

Development of Keras image classification model for use with a study on the effects of recreational trail use on small mammal species richness and activity

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Abstract

The recreational trails near the Rocky Mountain Biological Laboratory (RMBL) are an important resource for the community. They generate tourist income for the surrounding area. However, human activity can lead to behavioral and ecological changes in wildlife communities. Utilizing triggered camera traps for small mammals implemented from a study conducted in 2019 and 2020, along with trail cameras, we investigated the effects of recreational trails on small mammals along different habitats. This study developed a Keras image classification model for the rodent activity from bucket camera trapping. The Keras model successfully categorized the diurnal golden-mantled ground squirrel (*Callospermophilus lateralis*) and least chipmunk (*Tamias minimus*) but was unable to distinguish between the more similar deer mouse (*Peromyscus maniculatus*) and montane vole (*Microtus montanus*). We found that different levels of pedestrian and biker activity did not affect the presence of the small mammals overall. However, a more detailed analysis of the diurnal activity patterns of chipmunks and ground squirrels found that their activity near the trail decreases with increased pedestrian and biker activity. Closer attention should be put on smaller organisms found near trails to monitor how high human activity is leading to lowered small mammal activity.

Introduction

Recreational trails are essential for connecting people with nature, creating public support for protected areas, and generating \$80 billion in revenue in the U.S (USDA 2019). In particular, trails provide public access to lands and wilderness in a safe way and allows for a greater understanding of the environment. While the public is able to take advantage of all the benefits that recreational trails provide, trail usage can promote or cause trail proliferation, off-road vehicle use, vegetation trampling, and habitat alteration (Muter et al. 2005, Suavajot et al. 1998). Outdoor recreation is the second leading cause for the decline of federally threatened and endangered species on public lands (Losos et al. 1995). These factors can lead to ecological impacts on species abundance and biodiversity (Muter et al. 2005). Most protected areas are tasked with protecting natural resources while allowing for recreation (Hammitt et al. 2015). Although conservation efforts have implemented mandates to prevent habitat damage and strategies to reduce these threats, such as limited access for bikes and off-road vehicles, there are still impacts such as vegetation trampling, and habitat alteration caused by hikers.

Hikers might expect to interact with nature by sight-seeing, interacting with animals, and plant collecting. Although people wish to see scenic nature on their hike, high foot traffic causes vegetation damage and alters animal behaviors (Sauvajot et al. 1998). Research has shown that trails through meadows have less vegetation, more exposed soil and rock, and greater soil loss (Barros et al. 2013). In addition, biodiversity is potentially reduced by major disturbances which counters regulations and mandates such as hiking. (Kays et al. 2017). A study in California showed disturbed sites in the chaparral had lower mammal richness and a reduced mammal abundance (Suavajot et al. 1998). Habitat destruction can have direct effects of reducing food resources for animals. In addition, the presence of humans can affect foraging behaviors, antipredator behaviors, habitat selection, and time budgets of wildlife, in particular these effects are less studied in small mammals (Utrecht 2020). These indirect effects can also influence the fitness and abundance of both large and small mammals near trails.

Through these studies, it is imperative we gain a better understanding of how the presence of humans in nature affects the organisms that inhabit the wilderness near trails. At Gothic, Colorado it has not been studied how recreational usage can affect wildlife by negatively or positively impacting animal population, biodiversity and feeding behaviors. Leslie Macias, a former RMBL student, suggested that human activity may create a safe environment from predators for some mammals (Macias 2019). A similar study mentions that small mammal prey species can be more attracted to busier trails as they might use humans as shields against predators and potentially show no decrease in biodiversity (Cameron et al. 2020, Kays et al. 2017). For example, a study found that a bear and her cubs stayed near humans to avoid aggressive males. (Nevin and Gilbert 2005) These studies show that human presence can cause predator displacement which indirectly benefits prey species, as prey species may not be displaced by humans (Muhly et al. 2011). Even though the bear and her cubs are predators, it shows that people might influence wildlife when there is recreational trail usage. On the other hand, studies have shown that not all predators are affected the same by human activity. A study showed that bobcat, coyote, and gray fox (mesocarnivores) had little change in trail use when an increase of human activity happened on the trail. (Townsend et al. 2020) The effect hikers can have on wildlife can be direct and indirect. Small mammals that may never see a human can also be affected by the changes humans bring. In addition, there can be cascading effects through ecosystems, many carnivores depend on small mammal populations as food sources. For these reasons, we are interested in seeing how small mammals are affected by human activity to better manage human use of recreational trails.

In 2020, we conducted a study to observe the effects of recreational trails on small mammals and other wildlife. There were some limitations with our data that motivated us to change part of the experimental design. We were unable to control habitat and motorized traffic on trails and we believe that could have misinterpreted our rodent data. We also had difficulty categorizing the large number of trail and bucket pictures. We wanted to refine our methods and analysis with additional image data. In this study, we compared rodent activity from bucket-cam trapping to a live-trapping census to verify that our bucket traps were able to capture all of the rodents present in an area, their diversity and abundance. Longworth live-traps were used on established long-term research grids (used by Dr. Rosemary Smith) to obtain data of small mammal activity. The Longworth live-traps are designed to minimize discomfort without endangering or having a large impact on the animal. Comparing these two methods increased our understanding of small mammal communities and the best methods to study them. With camera-trapping, the technology of infrared sensors and digital photography leads to cost-effective and noninvasive means of generating reliable counts of wildlife and their activity (Burton et al 2015). By using human recreation trail data collected by Vaneza Rodriguez, a current student at RMBL, we were able to compare human activity along a trail to rodent activity on the same trail. To efficiently categorize the small mammal pictures, a Keras classification model was written. Keras is a deep learning library that abstracts neural networks and encapsulates rich and friendly application programming interfaces. Keras is written in Python and image recognition models built for other uses have had 90 - 97.6% recognition rates. (Wang et al. 2020, Li et al. 2017)

