Quantifying Disturbance of Under-Story Vegetative Biodiversity in Relation to Recreational Foot Traffic Intensity

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December 2019

Abstract

There have been numerous studies on the effect of human caused recreational disturbance towards plant populations [Cole, D. N., 1998], with some being specific to the rocky mountain ecosystems [Klasner, F. L. 1998]. In my literature review it was difficult to find modern studies that investigated human caused trampling in regards to its effect on the surrounding plant population diversities. Studies instead tended to focus on 'plant health' metrics and measurements of chlorophagy, which although interesting isn't particularly useful for investigating how recreation shapes local plant communities outside of knowing that stepping on plants is generally bad for their health. My project aimed to determine if vegetation community disturbance near trails can be reliably measured in relation to known metrics of foot traffic. I measured under-story vegetation populations 'near' (1 meter) and 'far' (30 meters) on 'high foot traffic' and 'low foot traffic' [USDA, 2019] recreation trails in the Lolo National Forest. I found evidence that there may be a correlation between the levels of under-story vegetation densities and foot traffic intensities, but did not find statistically relevant evidence that different levels of foot traffic intensity affects overall vegetation community biodiversity.

Introduction

Having grown up hiking in both wilderness and developed areas I have noticed differences between popular and unpopular trails in each region, specifically regarding trail-side plant diversity. I wondered if human recreational disturbances towards the plants closest to the trail ripples outwards to the surrounding ecosystem, or if the disturbances are relatively self-contained within our footpaths and the differences in vegetation community diversities are a product of their natural environment. Considering it has been proven that human caused trampling does negatively affect plant populations [Cole, 1985] it would follow that there is a relationship between high and low foot traffic trails. I predicted that high levels of foot traffic would be associated with lower levels of plant diversity, with only sub-climax species such as grasses or sedges thriving in the disturbed soil over the more delicate herbs and bushes.

Methods

Before I set out to gather field data, trails in the surrounding area were selected for having common attributes. The Lolo National Forest Region 1 Geospatial Database had recorded foot traffic measurements for some trails in the area. Using Quantum Geographic Information System (QGIS) trails were then filtered out for predefined elevation ranges that fit dominant over-story tree biome types common to the area [Pfister, R. D. et al, 1977]. This was meant to exclude trails that were in grasslands or at high elevations, intending for selecting trails with the regionally common evergreen pine dominated biome that would be consistent across all trails sampled. After the irrelevant trails were disregarded, three trails of each foot traffic level (high and low) were selected depending on their accessibility.

