COMPARISON OF SURFACE IMPACT BY HIKING AND HORSEBACK RIDING IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

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SOUTHEAST REGION

UPLANDS FIELD RESEARCH LABORATORY
GREAT SMOKY MOUNTAINS NATIONAL PARK
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COMPARISON OF SURFACE IMPACT BY HIKING AND HORSEBACK RIDING IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

Research/Resources Management Report No. 24

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ABSTRACT

This study attempted to quantify differences between horse and foot use on trails in Great Smoky Mountains National Park. Four types of surfaces -- pasture, foot trail, mesic foot and horse trail, and xeric foot and horse trail were investigated. Foot use included both lug and flat soles.

One hundred foot passes on the pasture surface increased compaction. Horse trampling initially increased compaction, but after twenty passes, compaction decreased and the surface became muddy. After one hundred passes the height of the vegetation had decreased by 85 percent under foot use and 96 percent under horse use.

All types of use on the foot path decreased compaction and the depth of litter. The effect of the horse was much greater than that of the foot users, causing the surface to become muddy. Horse use had a much greater effect on the mesic foot - horse trail section than on the xeric section.

Regressions are presented for change in trail surface condition by the number of passes.

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INTRODUCTION

Visitor use of Great Smoky Mountains National Park has increased tremendously during the past decade. In 1977, an estimated 244,533 visitors took day hikes, 101,759 camped in the backcountry, and 59,269 went horseback riding. This places an enormous burden on the park's trail system. Bratton, Hickler, and Graves (1978) estimate that 20 percent of the trails within the park are in poor or very poor condition. Forest type, successional stage, understory type, and physical environment all influence a trail's susceptibility to erosion. Heavily used trails tend to be more eroded.

Precise information on the effects of a measured amount of visitor use is potentially of value in planning to optimize backcountry use patterns and maintenance procedures. This study attempts to document the effects of walking and horseback riding on four different surfaces: (1) pasture, (2) unmaintained foot path (mesic forest environment), (3) hiking - horse trail (mesic forest), and (4) hiking - horse trail (xeric forest).

The study does not consider all the types of trail surface or condition found in the Great Smoky Mountains National Park, nor does it consider very intense use (hundreds of passes) or the relative timing of use seasonally.

METHODS

The first sampling site was a pasture adjacent to the Uplands Field Research Laboratory in the Twin Creeks area of Great Smoky Mountains National Park. It is mostly grass, with a few herbs, and has not been mowed or grazed for over a year. Three parallel transects of 50 meters each were measured off and marked with plastic flagging tape tied to stakes set into the ground. One was used for testing the effect of walking in heavy hiking shoes with lug soles (Vibram construction soles), another of lightweight shoes with smooth soles (Clark PolyVeldts), and the third of horseback riding. The investigator weighed 150 pounds (68 kilograms) The horse, with rider and saddle, weighed about 1,200 pounds (540 kilograms). Measurements of vegetation height and surface soil compaction (in kilograms per square centimeter of penetrability) were taken at five-meter intervals along the center of the strip before testing and after making 20, 50, 75, and 100 passes. Walking or riding along the transect once constituted one "pass" -- back and forth would be two passes. A Soiltest Pocket Panetrometer was used to measure surface compaction. Testing took place between November 11, 1977, and November 28, 1977.

The second sampling site was a foot path running parallel to Cherokee Orchard Road. It connects Cherokee Orchard Road just above Mynatt Park (City of Gatlinburg) to the driveway into the National Park Service quarters at Twin Creeks. The path runs gently downhill from Twin Creeks. Three 100-meter segments were measured and marked with flagging tape, with 50-meter control segments in between. The path runs through a mesic successional forest of mixed hardwoods and pines. The area was previously farmed, and the present forest is about 40 years old.

The segment closest to the driveway into Twin Creeks was used for riding, the second one for walking in heavy shoes, and the third for walking in light shoes. This way, the horse segment was accessible without impacting the others. The trail is lightly used by hikers traveling to the trails on LeConte and by Uplands Laboratory staff members but is not usually open to horses.

Measurements of surface compaction and depth of leaf litter were taken at 10-meter intervals at the center of the transect before testing and after making 10, 20, 40, 70, and 100 passes. Trail width and depth were measured at 5-meter intervals before experimentation and after 100 passes.

