MOUNTAIN BIKE TRAIL COMPACTION RELATION TO SELECTED PHYSICAL PARAMETERS

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Abstract: The purpose of this research is to explore the rates of compaction and their relation to trail contextual aspects of: soil type, slope and crown cover on a newly established mountain bike trail in the northern reach of Vermont. A random sample of 52 sites was selected for monitoring on the 1.09-mile trail. Three penetrometer readings were taken at each of the sample sights on two-week intervals beginning the day after trail construction was complete. Soil core samples were also taken at each site to determine soil type. Crown cover estimates were determined using the USDA Forest Service code-a-site estimation categorization, and slope aspect was evaluated by the use of a clineometer.

The data collected in this study support the basic premise found in (Hammitt & Cole, 1998) that compaction is curvilinear. Compaction on the midpoint of the trail occurred within six weeks of the inception of the trail and stasis was reached by the fourth time period (eight weeks). Compaction for the tread as a whole likewise occurred, but at a slower rate and to a lesser degree.

No interaction effect was observed between the effect of compaction measurement over time with slope and crown cover. The lack of an interaction effect between compaction and slope may have been a result of the relatively small deviation in slope among sites. The lack of an interaction between compaction over time and crown cover may be a result of the relatively virgin characteristics of the soil. The duff layer of organic material is being pulverized and compacted but is still able to dry even in areas with significant crown cover. The lack of variability in soils at this stage in the trail lifecycle may account for the non-significant interaction with soil type and compaction.

The study has multiple implications for managers of mountain bike trail systems in the eastern United States. Managers will need to monitor trails once stasis is reached because the forest duff levels are pulverized and the trails are susceptible to erosion. As established trails are compacted managers may: prefer to confine users to existing tracks by narrowing trial side conditions; hardening the track to minimize erosion and by educating riders to stay within the established track, and limiting access during prolonged wet conditions.

The relationship of the contextual or setting aspects of a trail to compaction rates and the interrelation with recovery rates provide a better understanding of the physical parameters of trail location. Understanding and study of these relationships can aid in trail planning and enable managers to build a sustainable trail. A study of this type can be easily replicated in other areas to account for differences in soil and vegetation type.

Introduction

Compaction of recreation trails and use areas is well documented in the literature. Increase in compaction vary with regard to soil type, type of use, and soil characteristics such as moisture content, texture and structure. Most studies have examined such compaction as a result of human trampling, pack stock, and off road vehicle use; and have focused on existing trails or use areas (Wilshire, Nakata, Shipley, & Prestegaard, 1978; Manning, 1979; Marion & Cole, 1996; Hammitt & Cole, 1998). Little literature has examined the compaction on newly established trails, especially by mountain bicycle users, nor related such compaction to other physical aspects of the setting. As more areas allow such use on new and established trails, there is a need to study the effects of compaction on soils in the context of slope, soil type, and crown cover as they are the basic structure for understanding vegetation loss and erosion.

This research was conducted on a trail managed Kingdom Trails Association (KTA) in East Burke Vermont. The trail was designed to utilize the natural contours of the landscape, thus eliminating the need for excavation. The site was chosen because it extended the existing system, the owner allowed trail development, and the new trail provided a scenic river vista. A Youth Conservation Crew from the Vermont Leadership Center in East Charleston Vermont cleared the trail, which was laid out by KTA. The crew cleared a tread to 20 inches in width and of 36 inches in width up to 7 feet high. The ground compacted as bicycles began to use the trail.

The purpose of this research was to explore the rates of compaction and their relation to trail contextual aspects of slope, crown cover, and soil type on a newly established mountain bike trail in the northern reach of Vermont. The trail is divided into two segments. The first is essentially a linear segment of four-tenths of a mile that allows the user to crossover to an intersection of trails, one of which was cut at the same time as the new linear segment and is essentially a loop approximating seven-tenths of a mile in length. A random sample of 52 sites was selected for monitoring compaction on the 1.09-mile trail. Sites were selected at intervals of 105 feet from the trailhead of the linear segment. The trail varies in vegetation type, slope, soil type, and degree of mature vegetation crown cover.

Methods

Three penetrometer readings were taken at each of the sample sites on two week intervals beginning the day after the trail construction was completed; readings continued until the first heavy frost penetration on unprotected sites the beginning of November 2000. Penetrometer readings were taken perpendicular (across) to the trail, one in the estimated middle of the trail, and one each, 25 centimeters on each side of the middle reading. Baseline data was collected at each of the 52 field sites on July 27, 2000, the first day after the cutting of the trail was completed. Five of the seven data collection days were dry; two were misty with intermittent light precipitation. Subsequent to the baseline data collection, increasing use of the trail was observed from July through the end of October. Although no actual counts were taken, it was estimated by observation and interpolation that an average of eighteen to twenty five riders used the trail segments weekend days and ten to twelve used them during weekdays.