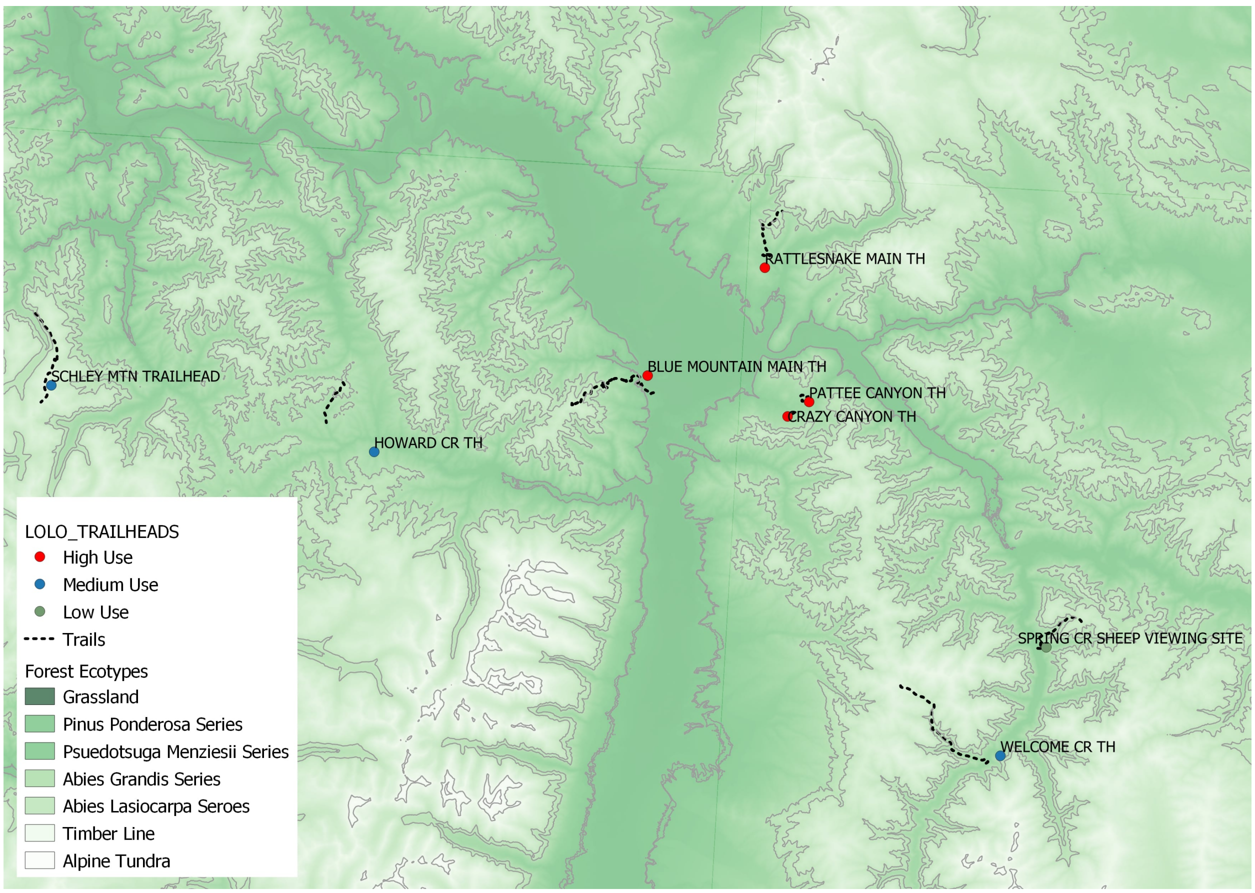

Figure 1: Partial map of the Lolo National Forest, ranking local trails by levels of Foot Traffic and filtering for elevation ranges known to occupy similar biomes

All trails were sampled a total of eight times. Two one meter square sample plots were placed one meter (near) and thirty meters (far) away from the trail on a perpendicular transects separated by one hundred meter increments. Each transect series began thirty meters from the official trail head to avoid automobile caused disturbances of plant communities of which this study was not interested in investigating. Each plot was then observed and recorded. These observations included: vegetation counts (categorized: trees, shrubs, herbaceous, sedges/grasses, mosses, fungi), cover percentage estimates, and bird's eye pictures taken for later reference.

The field data was then cleaned and filtered into a normalized format to more easily manipulate. Multiple statistical tests were then performed, which are discussed in the results section. Previous to the analysis it was determined that the tree level of the Vegetation Category would be omitted since I had not adequately planned for its unbiased measurement in our sampling design.

Results

First a MANOVA test (with replications) was performed (independent variables: vegetation type, foot traffic, and distance from trail; dependent variable: density) on the raw field data, to determine if there were any interactions within and between groups (appendix: Table 4.). It found significant interactions between Vegetation Categories and Foot Traffic ($9.18\text{E}^{-22} < \alpha$), but nothing in regards to Distance From Trail and any of the other independent variables. A Two-Tailed ANOVA with replications was performed to further investigate the relationship between Vegetation Categories and Foot Traffic in relation to density. It returned complimentary results, with a $7.65\text{E}^{-22} < \alpha$.

Source	SoS	df	Mean Square	F	Sig.
Corrected Model	7.334a	9	0.815	28.409	2.79E-28
Intercept	6.238	1	6.238	217.474	5.50E-31
Vegetation Type	2.997	4	0.749	26.124	**1.92E-16**
Traffic_Level	0.001	1	0.001	0.025	0.876
Vegetation Type * Traffic Level	4.336	4	1.084	37.791	**7.65E-22**
Error	4.303	150	0.029		
Total	17.875	160			
Corrected Total	11.637	159			

Table 1: Two Tailed ANOVA with replication, dependent variable is density, $\alpha = 0.05$

The established interaction between Vegetation Category and Foot Traffic was then graphed to better illustrate the differences, where a clear difference between high and low foot trafficked trails was observed (Figure 2.)

