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Occurrence and Ecosystem Effects of Hiking Off-Trail in Michaux State Forest

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Abstract

American public lands provide significant outdoor recreational opportunities that enhance an individual's physical and mental well-being. Hiking is an example of a highly accessible and affordable recreational activity that is popular and easy for people to engage in no matter how experienced they are. While hiking has improved the well-being of many individuals, its impacts on local ecosystems are often disregarded. For our research, we focused on the impacts that hikers deviating off-trail may have on a local ecosystem in Michaux State Forest in Southern Pennsylvania. Through partnering with the foresters at Michaux State Forest and using AllTrails data, we identified heavily trafficked, unmaintained trail areas and conducted numerous field visits to observe the ecological impacts of this continued off-trail use. At each of the sites, we set up trail cameras in order to measure trail traffic, measured trail dimensions at numerous locations, and used quadrats to examine noticeable impacts on ground cover and plant ecology. We found substantial off-trail use at Michaux State Forest, from legal trail "shortcuts" to fully illegal trails. Surprisingly, we found no evidence that off-trail use impacted overall vegetative cover. In all of the study sites, the official trail was wider than the beginning of the illegal trail area and the beginning of the illegal trail was wider than the trail at the placement of the trail camera. For future analysis, we recommend that soil analyses and longer data collection periods potentially through different seasons should be conducted, as our quadrat photos and physical observations were limited due to the leafy ground cover. Our recommendations for future management include increased signage intended to prevent off-trail travel as well as improved hiker education on the principles of Leave No Trace.

Keywords

Michaux State Forest, Trails, Illegal, Official, Usage

Disciplines

Forest Biology | Human Ecology | Place and Environment | Plant Sciences

Comments

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Occurrence and Ecosystem Effects of Hiking Off-Trail in Michaux State Forest

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ES 400

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Abstract

American public lands provide significant outdoor recreational opportunities that enhance an individual's physical and mental well-being. Hiking is an example of a highly accessible and affordable recreational activity that is popular and easy for people to engage in no matter how experienced they are. While hiking has improved the well-being of many individuals, its impacts on local ecosystems are often disregarded. For our research, we focused on the impacts that hikers deviating off-trail may have on a local ecosystem in Michaux State Forest in Southern Pennsylvania. Through partnering with the foresters at Michaux State Forest and using AllTrails data, we identified heavily trafficked, unmaintained trail areas and conducted numerous field visits to observe the ecological impacts of this continued off-trail use. At each of the sites, we set up trail cameras in order to measure trail traffic, measured trail dimensions at numerous locations, and used quadrats to examine noticeable impacts on ground cover and plant ecology. We found substantial off-trail use at Michaux State Forest, from legal trail “shortcuts” to fully illegal trails. Surprisingly, we found no evidence that off-trail use impacted overall vegetative cover. In all of the study sites, the official trail was wider than the beginning of the illegal trail area and the beginning of the illegal trail was wider than the trail at the placement of the trail camera. For future analysis, we recommend that soil analyses and longer data collection periods potentially through different seasons should be conducted, as our quadrat photos and physical observations were limited due to the leafy ground cover. Our recommendations for future management include increased signage intended to prevent off-trail travel as well as improved hiker education on the principles of Leave No Trace.

Introduction

America's public lands and parks provide a wide variety of different recreational opportunities that significantly enhance the lives of all individuals who visit them. The recreational opportunities provided through American public lands and wilderness areas, hiking being one of the most popular, are also critical due to their accessibility and affordability. Public lands consist of approximately 600 million acres of land throughout the United States, which include national parks, forests, wildlife refuges, and monuments, as well as state and local areas owned by the public (The National Wildlife Federation, n.d). This means that most Americans live within a reasonable distance from some form of public land in which recreational activities are possible.

While hiking is a popular recreational activity that is affordable and improves an individual's physical and mental health, the health of the natural environment is something that many fail to consider. Between 2000 and 2008, studies have observed a 12% increase in visitor days to primitive areas, often in mountain environments that are remote with great biodiversity (Butler & Martin, 2017). Prior work has acknowledged that both hikers and bikers traveling through forested and other sensitive ecosystems can cause erosion and trampling to occur (Cerdà & Salesa, 2020). Studies examining major trails with wide name recognition, such as the Appalachian Trail, have identified impacts caused by hiking and general overuse, as demonstrated through trail widening (Meadema, 2018). Throughout the past two years, the ongoing COVID-19 pandemic has driven more people to participate in outdoor recreational activities such as hiking. While this is a healthy choice for individuals looking to escape their increasingly isolated and sedentary lifestyles caused by the pandemic, there are potential impacts on environmental health that should not be ignored.

Mountain biking is a recreational activity which has recently gained popularity; therefore, not many are aware of its impacts on trails and ecosystems. Findings from numerous studies revealed that mountain biking did play a significant role in trail degradation and erosion; however, its impacts were on a similar scale to the impacts of hiking (Marion & Wimpey, 2007). Formal trails can be an effective method for mitigating environmental impacts of visitors in parks, through focusing traffic on one specific route to minimize the overall impact and damage (Leung & Marion, 1996). Informal trails, or off-trail hiking, are often created by hikers for purposes of reaching desirable locations; however, causing trampling and eventually larger scale erosion (Butler & Martin, 2017).