The third sampling area was a foot and horse trail connecting Rainbow Falls Trail to Grotto Falls Trail. This trail traversed both mesic and xeric forest types.

Three 500-meter segments were measured at the onset of the study. One of these, a segment running parallel to the Roaring Fork Motor Trail, about one-quarter mile above the entrance to the Motor

Nature Trail from Cherokee Orchard Road, was used for experimentation. The first 250 meters of the trail segment go through cove hardwood forest with an understory of rhododendron and small hemlocks. Granite boulders are distributed throughout the area. After 250 meters, the trail bends sharply and goes up a north-facing slope with xeric vegetation (pitch pine, oaks, and *Vaccinium*) and reddish sandstone soil with quar ite outcroppings. At 425 meters, it turns eastward into more mesic forest with a rhododendron understory and numerous chestnut snags. The trail is rated by Bratton et al. (1978) as being in fair condition. Nonexperimental use during the study period was negligible.

Measurements were taken prior to experimentation, after 100 foot passes in the heavy shoes, 20 at a time (from November 20, 1977, to November 26, 1977) and after 88 passes on horseback (from December 1, 1977, to December 8, 1977). Rainy weather combined with experimental impact made the trail slippery to the point where walking uphill became noticeably tiring as experimentation progressed. The original intention was to make 100 horse passes, 20 at a time, but before this goal was reached the lower (mesic forest) portion of the trail was 10 centimeters deep in mud. As experimentation progressed, the horse became increasingly obstinate and, after 88 passes, began to balk. Experimentation was subsequently terminated.

Measurements included width and depth of the trail, surface compaction, and depth of leaf litter at the trail center (deepest point) at 25-meter intervals; also, number of loose rocks greater than 2 centimeters in diameter, length of trail containing exposed roots, and length of trail containing exposed rock 5 meters on either side of the 25-meter point.

Data were divided into mesic forest (first 250 meters) and xeric forest (250 meters to 500 meters).

Data from all three sampling sites were keypunched and run on the IBM 360 computer at University of Tennessee, Knoxville. The Statistical Analysis Systems (SAS) PROC GLM was used to do analysis of variance and to calculate linear regression coefficients of surface compaction and vegetation height against the number of passes. Two procedures were used to test nonlinear models. University of California Biomedical Program BMD 05R was used to calculate polynomial regression of soil compaction against the number of passes. SAS PROC GLM was used to calculate inverse linear regressions of vegetation height against the number of passes -- INPASS = 1 large one (PASSES + 1) -- which is an asymiotic function. The procedures used are described in the respective user's handbook (Dixon 1971; Barr et al. 1976).

Paired statistics were used to evaluate differences (before testing, after 100 foot passes, and after 100 horse passes) for the mesic and xeric sections of the third sampling area.

RESULTS

Figure 1 shows the mean surface compaction in kilograms per square centimeter plotted against the number of passes for each of the three transects in the pasture area. Walking in heavy shoes resulted in soil compaction to about twice the original level after 100 passes. The linear regression $Y = 0.64 + 0.0056\,X$, where Y is the surface compaction in kilograms per square centimeter and X is the number of passes, gives a significant fit ($F^1{}_{58} = 4{,}324$, $P < .05$). Walking in light shoes produced no significant result, although compaction on this strip was initially much greater than on the others. Horseback riding resulted in a sharp increase in compaction after 20 passes, followed by a decrease as the horse's hooves wore through the grassy root systems and began to break the sod.

Figure 2 shows the mean height of vegetation plotted against the number of passes. Walking in both shoe types resulted in flattening of vegetation to a height of about 2 centimeters from an original average of 14 centimeters (85 percent total increase). The heavy shoes flattened the grass slightly faster than the light shoes.