A Tukey test was then applied to the Vegetation Category, which applied an adjusted P-value to each inner factor interaction to help differentiate non-relevant results (Table 4.) which can be found in the appendix. The Tukey test found that a couple inner factor interactions were statistically insignificant (Mosses - Grasses and Shrubs - Herbaceous), but 85% were deemed statistically significant with the adjusted p-values. This implies that my categorizations of under-story vegetation species may have been not accurately grouping species based on their ability to compete for space, future work should use this information to dig deeper into the spatial relationships between under-story vegetation species. This concluded testing the raw means of vegetation density data. Shannon Diversity, Simpson Diversity, and Simpson Evenness indices were calculated as means to find a normalized style of comparison for under-story vegetation diversity other than simple proportions of densities (Equation 1.).

$$\sum_{i=1}^{Shannon} p_i * ln(p_i) = H \qquad 1 - \frac{\sum_{i=1}^{Simpson} i(i-1))}{i(i-1)} = D \qquad \sum_{i=1}^{Evenness} 1/D = E \qquad (1)$$

The resulting values were put through multiple two-tailed ANOVA tests (Table 3.). All biodiversity indices accepted the null hypothesis that varying the Distance from Trail had no explanatory effect for potential human caused disturbance, implying that if there are human caused recreation disturbances on under-story vegetation communities in Lolo National forest they do not cascade significantly from the trail. If these recreation-caused disturbances do occur their potential cascading either occurs much farther from the trail (more than thirty meters), or they are spread evenly in some vicinity of the trail. The Simpson indices found a significant occurrences within different levels of foot traffic, but no other interactions. Shannon indices more uniformly measure variance of populations which meant it garnered more relevance in this study, and since it disagreed with the Simpson indices (which more accurately measure dominance as opposed to biodiversity) for their only significant interaction, it is of my opinion that there are no statistically relevant occurrences of biodiversity observed in this study in relation to Foot Traffic levels and Distance from Trail.

	Foot Traffic p-value	Distance from Trail p-value	Interaction p-value	
Simpson Index	**0.01110098652**	0.508180907	0.496955997	
Simpson Evenness	**0.04351737704**	0.6755567886	0.4895963224	
Shannon Index	0.1070606308	0.05331790782	0.220240037	

Table 2: Results for all Two-Tailed ANOVAs on Shannon, Simpson, and Simpson Evenness indices, $\alpha = 0.05$

Discussion

Considering the observed significant relationships between mean densities of Foot Traffic and Vegetation Category I had predicted that the normalized diversity values would share a similar significance. The fact that the Shannon Index and Simpson Index did not agree is a strong indicator that this study did not observe an interaction between human caused recreational disturbances and cascading effects on plant biodiversity farther from the trail. Another possibility is that our sample pool was too small for significant results. Future sampling would have to be larger than two samples of each foot traffic level, potentially transitioning from discrete to continuous framework of measurements. I had initially intended to do three of each, but weather caused two of the trail data sets to be unreliable. For the purposes of this study I agree with the null hypothesis that foot traffic has no significant effect on plant diversity over thirty meters from the trail.

I observed something interesting with results from the Simpson Evenness Index, which is a measurement of sameness across a population, with values increasing by around fifteen