Various studies have observed that hiking off-trail can have significant impacts on plant growth, especially in sensitive regions. Previous literature identified that hiking off-trail can have adverse negative effects on the ecosystem, caused by skipping switchbacks (areas in which the trail zig-zags through a steep incline), trampling critical and vulnerable species, and the transfer of invasive species and unwanted seeds into softer, more fertile soil found in off-trail areas. One study examined vegetation impacts in the Andes Mountains, which struggled to handle hiker disturbance, causing disproportionate growth of species that are more resilient to disturbance (Aschero et al, 2020). Aside from its impacts on plant ecology and vegetation growth, off-trail hiking can have significant impacts on wildlife and animal behavior. A study examining Red Deer in Kellerwald-Edersee National Park showed that the deer were not sensitive to on-trail hiking, but were very sensitive to off-trail hiking (Balkenhol et al, 2018).

Oftentimes, formal or official trails often fail to reach all desirable locations sought by visitors, meaning that in terms of trail management, off-trail travel is often inevitable. While focusing hiker traffic on specific trails can provide a balance between recreation and

environmental protection, effective management strategies are important as well. Prior studies on trail use determined that both indirect (messaging) and direct (barriers and fences) methods have been effective in controlling hiker traffic (Schwartz et al, 2018). These prior studies identified clear differences between trails with these indirect and direct methods in place versus those which have little to no precautions taken for guiding and managing hiker traffic.

In Acadia National Park, simple management strategies such as “no hiking” signs resulted in a significant reduction in off-trail hiking, from 68% to 17% (Marion, 2016). Similar results were achieved in various other National Parks such as Sequoia and Kings Canyon as well as Zion National Parks when simple signage was used for managing hiker traffic.

In terms of predicting the behaviors of individuals who venture off-trail, prior studies have determined that off-trail hiking is a non-volitional behavior. With limited off-trail signage and barriers, prior studies determined that park visitors likely felt confident and tranquil when venturing off-trail and breaching regulations (Goh, 2020). It was also determined that an individual's pro-environmental values had no impact on their likelihood to venture off-trail as well, those with heavily pro-environmental values had likely used the actions of prior visitors to justify hiking off-trail themselves (Goh, 2020).

Here, we examined hiker traffic and trail use at an IUCN IV Protected Area, Michaux State Forest. Michaux State Forest is located in South Central Pennsylvania approximately 15 miles Northwest of Gettysburg College. It is managed for purposes of clean water, recreation, scenic beauty, plant and animal habitat, sustainable logging and natural gas, and many other purposes (Pennsylvania Department of Conservation and Natural Resources, 2022). Previous studies have examined public recreational use within Michaux State Forest, which resulted in

some broad but useful information on the topic. A study conducted in 2016 found that both hikers and boulderers in Michaux State Forest generally respected the principles of “Leave No Trace,” although some areas of needed improvements were also noted (Pettebone et al, 2016). “Leave No Trace” is a set of outdoor ethics principles that focus on reducing human ecosystem impacts, and wishes to ensure that nature is conserved for its future enjoyment. While these prior case studies provided us with some good insight on the topic, we understood that many of these studies were conducted before the COVID-19 crisis began and more hikers who are uneducated on the principles of “Leave No Trace” were out in nature. Many of the prior studies conducted in Michaux only focused on the practices and attitudes of boulderers as well, not hikers.

Among the seven principles of “Leave No Trace,” we will be focusing on the principles stating to “travel and camp on durable surfaces” and “respect wildlife” (Leave No Trace Center for Outdoor Ethics, 2021). These principles most directly relate to our research, as it pertains to the ecosystem impacts caused by off-trail hiker traffic.

We aimed to examine the impacts on the ecosystem when hikers choose to deviate off official trails and forge their own route through the wilderness. The question we hope to answer is: are there noticeable impacts that occur when hikers choose to forge their own illegal trail, or travel down previously made illegal trails, and what are these impacts? We hypothesized in areas of Michaux State Forest where hikers have deviated off-trail, there would be observable evidence of human caused environmental degradation and erosion. Furthermore, we hypothesized that there will be less detrimental environmental impact in the officially maintained areas of Michaux State Forest. These maintained areas would be more likely to include adequate signage, trail markings, and a designated footpath meant for hikers and/or biker use. Through our research, we hope to limit human caused environmental impacts on Michaux State Forest, and help ensure the

preservation of these trails and the protection of vulnerable ecosystems and organisms that rely on the well-being of the natural environment within the forest.

Methods

Presence of Illegal Trails

We used AllTrails versions 14.4.0 to 15.2.1 to compile various trails throughout Michaux State Forest. We chose six of these trails, which we split into three different categories based on usage and reason for usage: heavily used (hiking trails that had over 200 recorded completions on the AllTrails page), less used (hiking trails that had less than 200 recorded completions on the AllTrails page), and attraction-based (trails that people use to get to a feature like an overlook or waterfall rather than just to walk the trail) (Table 1). We were encouraged by foresters working for Michaux State Forest to look into the intersection of Staley Road and Route 233 to the South Mountain golf course, which is how we found the Heaven or Hell loop and decided to include it as a study site. The rest were found via AllTrails. The following trails were chosen to be our study sites under the previous categories: Pole Steeple and Chimney Rocks (attraction-based), Long Pine Run Reservoir and Sunset Rocks (heavily used), and Heaven or Hell loop and Canada Hollow (less used). We decided to not use Chimney Rocks as a study site once the SD card from the trail camera placed on the illegal trail was stolen, and it already seemed to not be a very suitable site as we believe it is not actually off-trail, but instead part of the Appalachian Trail and not managed by Michaux State Forest.

