A COMPARISON OF SURFACE IMPACT BY HIKING AND HORSEBACK RIDING ON FOUR TRAIL SURFACES IN GREAT SMOKY MOUNTAINS NATIONAL PARK

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Four types of surfaces: pasture, foot trail, mesic foot and horse trail, and xeric foot and horse trail, were investigated for three types of impact: horse and rider, hiker with lug soles, and hiker with flat soles.

In the pasture, hiking produced a doubling of soil compaction after 100 passes, whereas horseback riding resulted in a sharp increase in compaction after 20 passes, followed by a decrease. On the foot path, both hiker use and horse use significantly decreased the leaf litter and the compaction of the soil, but horse use produced greater change in soil compaction. Mesic trail sections showed a much quicker change in surface condition than the xeric sections under horse use.

INTRODUCTION

Visitor use of Great Smoky Mountains National Park (GRSM) has increased tremendously during the past two decades. In 1977, visitors took an estimated 244,533 day hikes, spent 101,759 nights in the backcountry, and took 59,269 horseback rides. Trail erosion has become an important maintenance and resources management problem.

Physical variables, such as vegetation types, soil type, geologic substrate, trail slope, and annual precipitation are known to influence trail condition (Bayfield 1973, Helgath 1974, Dale and Weaver 1974, Liddle 1975, Boorman and Fuller 1977, Crawford and Liddle 1977, Bratton eta al. 1979) as do the type and intensity of use (Willard and Marr 1970, Merriam and Smith 1974, Bratton et al. 1978).

The purpose of this study was to quantify differences in trail impacts between the two major backcountry use groups in the GRSM, hikers and horseback riders.

METHODS

Four sites were selected for the study: an open pasture, a foot trail through mesic successional forest, a foot and horse trail through mesic forest, and a section of the same trail through xeric successional forest. Using a hiker who weighed about 70 kg, one test was made using heavy lug-soled (Vibram) hiking shoes and one test was made with light smooth-soled (Clark Poly-velts) shoes on each surface. A test was also made using a horse (shod) with rider and saddle weighing about 540 kg. Data were collected between November 11, 1977, and December 8, 1977.

On the pasture site, which had been free from mowing or grazing for over a year, vegetation height and surface soil compaction (using a Soiltest Pocket Penetrometer, in kg/cm^2 penetrability) were measured at 5 m intervals along 3 parallel 50-m strips, both before testing and after 20, 50, 75, and 100 passes. (For exact locations and site conditions, see Whittaker 1978).

On the foot trail, three 100-m sections were measured for surface compaction and depth of leaf litter after 10, 20, 40, 70, and 100 passes. Trail width and depth were measured at 5-m intervals before experimentation and after 100 passes.

The foot and horse trail was divided into 250-m segments by forest type (mesic and xeric). Measurements, including width and depth of leaf litter, were taken at 25-m intervals prior to and after each 20 passes on foot (heavy shoes only). One hundred horse passes were originally planned, but the experiment was terminated after 88 because the trail became slick and was 10 cm deep in mud.

Data were analyzed using Statistical Analysis Systems (SAS 76) (Barr and Goodnight 1976).

RESULTS

In the pasture area, walking in lug-soled shoes doubled the soil compaction after 100 passes. The linear regression $Y = .64 + .0056 X$, where Y is the compaction kg/cm^2 and X is the number of passes, gives a significant fit ($F_{1,58} = 4.324$, $p < .05$). Walking in flat-soled shoes did not produce a significant change, possibly because the compaction of this strip was initially greater than the others. Horseback riding increased the compaction from .4 kg/cm^2 to 1.2 kg/cm^2 after 20 passes, but this was followed by a decrease to .6 $kg.cm^2$ as the horse's hooves wore through the grassy root systems and began to break the sod (Fig. 1).

Walking in both shoe types resulted in a flattening of the original vegetation from a height of 14 cm to a height of 2 cm (85% decrease). The horse reduced the height of the vegetation to .7 cm (95.7% decrease). The impact of riding was qualitatively different from that of walking, as it broke the sod and produced tracts of mud along the transect.

All three types of use resulted in a significant decrease in the depth of surface leaf litter on the footpath. Walking in light shoes compacted the leaf litter from an average depth of 1.85 cm to .75 cm after 100 passes. The linear regression gives a significant fit ($F_{1,58} = 5.60$, $p > .05$). Horseback riding and walking in lug-soled shoes resulted in a decrease of similar magnitude after the first 10 passes, with little change thereafter. Walking in flat-soled shoes significantly reduced surface compaction from 2.06 kg/cm^2 to .77 kg/cm^2 after 100 passes. The pattern of change with lug-soled shoes was similar but not as regular (Fig. 2). The horse churned the trail surface into mud, decreasing surface compaction from an average of 1.7 kg/cm^2 to .12 kg/cm^2 after 70 passes. Significant linear or polynomial regressions were fitted for all three transects. One hundred horse passes significantly ($p < .05$) increased the width and depth of the path, but the results from the shoe segments were more variable, probably due to investigator error or movement of leaf litter. The horse segment was conspicuously eroded by the following spring.