The aim of this study was to investigate the species diversity and abundance of small mammals among trails with different levels of human recreational activity. We measured small mammal activity at four sites that vary in human usage (foot, foot+bike, low and high use) and compared it to the paired data collected by Vaneza Rodriguez. Our null hypothesis was that there

is no difference in species abundance and diversity among trails with varying levels of human activity. It's possible that biking or hiking activity might not affect small mammals, especially nocturnal mammals, and therefore there would be no differences among the four trails. Alternatively, trails with higher human activity might have the same diversity (species richness) of small mammals but might have lower or higher abundance. This is hypothesized as higher levels of foot-traffic or biker-traffic might cause vegetation damage, disrupt foraging activity, and/or avoidance behavior for small rodents, which would decrease abundance. Trails may decrease predators, and thus pose a safe haven for small rodents, so their abundance would be higher. Finally, another alternative is that trails with higher human activity will have lower diversity of small mammals, but a similar abundance of those species compared with trails with varying levels of human activity. This is hypothesized as some species may be negatively affected, while others may be positively affected by different types of human recreation.

Methods

Study Site and Species

The study site is located in the Upper East River Valley (UERV), on both private and USFS land near Gothic, Colorado, USA. The camera traps (trail and small mammal) were deployed at four trails sections that differed in their designated (signed) allowable use: USFS Trail 401 (horseback, hiking, biking), USFS Deer Creek Trail (horseback, hiking, and biking), and RMBL/private: Judd Falls and Gothic Shortcut hiking/horseback use only, and hiking only, respectively. These trail sections were selected to provide a range of expected levels of non-motorized recreational usage (Dr. Rosemary Smith, Vaneza Rodriguez and Daniel Novoa personal observations, 2020 study with Maddy Uetrecht). Expected small mammals that should enter the bucket traps are the diurnal golden-mantled ground squirrels (*Callospermophilus lateralis*) and least chipmunks (*Tamias minimus*) and the nocturnal deer mice (*Peromyscus maniculatus*), Western jumping mice (*Zapus princeps*), and montane voles (*Microtus montanus*).

Camera Traps

To measure non-motorized human activity on trails, we collaborated with Dr. Dan Blumstein (RMBL and UCLA), who provided the trail cameras for use in the project (Rodriguez). We deployed two cameras per trail paired with two small mammal bucket camera traps. Each trail had five camera placements in an open meadow habitat and five camera placements in a covered habitat (aspens or conifers). The trail cameras were moved to a random camera placement every week for 5 weeks (June 21-July 29). The Trimble Geo 7x was used to find the coordinates for the camera placements, and they were flagged on the first week. At the same time, the Garmin Etrex Vista HCx was used to mark waypoints, which allowed us to find our flagged placements throughout the experiment timeline. The cameras were placed on either a one third meter tall wooden stake or a tree no more than one meter away from the trail. See Table 1 for description of trail cameras and settings. The cameras were set with a photographic rate of 1 shot per trigger with an interval of 10 seconds between each shot. In addition, the cameras were set to low sensitivity and angled at a 45-degree angle facing the trail to decrease the risk of false positives. An image size of 4 MP was set to increase image storage space on the SD cards. Each week at each site, we checked each camera's battery percentage, recorded the number of pictures taken, and changed the SD cards. We sorted the pictures by human activity into different

categories and noted the time and habitat type (cover, open): number of bikers, number of pedestrians, dogs, predators, etc. Once the pictures were sorted, we obtained different measures of human activity per trail, habitat type, and nocturnal/diurnal. Each photo counted as an event, regardless of the number of people/bikes in the photo.

Bucket Camera-Traps

Using a similar approach to a method used in Macias (2019), a modified version of the Hunt trap, involving camera-trapping, was deployed on the trails to measure the relative abundance and richness of small mammal wildlife. The 16 modified bucket-traps were built with a 26.6 L (7-gallon US) bucket and a fitted lid. Each bucket had two ~4 cm round holes cut out of the sides of the bucket near the bottom to allow small mammals access. The camera was attached to the lid using two small holes threaded with metal wire and placed facing the bottom of the bucket. A small amount of bait was added when the buckets were deployed. A camouflage cloth was placed on top of the bucket with a tight mosquito net to keep the fabric in place. The purpose of the camouflage cloth was to conceal the bucket from humans using the trails and prevent excess light from overexposing the pictures. The Browning cameras had to have part of their flash covered by black electrical tape to help prevent picture overexposure inside the bucket (Figure 1).

The camera trap pictures were entered into an Excel spreadsheet and counted by rodent visits. We sorted the rodent pictures by trails, habitat and nocturnal or diurnal activity. We recognized that multiple shots could be taken in the same interaction and care was taken to group these sets as recommended by Rowcliffe et al. (2008). Once the pictures were sorted, a python script was used to create a rodent index. The rodent index was used to look at the rodent presence throughout the day. A day was divided into 15-minute increments with a total of 96 opportunities for a rodent to be in each bucket each day. The python scripts looked at the 96 time slots and noted whether a rodent was present, if a rodent was in the bucket, then it would also note the species of the rodent, the type of rodent activity (nocturnal or diurnal) and the time.