Our research was conducted under research permit SFDR 2203 through DCNR - Bureau of Forestry, which provided us with official trail data from Michaux State Forest. We downloaded between 25 and 60 recorded hikes from each of the study sites depending on how

many were available from AllTrails. We converted these .GPX files to .SHP files using ArcGIS version 2.8.6. We merged the shapefiles for each study site and overlaid the merged file over the official trail map to see where they intersected and diverged from each other. To account for GPS inaccuracies in AllTrails, we created a 30-meter buffer around the official trail and erased anywhere that the buffer overlapped with the merged file of the recordings. The sites remaining therefore focused on illegal trails of off-trail use at each of these sites. We then chose an area which had a visually high density of recordings going through it and chose that as where we would place our trail cameras at each given study site.

We placed a GardePro E6 Trail Camera at each of the study sites at the predetermined location, attached them to a tree that would have a clear view of the illegal trail area, and left them there between 18 and 24 days. The trail camera was set entirely to default settings, with the exception of setting it to take photos rather than videos whenever it detected motion to slow the rate that the SD card would fill up. We collected the photos taken at least once a week to ensure the SD card would not fill up, and checked if the cameras were still running without issues. Once the photos were collected, we went through them and counted the amount of people the trail cameras took pictures of and whether they were hiking or biking on these trails. We then normalized the amount of people counted over the time it was out by the amount of days the camera was taking pictures to account for each camera being out for a different amount of time. Importantly, cameras were also set out at different times of the week and in differing weather conditions.

Measures of Environmental Impact

At each study site, we took measurements of trail width at three points along each study site: on the official trail approximately 10 meters before the illegal section of the trail started, the location where the illegal trail diverges from the official trail, and at the location of the trail camera. We decided to analyze trail width because trampling and erosion seemed to be common and easily recognizable indicators of ecosystem damage, as the more people are going on a given trail, official or not, the wider it will be (Wimpey & Marion 2010).

We also took quadrat data from each of the study sites, which was done by placing a 1m x 1m quadrat around the study site and taking a picture of it to analyze vegetation. Initially we intended on analyzing invasive species present on official trail areas versus illegal trail areas, specifically looking at those listed on the Department of Conservation and Natural Resources (DCNR) website as species that are major issues (DCNR, 2020). These species include mile-a-minute, tree-of-heaven, Japanese angelica tree, Japanese barberry, autumn olive, Japanese privet, Japanese stiltgrass, multiflora rose, Japanese knotwood, and poison hemlock. We initially focused on invasive species because hikers can accidentally carry seeds of invasive species on their boots or clothing and spread it to areas it would not normally be prevalent in due to the existence of a trail (Van Winkle, 2014). However, we did not find any of those invasive species in any of the samples taken.

Instead, we measured vegetation ground cover as a metric to see how trampled a given area is. We took measurements using 1mx1m quadrats on the illegal trail area of each study site at the location of the trail camera at three places: directly on the illegal trail, directly to the side of the illegal trail, and 10 meters to the right side of the illegal trail. We took photos directly above each quadrat and superimposed a 10x10 grid using Gimp version 2.10.30. Next, we marked each square on the grid that had more than 50% of the square covered by a plant, moss,

or other form of vegetation. We used these data to calculate the proportion of vegetative ground cover ($\# \text{ cells with ground cover}/100$) at each location. We used Rstudio Cloud version 16.04 to run an ANOVA test to analyze the significance of our data for vegetation ground cover and trail width.

Anecdotal Information on Trail Use

As supplementary data, we also collected AllTrails reviews for each of the study sites. We took the average rating from each trail and a number of reviews with comments. We looked at 10 random reviews from each trail and read the comments. These data were collected to see if there was any clear reason as to why people had gone off-trail, primarily seeing if people had stated that the trail was poorly marked or not well maintained.

Results

Presence of Illegal Trails

Among our sites, Pole Steeple had some of the least illegal trail areas. One of the main areas we identified as illegal is actually a maintained trail, since it is merely a fork in the trail. On the other extreme, the Heaven or Hell loop was found to be entirely unmaintained and illegal. This loop is actually a collection of multiple illegal trails that happen to cross over each other (Figure 1).

Some of the illegal trail area for Pole Steeple was somewhat made up of what seems like official trails that were not present on the GIS layer provided by Michaux State Forest, as there was clear signage. However, the area we placed our trail camera was an area that goes around the overlook and provided an alternative route (Figure 2). Many of the illegal trail areas found on

Sunset Rocks were areas that cut across the trail, or shortcuts. There were a few clustered areas of illegal trail activity, but they are largely sporadic, with only a few people going on each (Figure 3). Canada Hollow had many different scattered areas of illegal trails with little overlap among users, other than one area to the West of the legal trail. Here, the trail thins out greatly and goes through what is likely a logging area (Figure 4). Long Pine Run had one main cluster of the trail where people tended to make their own trail toward the Southeastern part of the reservoir (Figure 5).

The trail camera captures that took place over the course of the two-to-three-week period showed that Pole Steeple's illegal trail area had the highest hiker density, with 8.25 people on it per day, Heaven or Hell loop had the second highest with 6.45 people per day, Long Pine Run Reservoir had 4.82 people per day, Sunset Rocks had 1.1 people per day, and Canada Hollow had only 0.59 people per day. The only trail with documented mountain biking activity was the Heaven or Hell loop, where 45% of the trail users were mountain bikers (Table 2).