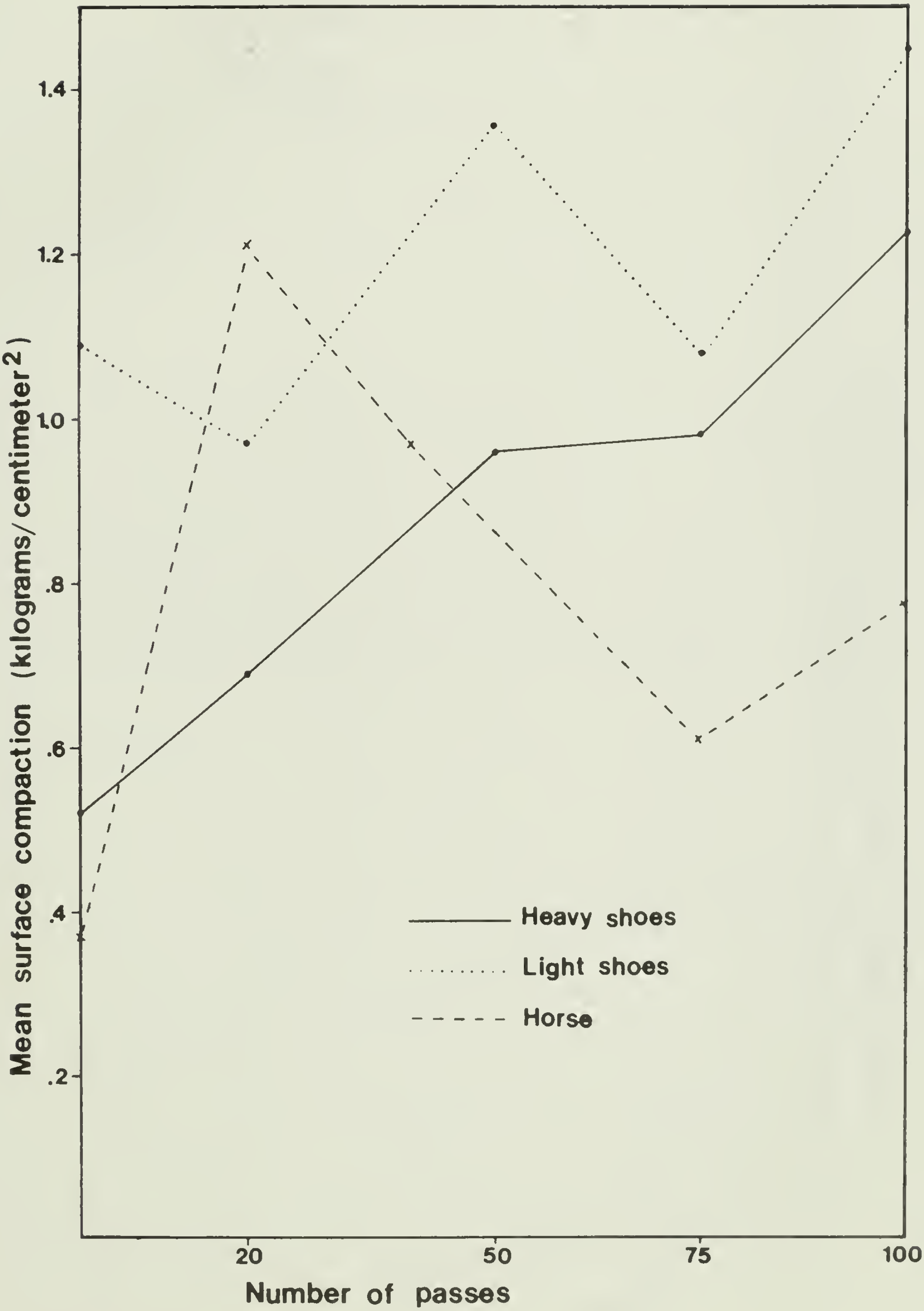

Figure 1: Mean surface compaction on pasture in kilograms per square centimeter plotted against number of passes.