Two bucket traps were paired with a trail camera. An image size of 20 MP was set to increase quality for image recognition model training. The buckets were placed five meters left and right from the trail cameras, no more than one meter away from the trail. Each week, the bucket traps were relocated based on the new location of their paired trail camera. Bait consisting of oats, horse feed, and peanut butter was placed directly in the camera's field of view. We visited the placements each week to relocate, check battery life, exchange SD cards, and replenish bait. The images were reviewed and indexed. Because of the proximity, the number of visits for both buckets within the same habitat were combined into one total activity measure per trail camera location.

Live Traps vs. Bucket Camera Traps

A live-trapping mark-recapture study using Longworth live-traps was conducted to estimate population sizes of nocturnal small mammals' species. The live traps were set out in grids, consisting of 49 trap stations arranged in 7x7 configuration and with each being set 10 meters apart. Traps were baited with a mixture of oats, horse feed, and peanut butter. Bedding

was placed in the nesting-chamber box. Each individual captured was identified by species, weighed, sexed, and marked before their release. Traps were opened at dusk and revisited early in the morning after dawn. One site was set and revisited for a total of six trapping days per site. The Schnabel multiple mark-recapture method was used to estimate population sizes for each species at each site. This estimate was compared to small mammal activity based on images from bucket camera traps placed on the same trapping grid on days that live trapping did not occur. Two bucket traps were set out for six days. The images were reviewed, and the number of unique visits were counted for each species. The pictures collected were indexed in the same way as the trail bucket cameras.

Keras Image Recognition Model

A Keras based image recognition model was built using 2021 rodent images as a training sample. 1,400 images were used for *Callospermophilus lateralis*, *Tamias minimus* and *Microtus montanus* 2000 images were used for *Peromyscus maniculatus*. More pictures were used for *Peromyscus* because our initial models had trouble distinguishing between *Peromyscus* and *Microtus*. Images of *Zapus princeps* were not used because the amount captured on the bucket cameras were not sufficient to process and teach the program to recognize the species.

Results

Our initial Keras based image recognition model (model A) was successful at recognizing *Callospermophilus lateralis* and *Tamias minimus* at about 97% accuracy but had trouble distinguishing between *Peromyscus maniculatus* and *Microtus montanus*. To solve this issue, we created an additional model (model B) that was able to separate *Peromyscus* and *Microtus*. To completely sort all pictures, two passes of the new data are required. Model A separates *Callospermophilus*, *Tamias* and “Others” into their respective folders and model B separates the others folder into the *Peromyscus* and *Microtus* folders. All python scripts and data sets can be found in our 2021 project metadata form.

We found that on the established rodent census grids, live trapping and bucket trap camera images detected the presence of mostly the same rodent species (Table 2). We also counted the number of rodent visits from the bucket traps, indexed the rodents and compared it to the Schnabel estimated number of rodents of each species from the live trapping grid. There was a positive relationship between the index of rodents from the bucket traps and the live-trapping estimates of abundance of the species for both *Peromyscus maniculatus* and *Microtus montanus*, but not for *Zapus princeps*, where there were no captured images/visits (Figure 1, Table 4).

To detect differences in trail, use and to quantify the usage patterns by activity type (pedestrians, bikers, etc.) time (diurnal/nocturnal, day of year, etc.) Vaneza Rodriguez categorized over 68,000 trail camera images. Using Rodriguez’s dataset, we combined the bucket camera and trail camera data across the five-week study. When we looked at our rodent index split into *Peromyscus maniculatus* (nocturnal), *Microtus montanus* (nocturnal and diurnal mix) and *Callospermophilus lateralis* and *Tamias minimus* (diurnal) versus all human activity,

we found that there was no significant increase or decrease of rodent activity on trails with higher human activity (Figure 2, Table 5).

However, when we looked at direct effects of human activity on diurnal species on individual trails by combining and comparing the pictures taken from our paired buckets and trail camera. We saw strong evidence of a significant decrease of diurnal rodent activity in the bucket camera when there was high human activity on the trails. This was the case both when looking at the entire five weeks of data and at individual days, especially for *Tamias minimus*. When looking at the combined activity of the diurnal species *Callospermophilus lateralis* and *Tamias minimus* over an individual day, we saw that both species avoided human activity (Figures 3 and 4). We also saw a significant decrease in *Tamias* activity on Judd Falls trail with pedestrian activity, but no effect on *Callospermophilus* activity (Figures 5 and 6, Table 6). Similarly, we saw a significant decrease in *Tamias* activity on RMBL Shortcut trail with pedestrian activity, but no effect on *Callospermophilus* activity (Figures 7 and 8, Table 6). On the 401 trail we saw a significant decrease of *Tamias* activity with biking activity (Figure 8, Table 6).

Discussion

Overall, our studies showed that there were no significant negative impacts of high trail use on rodent species richness and abundance when looking at total human activity. However, when looking at direct effects on *Tamias minimus*, our results show that there is a significant negative effect with both high pedestrian and biking activity. Our results are similar to our 2020 study that showed there was a significant decrease of *Tamias* with high biking activity. They were also similar to studies that show human activity can lead to negative ecological impacts on species abundance and biodiversity (Muter et al. 2005). Although these studies focus on larger mammals (deer, elk, etc.) we expect that small diurnal mammals encounter humans at similar rates and scare away the rodents from the trails. Even though human activity did not show a negative or positive effect on *Callospermophilus lateralis*, we believe that since our *Callospermophilus* data was not as robust as our *Tamias* data it did not have enough data points to show us exactly how *Callospermophilus* react to human activity. This thinking comes from looking at a single day and noting that *Callospermophilus* activity tends to decrease as human activity increases (Figure 3).