Measures of Environmental Impact

In all of the study sites, the official trail was wider than the beginning of the illegal trail area and the beginning of the illegal trail was wider than the trail at the placement of the trail camera (Figure 6). Although the results did not prove to be statistically significant ($p=0.438$, $df=11$), there is an apparent trend where the trail becomes thinner as it gets farther into the illegal trail area.

The initial quadrat data looking for invasive species turned out to be inconclusive since none of the invasive species listed on the DCNR website (DCNR, 2020) were found in any of the quadrat samples taken at any of the five study sites. The secondary quadrat dataset looking at

ground cover found mixed results. For example, among the samples taken at the Long Pine Run illegal trail area, the highest ground cover was found directly on the off-trail area. The trail was very thin and the margins were covered in moss, which were captured in the quadrat (Figure 7). Vegetative cover was widely variable and we found no evidence for differences in vegetative cover directly on the illegal trail, directly to the side of it, or 10 meters to the side of it ($p=0.805$, $df=12$).

Anecdotal Information on Trail Use

When looking at the AllTrails reviews for each of the study sites, Heaven or Hell loop was found to have an average of 3.6/5 stars out of 34 reviews, with mostly comments about how the trail was poorly marked and maintained as well as being hard to follow. Long Pine Run had 225 reviews with an average of 4.5/5 stars, with predominantly positive comments, but some complained that the trail was poorly marked. In one instance, AllTrails responded to a comment about how the trail recording was incorrect and that they had reviewed and made the necessary corrections. Canada Hollow had an average of 4/5 stars with 89 reviews, with not many comments, but most of them simply being compliments about the trail. Sunset Rocks had an average of 4.5/5 stars out of 68 reviews, with no comments about quality of trail, mostly about difficulty. Pole Steeple had 4.5/5 stars out of 611 reviews, with mostly comments about difficulty, rather than the trail quality.

Discussion

In this study, we identified illegal trail usage in Michaux State Forest based on three categories of trails, using user-recorded hikes from AllTrails and overlaying those recordings with official Michaux State Forest trail data from DCNR. We originally hypothesized that in

areas of Michaux State Forest where hikers have deviated off-trail, there would be observable evidence of human caused environmental degradation and erosion. Though we found significant off-trail use at various scales in Michaux State Forest, our hypothesis regarding environmental degradation was not supported. We also hypothesized that there will be less detrimental environmental impact in the officially maintained areas of Michaux State Forest than on illegal trails, which was supported based on some of our results[NG1].

We did not identify much evidence of ecosystem impacts through most of our quadrat photos, which could be a result of the time of year that these site visits took place or it could be that there are few invasive species physically impacting the trails at our study sites. Similar analyses have been conducted in a study by Winkle et al. (2014) in Forest Park, Portland, Oregon. Their quadrats that were placed one meter from informal (illegal/off-trail) trails showed higher species richness due to an increased number of introduced invasive species” (Van Winkle et al., 2014). The results of their study indicated the most noticeable effects were observed within two meters of the trail edge, for both the official trails and illegal trails, however, the specific role of invasive species is less clear in the impacted understory of their research. It is important to note here that the sample size used in Van Winkle’s paper (2014) was far greater than in this study, given that they identified 73 species within their 330 quadrats at a variety of distances from both their official and their illegal trails. For our study, further research and ground analyses could be done to test other effects of soil trampling and to track vegetative cover throughout the year, and most importantly during the summer months.

We found that the start of the illegal trail section was always thinner than the official trail, and the location next to our trail cameras on the illegal trail was even thinner than the beginning of the illegal trail. Given that these illegal trails have been created through forest trampling to the

point of clearing ground vegetation, it supports our hypothesis that there is evidence of human-caused environmental degradation. It is important to note that just because the illegal trails are thinner than the official trails, it does not necessarily mean that they are causing less damage to the forest ecosystem. The creation or use of the illegal trail is causing more damage than the official trail because it allows for the human impacts to spread further into the forest ecosystem rather than be concentrated on one foot path, leading to habitat fragmentation. These results indicate that people predominantly stay on the official trail and only a subset of people go onto the illegal trails, and even fewer make it far enough on the illegal trail to reach where we placed our trail camera. These results make sense, given that official trails are typically created and maintained by forest management to be a certain width along the entirety of the trail so as to be accessible for hikers. Since our illegal trails are not maintained by Michaux State Forest, the width of the trails is dependent on the hikers who have decided to deviate from the official trails.

Our second hypothesis was supported through our analysis of AllTrails ratings and reviews, since the Heaven or Hell Loop and the Long Pine Run Reservoir trails had reviews based on lack of trail markings and maintenance, as well as being difficult to follow. These reviews correspond to the experience that we had while hiking these specific trails, which we were only able to follow with the help of the AllTrails app. AllTrails is beneficial in many ways since it provides people with more opportunities to find trails and get outside in nature, but there are some drawbacks as well. The AllTrails app can perpetuate usage of illegal trails that people otherwise would not know about that are not officially recognized and managed. One of the reviews of Long Pine Run Reservoir from an AllTrails user mentioned that there was a lack of trail markings on the trail and the AllTrails route takes you the wrong way at one point. The AllTrails support team responded back to this review that they have corrected the hiking route on

the app so that it does not lead users astray. This response indicates that AllTrails does not provide the most accurate trail data, but that they heed user reviews and the importance of keeping hikers on the correct route. Given that the Heaven or Hell Loop is not marked at all, nor is it labeled as an official trail based on data obtained from DCNR, a majority of the hikers on this loop would be AllTrails users and locals who know the trails are there. In one situation, we met a biker at Heaven or Hell Loop who mentioned that there was a post on a Facebook group that talked highly of the trail for biking purposes.