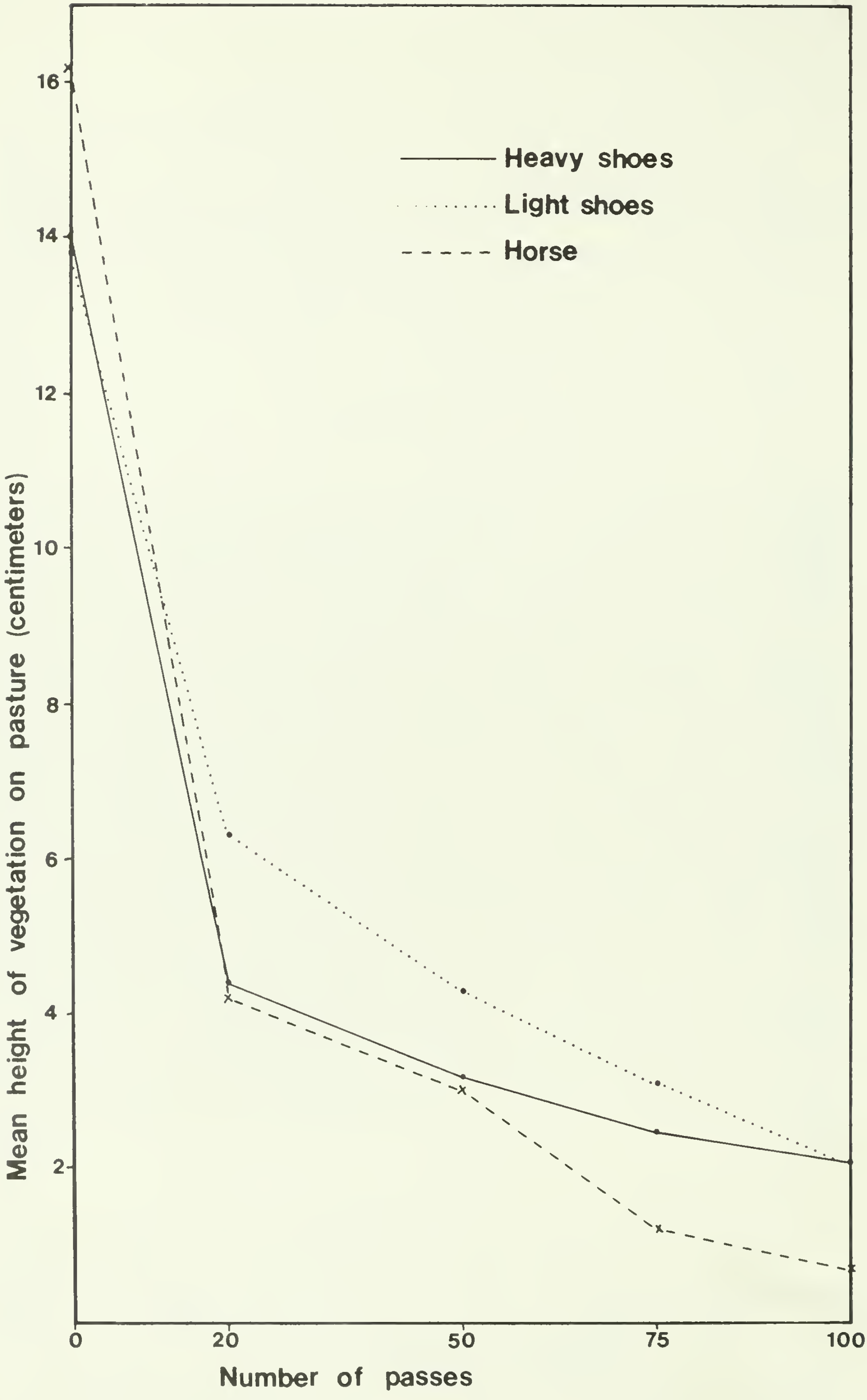

Figure 2. Mean height of vegetation on pasture in centimeters plotted against number of passes.

The horse reduced the average height of vegetation to 0.7 centimeters (95.7 percent total decrease). The inverse linear regression model gave a highly significant fit on all three segments (Appendix Table 1).

The impact of riding was qualitatively different from that of walking. The hooves broke through the sod, resulting in tracts of mud along the transect. In addition, impact was distributed over a broader area. The three transects of flattened vegetation were still noticeable in March 1978 after four months of no disturbance. Imprints of the horse's hooves were still visible.

Foot Path

All three types of use resulted in a significant decrease in the depth of surface leaf litter on the footpath (Fig. 3). Walking in light shoes compacted the leaf litter from an average depth of 1.85 centimeters to 0.75 centimeter after 100 passes. The linear regression gives significant fit (F^{1}_{58} = 5.60, P > .05). Horseback riding and walking in heavy shoes resulted in a decrease after the first 10 passes, with little change thereafter. The decrease caused by the horse was more pronounced.