We wanted to make sure the bucket traps images would be a reliable way to capture the species in our study area. Table 2 shows that the bucket traps and the camera traps captured mostly the same species of rodents. This allowed us to further confirm that the bucket traps were an effective way to determine the species diversity in an area, similar to the results found by Leslie Macias in 2019 and our 2020 study. Figure 1 shows that *Peromyscus* was captured in high amounts in both the bucket traps and the live traps, and that the captures were correlated. This was also the case for *Microtus*. However, there were not any *Zapus* images, even on sites where *Zapus* were known to be abundant. This could be for various reasons. One reason that *Zapus* failed to be reliably captured may be because the high number of *Peromyscus* might make them the dominant rodent in the area, and they kept the *Zapus* out of the bucket traps. Another reason we believe had a significant effect was the timing the bucket traps were placed in the rodent grid. Buckets placed at the Bellview site were placed right at the beginning of the study, while the live trapping happened almost one month apart from when the buckets were placed.

This could have caused our bucket trap data and our live-trap data to show different rodent distributions. Another reason for this difference could be that since our rodent grids are so large, having only two bucket traps per site could not be a fair way to estimate presence for the entire grid area. Our study in the live-trap comparison was not able to find a strong presence connection between live-traps and bucket traps. In future analysis, consideration of bucket number and placement in the live-trap grid should be made. Having a larger number of buckets per rodent grid placed evenly throughout the grid should be able to capture the presence of the entire grid. Another consideration could be to alternate live-trapping days and bucket trap days to not have live-trap data and bucket data be separated by a large amount of time.

Even though, from general observation while executing this study, the general public using the recreational trails near RMBL have been doing a good job at keeping the trails clean and undamaged. In our highest used trails, the diurnal mammals seem to be negatively affected by human activity. Closer attention needs to be put on smaller organisms found near trails to monitor how high human activity is leading to lowered small mammal activity. While our data indicated overall there were no significant impacts of high trail use on overall rodent activity, when looking at individual species we can see that is not the case. The USFS should be aware of the different affects pedestrian and biking activity have on the different species found near their trails. The USFS should also keep track of any significant increase of bikers and pedestrians on the trails because of the negative effect it has on the diurnal rodent species.

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Tables and Figures

Table 1: Camera settings for cameras used on trails and in buckets.

Camera	Photographic rate	Interval	Resolution	SD Card	Type
Browning Strike Force HD Pro X	1 shots per trigger	10 Seconds	4MP	Ultra San Disk	Trail
Browning Strike Force HD Pro X	1 shots per trigger	10 seconds	20MP	Ultra San Disk	Bucket

Table 2: Species present in live trapping and bucket camera comparison.

Species	Activity	Live Traps	Bucket Traps
<i>Peromyscus maniculatus</i>	Nocturnal	Present	Present
<i>Microtus montanus</i>	Nocturnal	Present	Present
<i>Zapus princeps</i>	Nocturnal	Present	Absent

Table 3: Summary of biker and pedestrian levels in each trail section from Rodriguez's dataset.

Trails	Bikers	Pedestrians
RMBL Shortcut	None	Low
Judd	Very Low	High
Deer Creek	Medium	Low
401	High	Low

Table 4: Regression data of rodent index and Schnabel population estimate.

Species	Degrees of Freedom	R ²	F - value	Significance
<i>Peromyscus maniculatus</i>	1, 1	0.2493	0.3321	p = 0.6672
<i>Microtus montanus</i>	1, 1	0.7116	2.4676	p = 0.3609
<i>Zapus princeps</i>	1, 1	0.0830	0.0905	p = 0.8140

Table 5: Regression data of rodent index and total human activity.

Rodent Activity	Species	Degrees of Freedom	R ²	F - value	Significance
Nocturnal	<i>Peromyscus maniculatus</i>	1, 38	0.0122	0.4676	p = 0.4982
Mix	<i>Microtus montanus</i>	1, 38	0.0399	1.5798	p = 0.2165
Diurnal	<i>Callospermophilus lateralis</i> and <i>Tamias minimus</i>	1, 38	0.0830	0.0905	p = 0.8140

Table 6: Regression data of human activity and diurnal species comparisons.

Trail	Comparison	Degrees of Freedom	R ²	F - value	Significance
Judd Falls	Pedestrians vs. <i>Tamias</i>	1, 16697	0.0444	775.873	p < 0.001
Judd Falls	Pedestrians vs. <i>Callospermophilus</i>	1, 50	0.0002	0.0097	p = 0.9219
RMBL Shortcut	Pedestrians vs. <i>Tamias</i>	1, 1845	0.2112	494.100	p < 0.001
RMBL Shortcut	Pedestrians vs. <i>Callospermophilus</i>	1, 363	0.0017	0.6332	p = 0.4267
401	Bikers vs. <i>Tamias</i>	1, 4575	0.1390	738.379	p < 0.001