Abundance & Drivers of off-trail Use

Official trails are generally considered effective methods for mitigating environmental impacts since they focus foot traffic onto one specific route, reducing habitat fragmentation (Leung & Marion, 1996). However, in the situations of the attraction-based trails like Pole Steeple, there was evidence of cutting through switchbacks to make the trail shorter or, in the case of where we put our trail camera, wrapping around the back of the attraction to get around the crowds of people who are at the overlook area. In the heavily-used trails of Long Pine Run Reservoir and Sunset Rocks, there were illegal trails created to make the trail into a loop for a more convenient experience at Long Pine Run, and to add an attractive overlook aspect of the trail at Sunset Rocks. Similar to Long Pine Run, Canada Hollow Loop appeared to have an illegal trail created in order to complete a looped trail for convenience. Heaven or Hell Loop, which was in the initially suggested focus area, was difficult to analyze based on the entirety of that area not being recorded in the Official Michaux State Forest trail data that was received from DCNR. However, based on the numbers collected from our trail camera at the intersection of Heaven or Hell Loop and a few other trails in that area, it is possible that a combination of hikers

and bikers together could have caused enough erosion to make their own trails (Cerdà & Salesa, 2020), likely unmanaged by Michaux State Forest.

Methods of Mitigation

A study that was conducted on a fragile, subalpine environment at Cadillac Mountain in Maine used remote sensing to observe the impacts of hiker traffic and management on the local environment (Kim & Daigle, 2012). The study examined a control site with none or limited visitor impact and no management strategies, and an experimental site with visitor impact and management strategies. At a medium to large spatial scale, the experimental site displayed more increases and fewer decreases in vegetation cover, demonstrating that the management strategies were visibly effective (Kim & Daigle, 2012). Below, we review some options that might help to reduce off-trail use and impacts at Michaux State Forest.

Increasing signage or barriers preventing the creation or use of illegal trails has proven to be beneficial in controlling hiker traffic, in turn controlling the human-caused effects on forest ecosystems (Schwartz et al, 2018). Hockett and colleagues (2017) have noted that, based on their observations, personal communications have been the most efficient means of reducing off-trail hiking. In the case of adding more signage to trails, there is some research on the types and verbatim of signs that have different effectiveness on trails. Johnson (1992) tested the use of different sign messages, the following two being the most effective: (1) “OFF-TRAIL HIKERS MAY BE FINED”, which reduced off-trail hiking by about 75 percent” and (2) “STAY ON PAVED TRAILS and PRESERVE THE MEADOW,” which reduced off-trail hiking by 52 percent (Johnson, 1992). This tactic could be useful to include in heavy off-trail use areas at Michaux State Forest.

AllTrails has a feature that pops up during your hiking route that says if you start to deviate off-trail. This feature only pops up if you are following an already completed or AllTrails created route, with no indication as to if the trail is officially managed or if it is an unofficial trail. The feature states the following: “Off Route Alert: you are no longer following your planned route. Check Navigator to ensure you are headed in the right direction.” This feature informs the user that they are no longer on the intended path, so the user knows to get back onto the official trail. It would also be beneficial to post in Facebook groups, like the group that encouraged bikers to ride around the trails near Heaven or Hell Loop for example, on the importance of staying on the official path.

Additionally, posting more signage and educating more highly on the seven principles of “Leave No Trace,” and, specifically, the principle of traveling and camping on durable surfaces, will communicate to hikers the importance of staying on official trails (Leave No Trace Center for Outdoor Ethics, 2021).

Limitations

There are a significant number of limitations to this study. For starters, our user-recorded map data (shown in red in the map figures) is based solely on AllTrails user data, which requires the hiker to have a smartphone and download the app to record the hike, rate the trail, and make comments about their hiking experience. Along with this, the Official Michaux State Forest GIS layers could be out of date, so some of the off-trail user-data could be an official trail by now. One specific area that we recognized as having out-of-date information was at Pole Steeple trail, where there are signs indicating the option to take the steep trail or the moderate trail. After

obtaining the official trail data from DCNR, we noticed that the moderate trail was not included in the GIS layer.

As far as our trail camera placement goes, we chose random locations on the identified illegal trails, so the ecosystem effects would likely vary all throughout the illegal section of the trail. We had originally set out a total of six trail cameras, with two cameras at each of the different use areas (heavily-used, less-used, and attraction-based). However, one of our attraction-based trails, Chimney Rocks, had the SD card taken out of our camera, so we did not have enough data to be used for our data analyses. Additionally, the Heaven or Hell Loop (Figure 5) is a combination of multiple trails that has been combined and named through AllTrails. “Heaven or Hell” is one of the trails in this loop, which gave the loop its name, but the actual “Heaven or Hell Loop” name was not created by Michaux State Forest or advertised as such. Our trail camera at the Heaven or Hell Loop trail was placed in a location that was right before an intersection of multiple hiking trails, so there is no way for us to know if the hiker count data (Table 2) is an accurate representation of the Heaven or Hell Loop specifically. Finally, given that this research was to be completed within the span of one semester at Gettysburg College, we had to work with a limited timeframe. This timing limited our study as there was little vegetative ground cover in our quadrat analysis and there were many fallen brown leaves covering all of our trail sites.