Mean surface compaction is plotted against the number of passes in Figure 4. Walking in light shoes significantly reduced surface

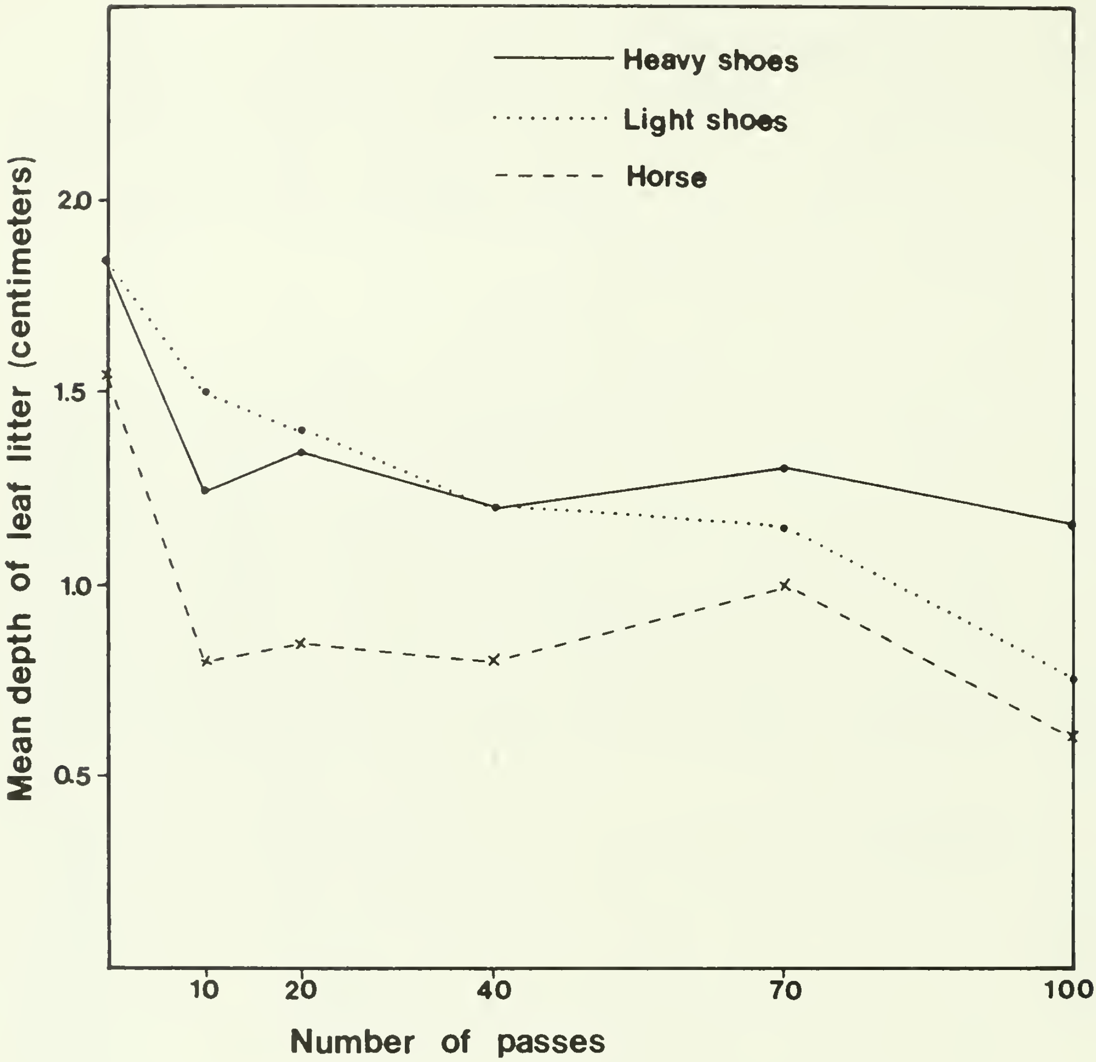

Figure 3. Mean depth of leaf litter on foot path in centimeters plotted against number of passes.