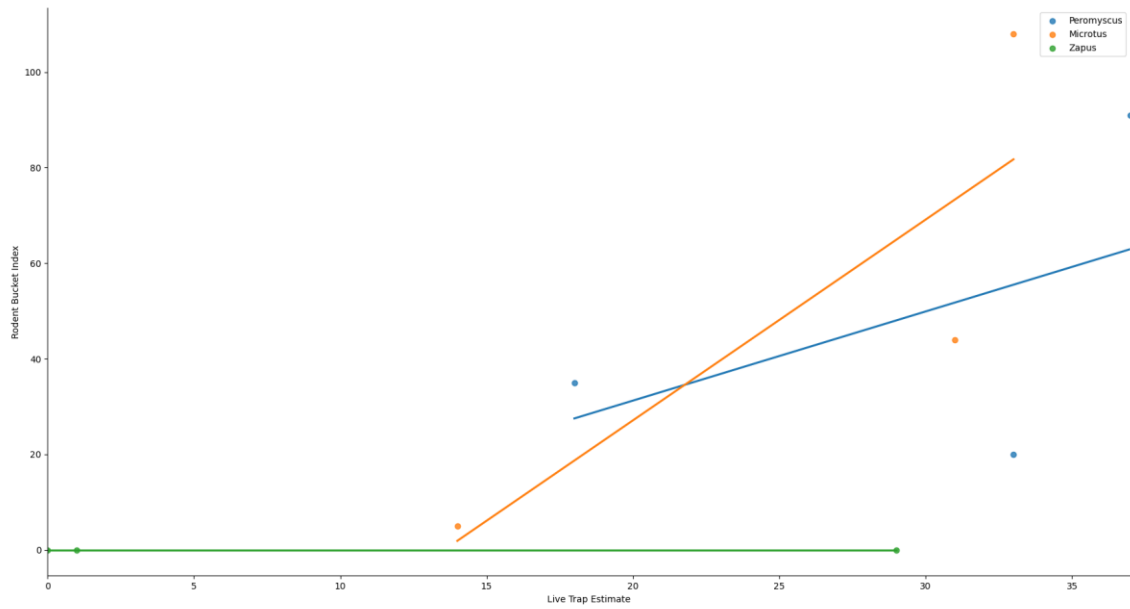


Figure 1: Relationship between number of rodents estimated from live trapping and number of rodents counted in the camera bucket traps.

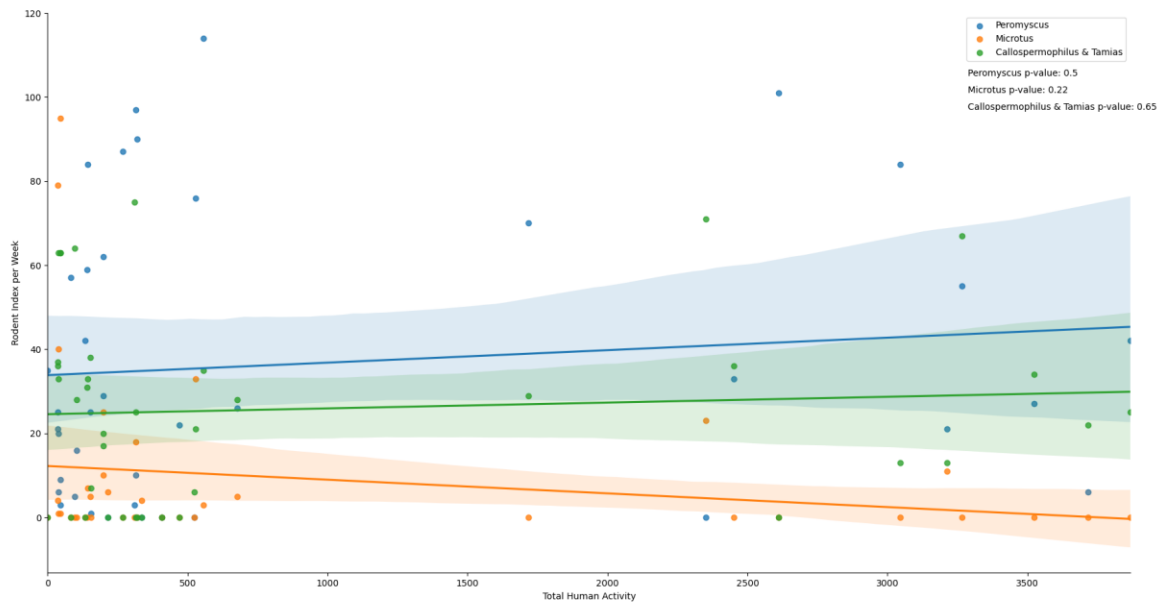


Figure 2: Rodent index per week vs. total human activity over five weeks.