Future Research

Clearer observations of hiker use and vegetative ground cover or invasive species presence could be gathered if this same research was continued for a longer duration of time and across seasons. Some forms of future research that could be done in order to better identify forms

of environmental degradation based on hikers deviating off-trail are soil and trampling analyses to quantify how compacted or worn out the soil complexes are on the official trail versus illegal trails. It was originally suggested to us by Michaux State Forest to focus on the greater area between the intersection of Staley Road and Route 233 to the South Mountain golf course, which is where Heaven or Hell Loop is. Based on our findings of extensive illegal trail use in this area, it would make sense for Michaux State Forest to conduct more research solely on this area and to implement trail markings, signage, and better management control of the trails in this area.

Conclusions

Based on our research and analyses of illegal trails in Michaux State Forest, we recommend considering management action to reduce this use. Next steps could be to turn the well-used off-trail deviations into official Michaux State Forest trails so that they are properly monitored and managed. Other than ecosystem degradation, safety is another key concern that arises through the creation and use of unmarked and unofficial trails. Hikers, especially those without AllTrails or another form of map, can more easily get lost on a trail with no signage or tree markings, like what was observed at the Heaven or Hell Loop. Furthermore, if a hiker is lost or injured on one of these unmarked trails, it becomes increasingly more difficult to identify the hiker's location to emergency personnel. We suggest adding more signs on heavy off-trail areas, as well as marking all of the trails in the area between the intersection of Staley Road and Route 233 to the South Mountain golf course.

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Data Sources Table

File	Created by	Time Valid for	Description
Various user recorded hikes	AllTrails	Spring 2022	Hikes recorded by various hikers downloaded from AllTrails
20220315_Michaux_Trails.shp	DCNR	March 2022	Shape file of all of the official maintained trails in Michaux State Forest

Tables and Figures:

Table 1: Table showing AllTrails data for each study site analyzed, including the total AllTrails completion count, the number of times we visited each site, the location of each trailhead, and the classification categories that we placed each trail under.

Site Names	Category	Trailhead Coordinates	Site Visit Count	AllTrails Completion Count
Pole Steeple	Attraction-based	40.03823, -77.26963	3	1714
Sunset Rocks	Heavy use	40.03884, -77.32522	3	933
Canada Loop	Less use	39.99655, -77.45790	3	103
Long Pine Run Reservoir	Heavy Use	39.94343, -77.4545	3	267
Heaven or Hell Loop	Less use	39.83672, -77.52900	3	35

Note: Heavy use trails had over 200 recorded completions on AllTrails, less use trails had under 200 recorded AllTrails completions, and attraction-based trails had an overlook or other point of interest people use the trail to get to.

Table 2: Table showing trail camera recorded data from each study site and the amount of time each trail camera was out for. Data were normalized by dividing the total number of people counted by the amount of days the trail camera was collecting data.

Site Name	Trail Cam Coordinates	Days out	People counted	Bikers counted	People/day
Pole Steeple	40.03180, -77.26677	24	228	0	9.5
Sunset Rocks	40.03355, -77.32555	18	36	0	2
Canada Loop	39.99436, -77.46469	22	15	0	0.7
Long Pine Run Reservoir	39.93354, -77.44390	22	133	0	6.0
Heaven or Hell Loop	39.83788, -77.52535	22	180	81	8.2

Off Trail Activity at Heaven or Hell Loop

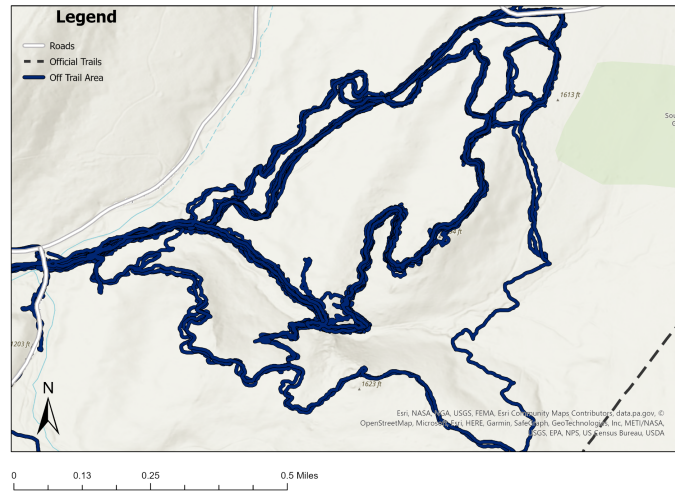


Figure 1: Map showing AllTrails recordings of areas where hikers have gone off-trail and made illegal trails at the Heaven or Hell Loop in Michaux State Forest. Map was made by merging 26 individually recorded hikes and erasing areas where they overlapped with the official trail. This entire trail is considered illegal, but there were many bikers found from trail camera counts, so it is likely the trail was found through some other means. The trailhead is located at 39.83672, -77.52914.