Walking in lug-soled shoes on the foot and horse trail in the mesic forest section resulted in compaction, from 2.64 kg/cm^2 to 1.94 kg/cm^2 , and in depth of leaf litter from 2.10 to 100 cm, but neither of these changes is statistically significant. Horse use reduced surface compaction to .89 kg/cm after 88 passes (t_9 - 2.64, $p < .05$). Walking in the xeric forest section resulted in a slight increase in surface compaction from 1.86 kg/cm^2 to 2.46 kg/cm^2, and a statistically significant decrease in the depth of the leaf litter from 1.80 to .75 cm.

The horse also decreased the depth of the leaf litter, but the greatest change was in the compaction, which was reduced to .69 kg/cm^2, a greater decrease than in the mesic section.

DISCUSSION

On the pasture, walking caused flattening of vegetation and compaction of the underlying soil. The type of shoe did not make a significant difference; heavy shoes resulted in definite surface compaction, whereas the measurements taken for the light shoe transect were ambiguous. The total variance of the measurements on this transect was also high, and on both walking transects the position of the strip accounted for more of the overall variance in surface compaction than the number of passes, implying that surface conditions may be very important, even in the early stages of erosion. Because of the gouging action of the horse's hooves, vegetation was torn up by the roots instead of merely being flattened, and soil was loosened rather than compacted. This type of impact clearly has much greater potential for extensive erosion damage. The impact of the horse was great enough to eventually eliminate the relationship between surface compaction and position of sample sites along the strip.

On the footpath, somewhat different effects were observed for the different shoe types, partly because of differences in topography and soil structure between the two segments and partly because of the somewhat different walking motion. The experimenter stepped a little more cautiously in the light shoes and was inclined to step straight down. Leaf litter was compacted against the ground, resulting in a linear decrease in overall depth. When the experimenter wore heavy shoes, the successional vegetation of the pasture was reduced in height by 85% to 95%. The effect of trampling on the leaf litter on a trail was less radical. One hundred passes reduced the depth of litter by 50% or less under foot use.

The degree of surface compaction is apparently dependent on topography, soil structure, and soil moisture. The mesic section of the foot and horse trampling site deteriorated more quickly than the xeric section, especially under horse use.

From a managerial point of view, it is important to note that, relative to the number of passes, horse use not only caused greater changes in trail conditions than foot use, but the types of changes may be different. Soil loosening was very pronounced. This explains the association of mud with intensive horse use (Bratton et al. 1978, 1979). Loose soil is more prone to removal by water, and rutting may also develop. Under wet conditions or on low density soils (such as those high in organic matter), a single party of 10 horses may noticeably loosen the trail surface). Ten passes by a horse dropped the surface compaction from 1.7 kg/cm^2 to less than 1.0 kg/cm^2. Maintenance of trails used by horses may, therefore, require different techniques than maintenance of foot trails. Rolling or grading may be more important, and optimal surfacing materials may not be the same.

It would be interesting to determine relative carrying capacities for foot and horse users, but this has to be accomplished relative to trail surface and moisture conditions. On some surfaces, foot and horse use may have more similar impacts than on others. In many cases, 10 to 20 passes on a horse may lossen the soil more than 100 passes on foot. Although more data are needed, one might use a ratio of 2.5:1 or 3:1 for dry and compacted surfaces (horse pass:foot pass relative trail impact), and a ratio of 6:1 or 8:1 for a new, loose, or very wet surface. A riderless horse carries 3 or 4 times as much weight per foot as a hiker and distributes the weight over the relatively small surface area of metal horseshoes. A horse with rider weighs 400 kg to 600 kg, whereas most hikers weigh less than 100 kg. Just on a weight basis, a party of 20 horses is at least equal to a party of 100 adult hikers, so these differences in impact are to be expected.

The results of this study are comparable to those of other researchers. McQuaid-Cook (1978) found that horses tend to decrease soil compaction, which, in turn, causes gullying. Nagy and Scotter (1974) found that horses "destroyed about 3 to 8 times as much vegetation and exposed more mineral soil than hikers" on test trampling strips in Waterton Lakes National Park in Canada. Although they were looking at effects in widely differing ecosystems, the pattern of disturbance tends to be similar; horses usually cause more damage than hikers, and the magnitude of the difference depends on soil, vegetation, and topographic variables.

CONCLUSIONS

This study indicated that horse use results in much more rapid surface deterioration than foot use, especially in sensitive mesic forest communities. Topography, soil and vegetation type, and climatic conditions were important in determining the exact impact of a given amount of use; the same number of passes (hiker or horse) may have contrasting effects under different conditions. The type of shoe worn by the hiker may be important under certain conditions.

Further research is needed to determine the response of trails under different weather conditions. The effects of leaf litter reduction and slight changes in surface compaction on the trail's susceptibility to erosion damage have not been established. The weight of the hiker may also be important; presumably, a heavy hiker would cause a greater impact than a light one (the present experimenter weighs 70 kg). Further research combined with accurate estimates of numbers and seasonal distributions of users is needed to accurately predict the condition of trails under specific visitor regimes.

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