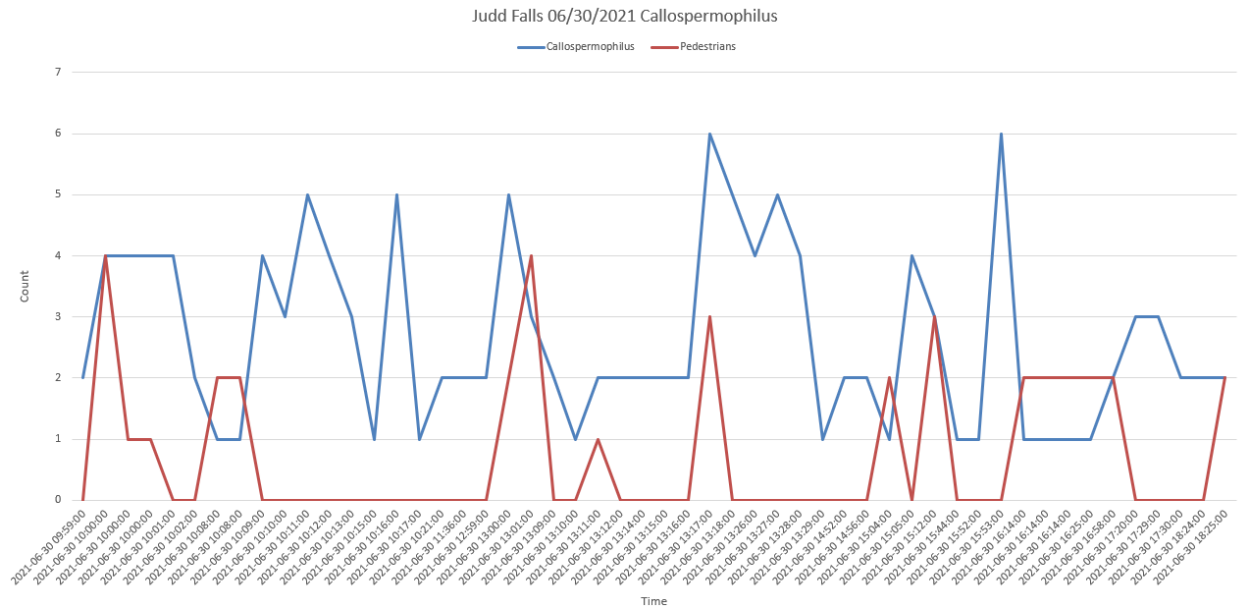


Figure 3: Callospermophilus and pedestrians over one day.

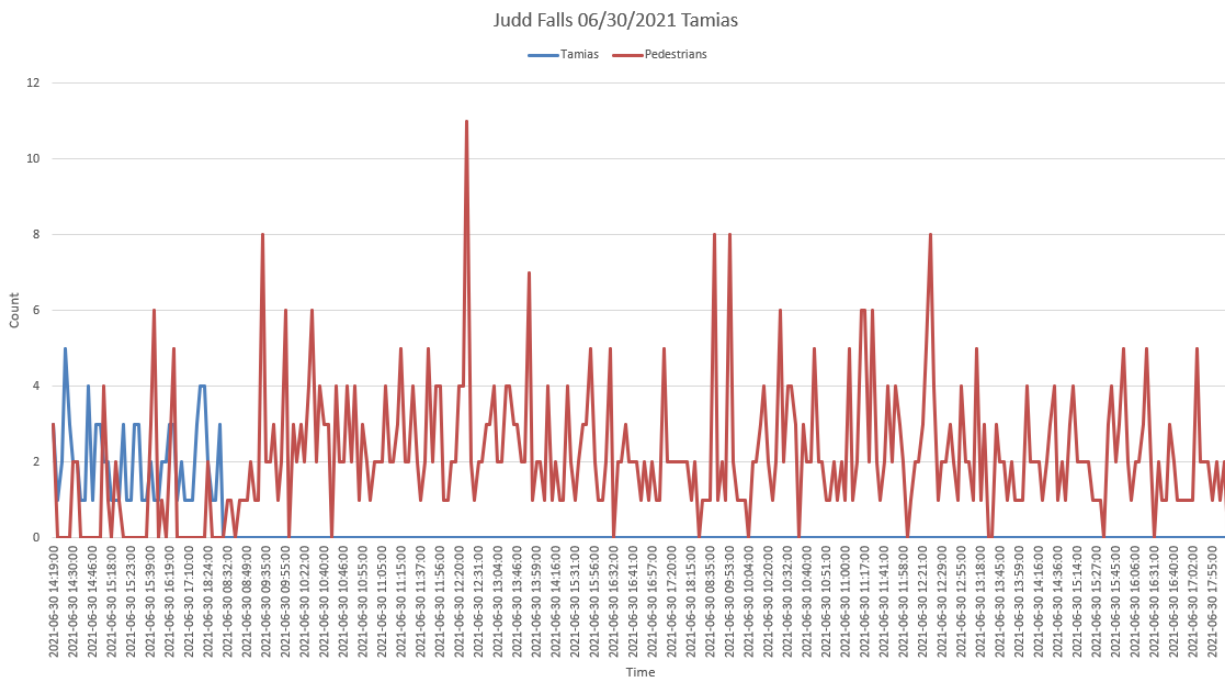


Figure 4: Tamias and pedestrians over one day.

