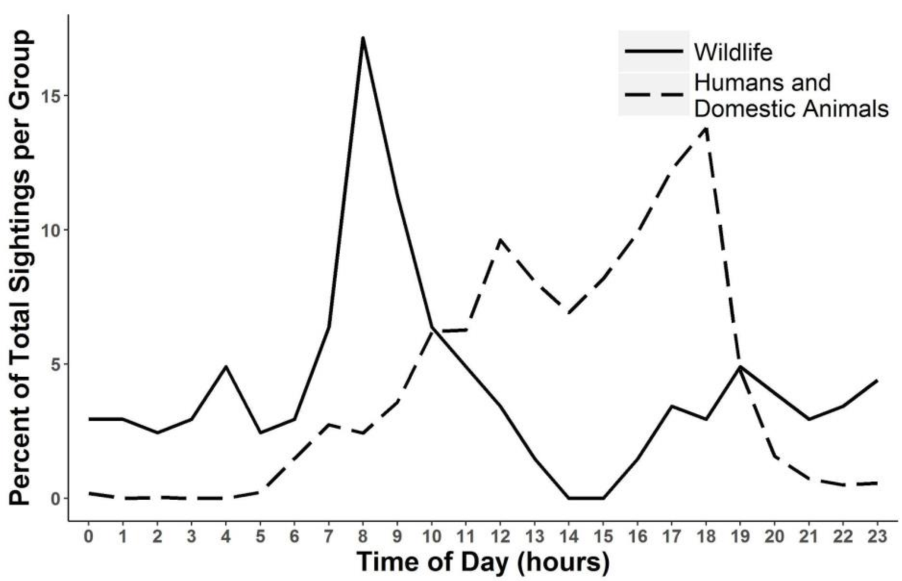

Figure 4. Total sightings per hour over the duration of the study period (October 16 – November 27, 2016) for both human/domestic animals (dashed line) and wildlife (solid line) based on images from 20 trail cameras on a private trail system in Collegedale, TN.

Discussion

Our findings suggest that non-consumptive recreation can cause animals to adopt behaviors for avoiding human presence. Overall, our results suggest that 1) greater human traffic on a particular day lowers the amount of wildlife present on that day, 2) areas that have been exposed to significant human traffic for longer periods of time may have lower wildlife abundances, and 3) that some animals may alter the timing of their normal activities in order to avoid humans.

Relationship of human traffic and wildlife abundance

Our most robust finding, based on the GEE model, is that amount of human traffic per day is inversely related to the rate of wildlife detection per day. This is consistent with previous findings. Human traffic in outdoor recreational areas is known to distress wildlife and disrupt normal behaviors which can lead to animals, particularly large mammals, abandoning areas even when they contain useful resources (Boyle and Samson, 1985; see Table 1).

Comparison of White Oak Mountain and Bauxite Ridge

We also found a notable difference in the number of wildlife sightings between the older White Oak Mountain trail system and newer Bauxite Ridge trail system; with our GEE model suggesting that the rate of wildlife sightings being 4.55 times greater on the newer trail system (also see Table 2). Since the GEE model controlled for human traffic, this difference cannot be accounted for simply by noting the difference in human/domestic animal traffic between the two trail systems. The fact that Bauxite Ridge was opened to the public more recently may offer a reasonable explanation. Since human/domestic animal traffic in this area is more recent, wildlife in the area will have had less exposure to human traffic and, therefore, less disruption and displacement. While the infrequent presence of a low number of hikers may only result in the temporary displacement of wildlife, recurrent human traffic could result in certain wildlife permanently abandoning areas that may even contain crucial resources (Taylor and Knight, 2003). If this hypothesis is true, then we expect the wildlife abundance on the Bauxite Ridge trail system to decrease until it becomes similar to that of the White Oak Mountain trail system. This hypothesis is supported by other studies, which show that non-motorized human activities within wildlife areas can disrupt and displace wildlife (Knight and Cole, 2013; MacArthur et al., 1982; Cassirer, 1992; Sauvajot et al., 1998, Blake et al., 2017).

However, since our analysis did not control for other factors between the trail systems, such as differences in habitat types and proximity to residential development, this hypothesis is less robust. For instance, while both trail systems are primarily located in forested areas and are near some residential developments, the Bauxite Ridge trail system does boarder more open pastureland and is adjacent to fewer residential areas (see Figure 1). This greater diversity of habitats and reduced exposure to human development may facilitate greater abundance and diversity of wildlife (Kays et al. 2016).

Diel Activity Patterns

The time of day we observed the most human/domestic animals is consistent with other studies and corresponds to people engaging in recreation after the day's activities, such as work or school (Pigram and Jenkins, 2006). However, patterns of wildlife observation we observed may not be consistent with normal diel activity. Previous research on white-tailed deer (the most abundant wild animal observed in our study) shows a crepuscular activity pattern with peak activity at dawn and dusk (Beier and McCullough, 1990; Coulombe, Massé & Côté, 2006; Saunders, 1988). While our study does observe wildlife activity peaking in the morning, we did not observe the corresponding peak in activity in the evening that we would expect from the white-tailed deer in our study (Figure 4). Since peak human activity occurs precisely during the time we would expect to see an increase in crepuscular wildlife activity, the absence of a significant wildlife activity peak in the evening may suggest avoidance of human presence.

However, white-tailed deer are also known to move to more open habitats at night (Beier and McCullough, 1990). Since all of our camera sites were located in forested areas, the lack of evening sightings could be the result white-tailed deer moving to more open habitats and away from the forested areas were they could be detected by our cameras during that time.

Conclusion

Taken as a whole, our results add to the growing body of research that documents the impact of non-consumptive recreation on wildlife and suggests that hiking and mountain biking can cause animals to alter their normal behavior to avoid humans and can reduce wildlife abundance and diversity in areas with human traffic. Our findings may be useful in informing the decisions of those who maintain recreational trails systems for hiking and mountain biking and spur further research into how the negative impacts of non-consumptive recreation on wildlife can be minimized.

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