Off Trail Activity at Pole Steeple

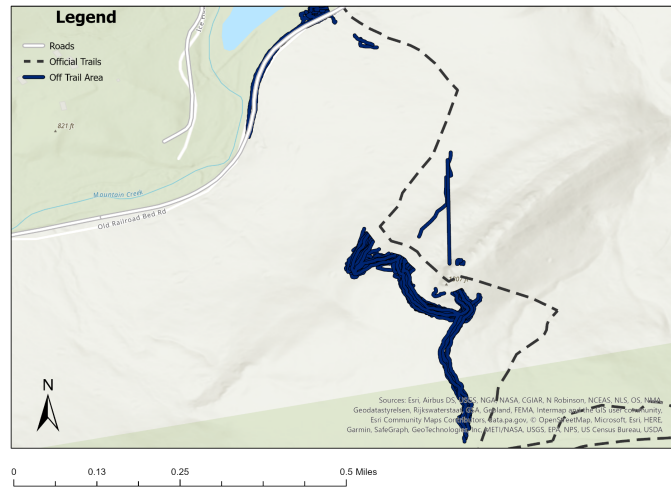


Figure 2: Map showing AllTrails recordings of areas where hikers have gone off-trail and made illegal trails at Pole Steeple in Michaux State Forest. Map was made by merging 47 individually recorded hikes and erasing areas where they overlapped with the official trail. This illegal trail area was likely started by people wanting to take a more scenic route and avoid tourists, as it is primarily used by avid hikers rather than beginners. The trailhead is located at 40.03842, -77.26957.

Off Trail Activity at Sunset Rocks

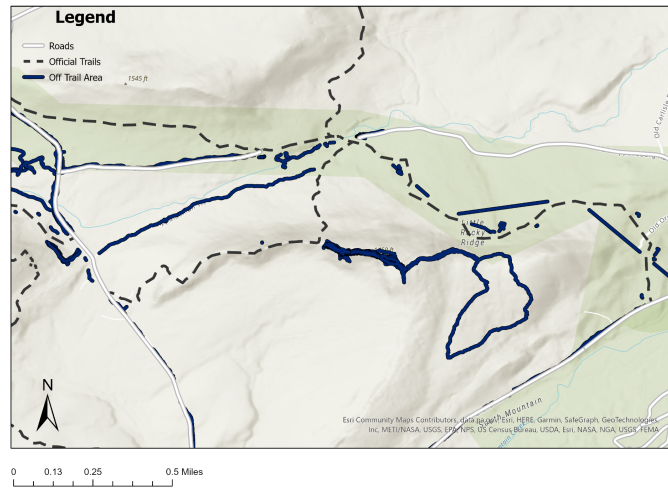


Figure 3: Map showing AllTrails recordings of areas where hikers have gone off-trail and made illegal trails at Sunset Rocks in Michaux State Forest. Map was made by merging 36 individually recorded hikes and erasing areas where they overlapped with the official trail. This trail is one of the longest examined, and due to that, many of the illegal trails created are likely due to people wanting to shorten the trail and make shorter loops. The trailhead is located at 40.03243, -77.30616.

Off Trail Activity at Canada Hollow

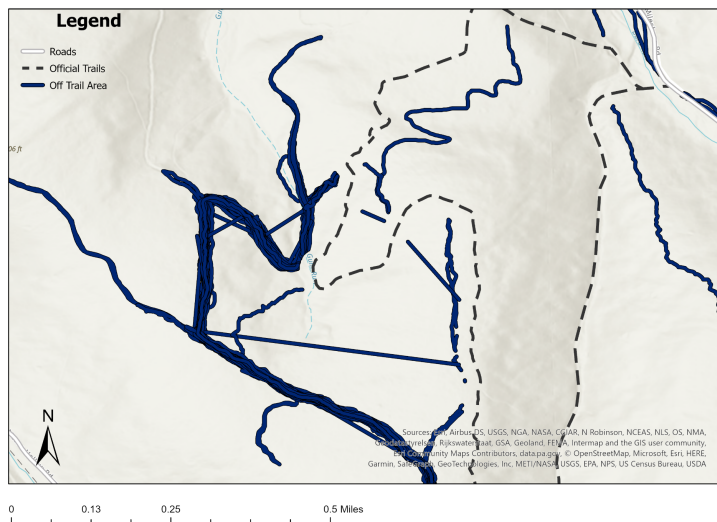


Figure 4: Map showing AllTrails recordings of areas where hikers have gone off-trail and made illegal trails at the Canada Hollow Loop in Michaux State Forest. Map was made by merging 28 individually recorded hikes and erasing areas where they overlapped with the official trail. This illegal trail was likely created to make the typically out-and-back trail a loop. The trailhead is located at 39.97616, -77.45905.

Off Trail Activity at Long Pine Run

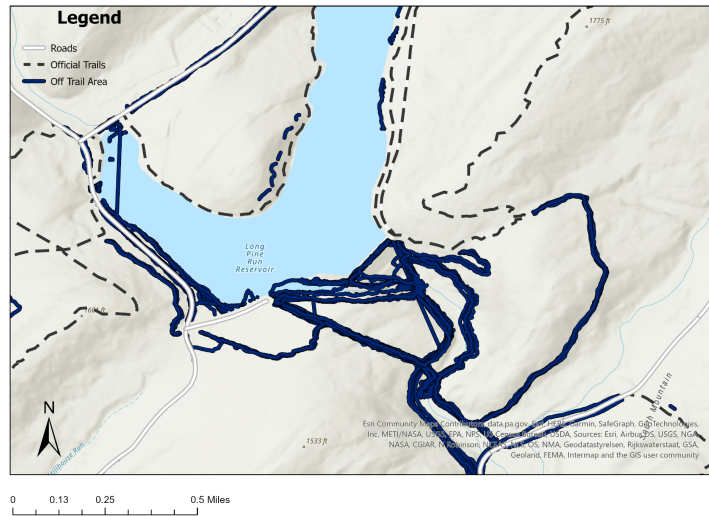


Figure 5: Map showing AllTrails recordings of areas where hikers have gone off-trail and made illegal trails at the Long Pine Run Loop in Michaux State Forest. Map was made by merging 43 individually recorded hikes and erasing areas where they overlapped with the official trail. This illegal trail was likely created to make the typically out-and-back trail a loop, although many seem to have different paths to make the illegal trail, forming the various similar trails seen in the map. The trailhead is located at 39.94311, -77.45490.