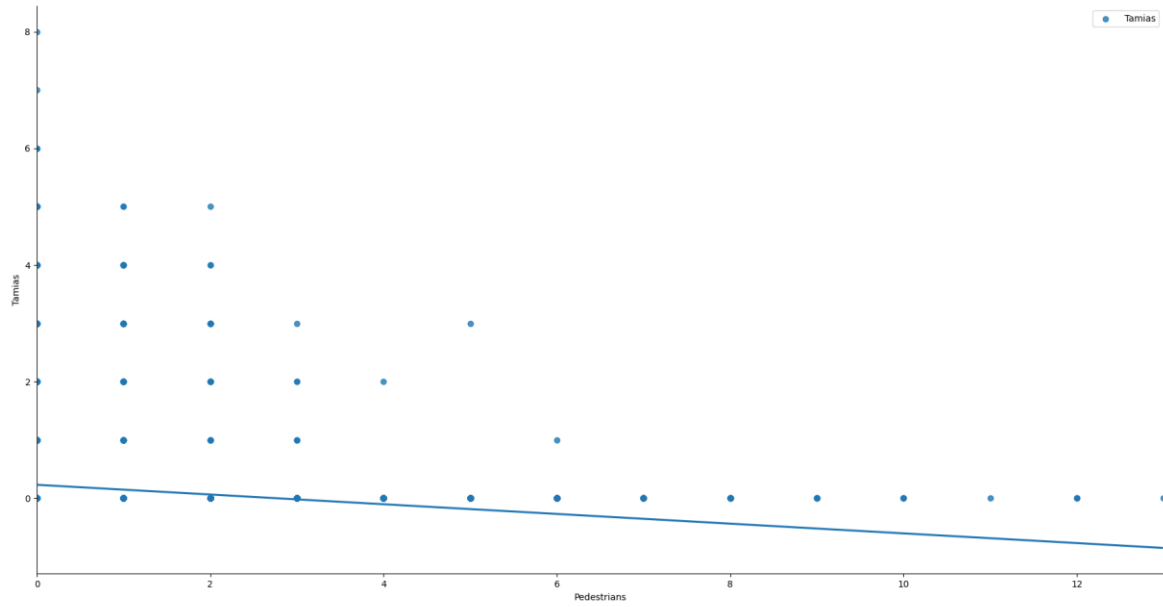


Figure 5: Pedestrians vs. Tamias on Judd Fall trail over five weeks.

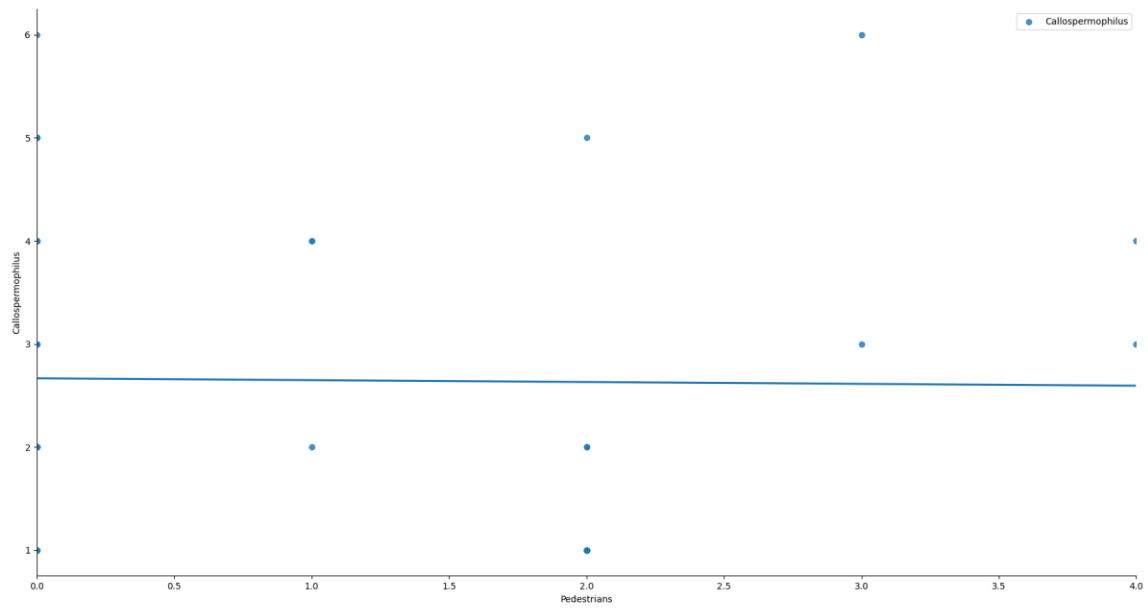


Figure 6: Pedestrians vs. Callospermophilus on Judd Fall trail over five weeks.

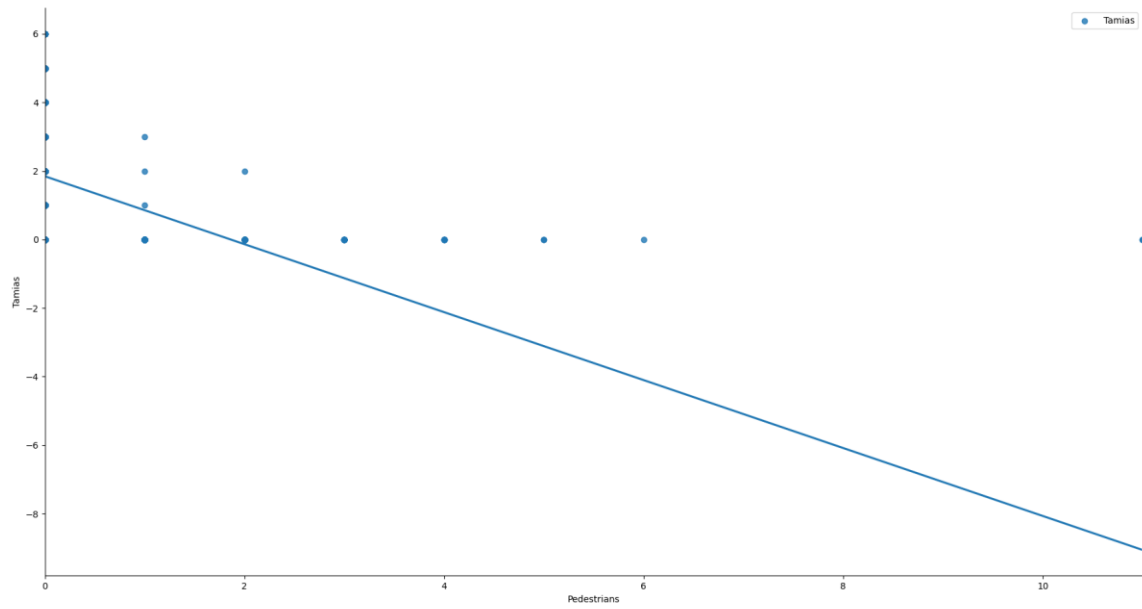


Figure 7: Pedestrians vs. Tamias on RMBL Shortcut trail over five weeks.