Soil core samples were also taken at each site to determine soil type. Soil samples were taken at each site at a constant depth of approximately four inches and were subsequently typed by a soil scientist of the USDA Natural Resource Conservation Service. Crown cover estimates were determined using the USDA Forest Service code-a-site estimation categorization, and slope aspect was evaluated by use of a clineometer. The relationship between compaction rate and percent of crown cover and degree of slope was tested using Repeated Measures ANOVA.

Results

The mean penetrometer measures from the initial reading and the final seventh reading indicated an increase in the resistance levels for each of the three site measurements (middle, left, and right side of trail), over the 52 sites. An averaged reading over the three measurements at each of the 52 sites had a similar pattern, showing a significant difference between the baseline measurement and the end of the season (see Table 1). The middle trail reading indicates a higher compaction differential than the two outside readings on the trail tread.

Repeated measures ANOVA were calculated for both the averaged penetrometer readings and for those in the middle of the trail, comparing the penetrometer readings of the 52 sites at seven different times. A significant effect was found (F (6,306)= 41.91, $p<$ .000) for the averaged penetrometer readings. Protected t tests were used to compare the time periods; because we are in essence conducting tests on all possible pairs (21 tests) and therefore inflating our Type I error rate, we used a significance level of .0024 (.05/21) instead of .05. Protected t tests revealed that averaged penetrometer readings did not increase from the first time period (m=201.07, sd=85.14) to the second time period (m=200.23, sd=60.03), but increased from the second time period to the third (m=225.51, sd=56.12), and again increased from third to fourth time period (m=260.43, sd=72.45). There was no significant increase from the fourth time period (m=260.43, sd=72.45) to the fifth (m=267.85, sd=46.02), no significant difference from fifth to the sixth (m=274.53, sd=55.02), and again, no increase from the sixth to the final, seventh time (m=295.35, sd=58.15, $p=$ .007). This indicates that most of the compaction occurred across the tread before the fifth penetrometer reading.

The repeated measures ANOVA, with slope as a covariate, for the middle of the trail readings, revealed a similar pattern—there was a significant effect (F (6,300)= 37.45, $p<$. 000) for the penetrometer readings taken in the middle of the trail. Follow-up protected t tests (see Table 2) indicated an increase in penetrometer resistance in the middle of the trail from the first time period (m=252.85, sd=104.98) to the second period (m=300.82, sd=57.36), again from the second time period to the third period (m=345.81, sd=69.91), but not from the third to the fourth period (m=403.64, sd=148.16). No significant differences were found between successive time periods from the third period. This suggests that compaction occurred more quickly in the middle of the tread than across the width of the entire tread.

An analysis of within subject effects of the covariate of slope with the middle of trail penetrometer readings over time indicated no interaction effect (F (6,300)= .998, $p>$.05). Similarly, there was no interaction of penetrometer readings over time and the covariate crown cover (F (6, 300)= 1.462, $p=$ .191).

Table 1: Paired Sample Differences in Penetrometer Resistance (psi) for the Three Measurement Points on the Trail

Measurement Point	Mean PSI	Std. Deviation	Paired samples t	Sig.
Middle of Trail				
Pair Mid 1-	252.85	104.98	-10.42	.000
Mid 7	429.24	73.29		
Left Side				
Pair Left 1-	241.04	100.92	-2.53	.015
Left 7	274.14	75.45		
Right Side				
Pair Right 1-	208.73	91.70	-48.20	.000
Right 7	282.02	81.12		
Average Over Three				
Pair Ave 1-	201.07	85.14	-8.58	.000
Ave 7	295.35	58.15		

Table 2: Paired Sample Tests for Seven Successive Time Periods

Pairs	Mean	Std. Deviation	Paired samples t	Sig.
Pair Mid 1- Mid 2	252.85 300.82	104.98 57.36	-3.56	.001
Pair Mid 2- Mid 3	300.82 345.81	57.36 69.91	-5.36	.000
Pair Mid 3- Mid 4	345.81 403.64	69.91 148.16	-2.49	.016
Pair Mid 4- Mid 5	403.64 426.55	148.16 63.24	-1.13	.266
Pair Mid 5- Mid 6	426.55 418.23	63.24 63.15	.764	.448
Pair Mid 6- Mid 7	418.23 429.24	63.15 73.29	-.868	.389

Discussion

The data collected in this study supports the basic premise found in Hammitt and Cole (1998) that compaction is curvilinear (see Figure 1). Compaction on the midpoint of the trail occurred within six weeks of the inception of the trail and stasis was reached by the fourth time period. No statistically significant compaction occurred after the third time period for the middle of the trail. Compaction for the tread as a whole (average in Figure 1) likewise occurred, but at a slower rate and to a lesser degree.

No interaction effect was observed between the effect of compaction measurement (penetrometer readings) over time and slope or crown cover characteristics of the trail at each site. Slope gradients averaged 5.15 degrees, sd = 4.31, and other than three outliers, the gradients ranged between 1 and 11 degrees; only thirteen percent of sites were over 9 degrees in slope.