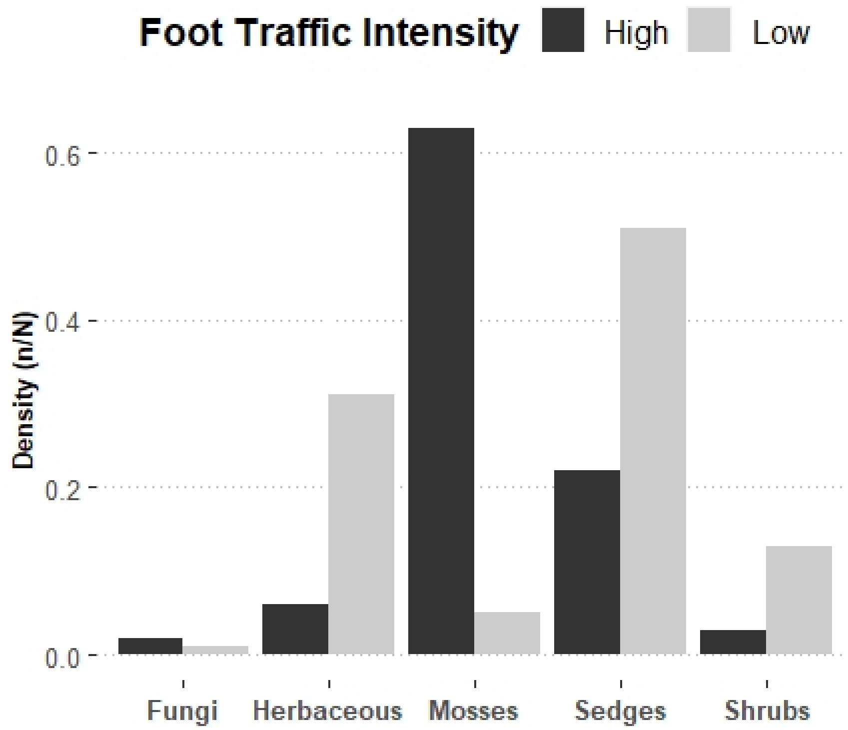

Figure 2: Averages of Vegetation Densities across high and low foot trafficked trails

percent on trails with high foot traffic. This would imply that lower foot trafficked trails see noticeably more heterogeneous/uneven under-story vegetation populations. Why this is the case would need further study, but one possible cultural explanation is that trails with more even distributions of species are sought after for recreation as opposed to hikes with more dominant vegetation structures. Another possible reason for this is that the consistent disturbance by human recreation on high foot traffic trails creates an unstable environment where more sensitive climax species are disadvantaged and disturbance friendly pioneer species are given a boost in an area that might not normally leave much room for them. Further research would need to have a larger sample size, species level vegetation surveys, and a sampling design that incorporates trees.

References

Cole, D. N., Spildie, D. R. 1998. Hiker, horse and llama trampling effects on native vegetation in Montana, USA. Journal of environmental management: 61-71.

Klasner, F. L. 1998. Spatial changes in alpine treeline vegetation patterns along hiking trails in Glacier National Park, Montana. Journal of environmental management: 20-33

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Pfister, R. D., Kovalchik, B. L., Arno, S. F., Presby, R. C. 1977. Forest habitat types of Montana. Intermountain Forest Range Experiment Station: 14-40

(I) Vegetation Type	(J) Interaction	Mean Difference (I-J)	Std. Error	Sig.
Fungi	Herbaceous	-.190888434764293*	0.04234186	0.000126472
	Mosses	-.327998353920753*	0.04234186	1.36E-11
	Sedge/Grasses	-.349120404588265*	0.04234186	1.25E-12
	Shrubs	-0.075032533	0.04234186	0.39372444
Herbaceous	Fungi	.190888434764293*	0.04234186	0.000126472
	Mosses	-.137109919156461*	0.04234186	0.012695746
	Sedge/Grasses	-.158231969823972*	0.04234186	0.002421448
	Shrubs	0.115855902	0.04234186	0.05339641
Mosses	Fungi	.327998353920753*	0.04234186	1.36E-11
	Herbaceous	.137109919156461*	0.04234186	0.012695746
	Sedge/Grasses	-0.021122051	0.04234186	0.98736564
	Shrubs	.252965820657773*	0.04234186	1.60E-07
Sedge/Grasses	Fungi	.349120404588265*	0.04234186	1.25E-12
	Herbaceous	.158231969823972*	0.04234186	0.002421448
	Mosses	0.021122051	0.04234186	0.98736564
	Shrubs	.274087871325285*	0.04234186	1.28E-08
Shrubs	Fungi	0.075032533	0.04234186	0.39372444
	Herbaceous	-0.115855902	0.04234186	0.05339641
	Mosses	-.252965820657773*	0.04234186	1.60E-07
	Sedge/Grasses	-.274087871325285*	0.04234186	1.28E-08

Table 3: Tukey Test to find adjusted p-values within Vegetation Type, $\alpha = 0.05$

USDA. 2019. Region 1 Geospatial Database. https://www.fs.usda.gov/detailfull/r1/

Appendix

Source	SoS	df	Mean Square	F	Sig.
Corrected Model	7.710a	19	0.406	14.464	0
Intercept	6.238	1	6.238	222.371	0
Foot Traffic Level (A)	0.001	1	0.001	0.025	0.874
Distance From Trail (B)	0.001	1	0.001	0.032	0.859
Vegetation Type (C)	2.997	4	0.749	26.712	**1.80E-16**
A * B	0.001	4	0.001	0.021	0.886
A * C	4.336		1.084	38.642	**9.18E-22**
B * C	0.26	4	0.065	2.314	0.06
A * B * C	0.114	4	0.029	1.017	0.401
Error	3.928	140	0.028		
Total	17.875	160			

Table 4: MANOVA with replication, dependent variable is density, $\alpha = 0.05$