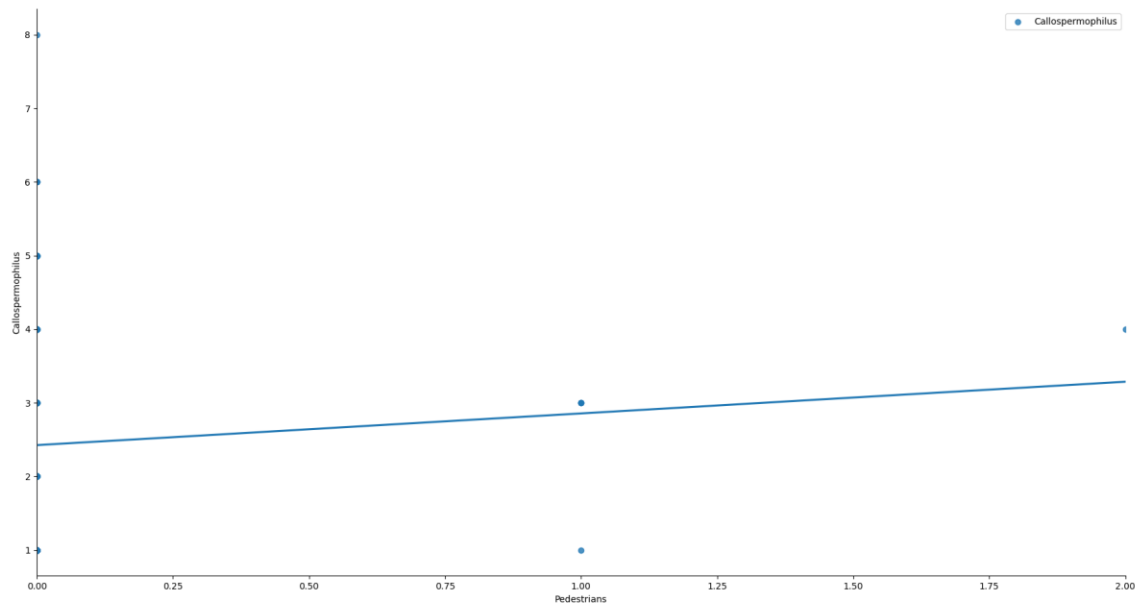


Figure 8: Pedestrians vs. Callospermophilus on RMBL Shortcut trail over five weeks.

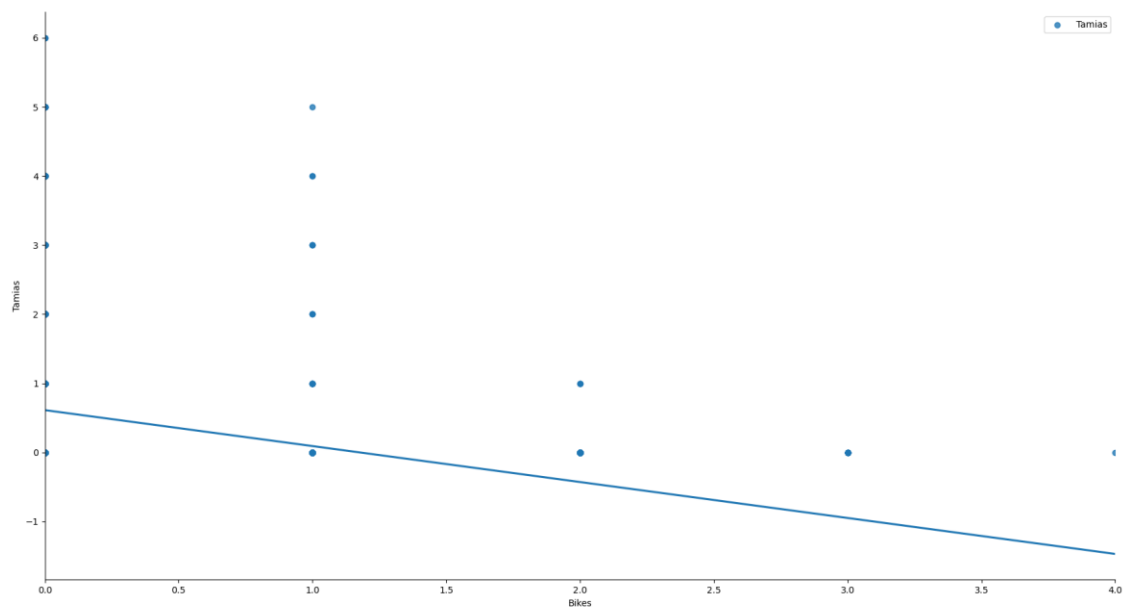


Figure 9: Bikers vs. Tamias on 401 trail over five weeks.



Figure 10: Examples of how to cover camera flash for trail use.



Figure 11: Map of Deer Creek trail with uncovered (blue) and covered (green) habitat bucket camera placements.



Figure 12: Map of Judd Falls trail (top) and RMBL Shortcut trail (bottom) with uncovered (blue) and covered (green) habitat bucket camera placements.



Figure 13: Map of 401 trail with uncovered (blue) and covered (green) habitat bucket camera placements.