The decline in compaction between the fifth and sixth time period may be the result of the level of compaction that was measured at the fifth time period in which wet soil

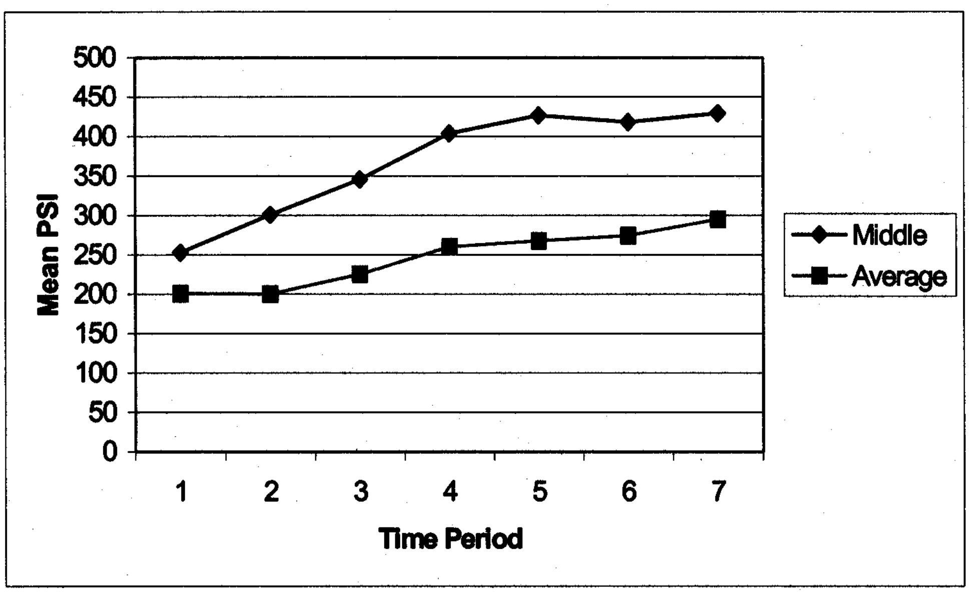

Figure 1: Mean PSI for Middle of Trail and Average over Tread for Seven Time Periods

conditions occurred after two days of steady rain. The lack of an interaction effect between compaction and slope may have been a result of the relatively small deviation in slope among sites. The lack of an interaction between compaction over time and crown cover may be a result of the relatively virgin characteristics of the soil, the duff layer of organic material is being pulverized and compacted but is still able to dry even in areas with significant crown coverage.

Implications

The study has multiple implications for managers of mountain bike trail systems in the eastern United States. Similar to previous studies in the west, mountain bike trails compact quickly. Little traffic causes compaction to accelerate fairly rapidly—there was observable evidence of compaction within three days of the trail opening and significant compaction occurred within six weeks, at which time stasis appears to have been reached. Managers will need to monitor trails during periods of this stasis, as this appears to be the point at which forest duff levels are pulverized and susceptible to erosion. As established trails are compacted, managers may prefer to confine trails to existing tracks by altering trail side conditions, harden the track to minimize erosion, and by educating riders to stay within the established track. Wet soils resulted in greater compaction, suggesting that managers may wish to limit access during prolonged wet conditions.

The relationship of contextual or setting aspects of a trail resource to compaction rates and their interrelation with recovery rates provides a better understanding of the physical parameters of trail location for more effective trail planning and for decisions regarding trail maintenance. Such a study can be easily replicated in other areas to account for differences in soil and vegetation type.

KTA saw a need to develop a monitoring system in order to quantify the rate of change as trail use increases. The results provide criteria for future monitoring (i.e. desirable slope, canopy cover and sustainable soil characteristics) as KTA studies the effect of freeze-thaw conditions on trail recovery, rates of compaction the second year, and as soil duff levels dissipate and erode to the mineral level. The monitoring of the trail over time may also provide management with indicators for implementing action strategies such as hardening the trail before over use occurs.

Future Monitoring Activities Will Incorporate:

1) number of users – with the use of counters;
2) how a trail effects the surrounding vegetation;
3) extent of recovery and subsequent acceleration of compaction; and
4) continued monitoring of the relationship between compaction over time and slope, crown cover, and soil type.

References

Hammitt, W. E., & Cole, D. N. (1998). Wildland recreation: Ecology and management. New York: John Wiley & Sons.

Manning, R. E. (1979). Impacts of recreation on riparian soils and vegetation. Water Resources Bulletin, 15(1), 30-43.

Marion, J. L. & Cole D. N. (1996). Spatial and temporal variation in soil and vegetation impacts on campsites. Ecological Applications, 6(2), 520-530.

Wilshire, H. G., Nakata, J. K., Shipley, S., & Prestegaard, K. (1978). Impacts of vehicles on natural terrain at seven sites in the San Francisco Bay area. Environmental Geology, 2, 295-319.