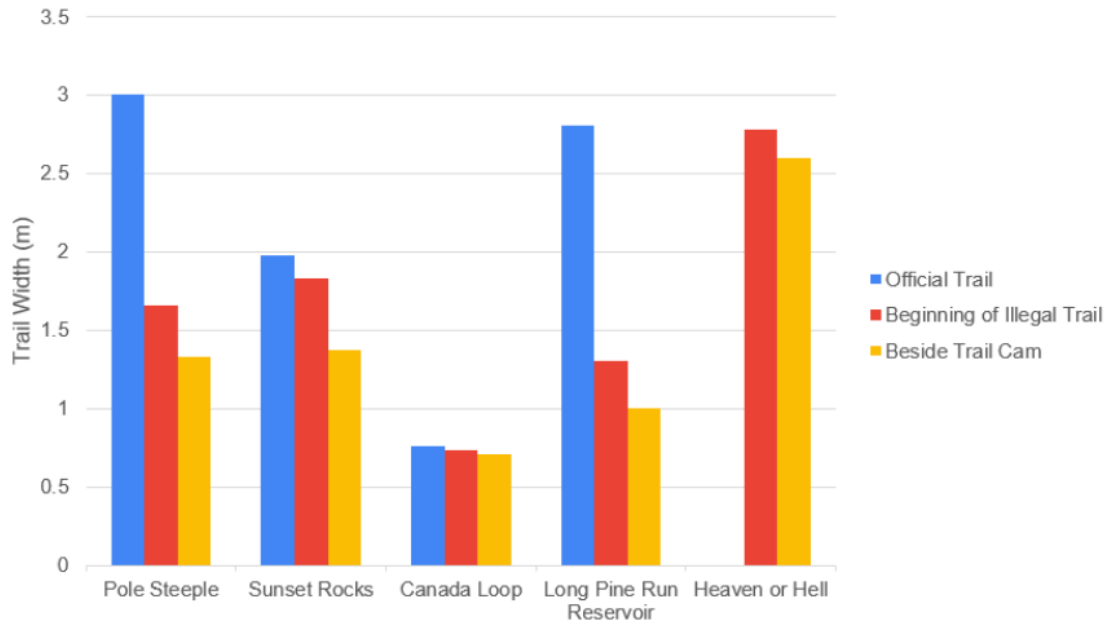


Figure 6: Graph showing trail width data from each study site. The blue bars represent trail width measured on the official trail about 10 meters before the illegal trail begins, the red bars represent trail width measured on the illegal trail directly where it diverts from the official trail, and the yellow bars represent trail width measured at the location of the trail camera.

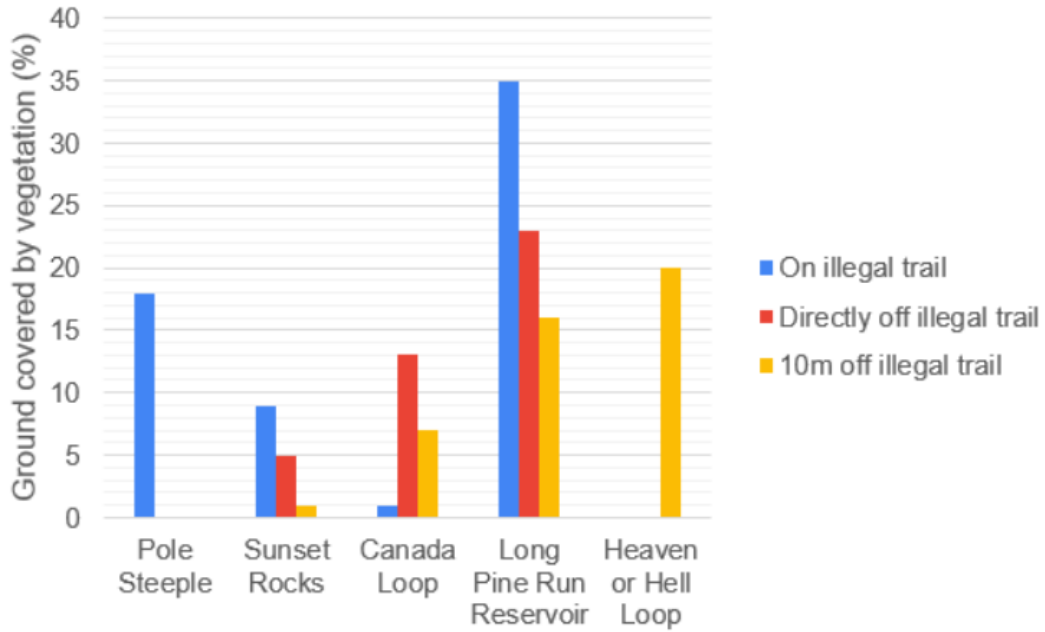


Figure 7: Graph showing vegetation ground cover on the illegal trail of each study site. The blue bars represent percentage of vegetation ground cover taken directly on the illegal trail, red bars represent percentage of vegetation ground cover directly to the side of the illegal trail, and yellow bars represent percentage of vegetation ground cover measured 10 meters to either side of the illegal trail. Vegetation ground cover was measured by overlaying a 10 by 10 grid over an image of the quadrat placed in the given position and counting how many of the squares had vegetation cover.