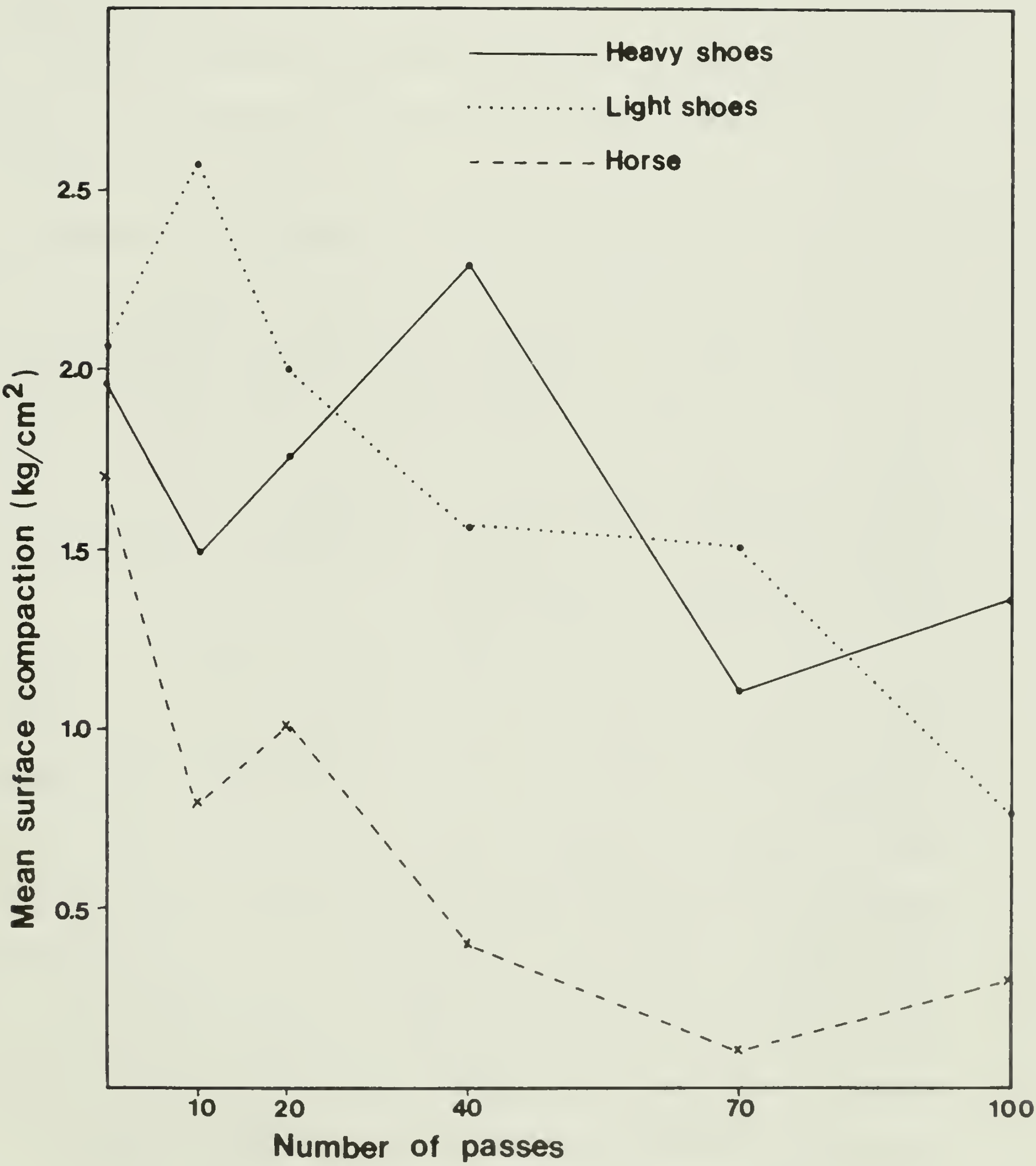

Figure 4. Mean surface compaction on foot path in kilograms per square centimeter plotted against number of passes.

compaction to about one-third of its original level, from an average of 2.06 kilograms per square centimeter to 0.77 kilograms per square centimeter after 100 passes. Walking in heavy shoes resulted in an overall decrease in surface compaction, with relative increases observed after 20, 40, and 100 passes. The horse churned most of the surface into mud, decreasing surface compaction to an average of from 1.7 kilograms per centimeter to 0.12 kilogram per square centimeter after 70 passes. Significant linear or polynomial regressing were fitted for all three transects; the most significant model and associated F values are given in Table 1. The significant polynomial regression indicates that fluctuations were due to experimental effect, not merely to high variance.

Table 2 shows mean width and depth measurements before and after 100 passes. One hundred horse passes significantly increased the width and depth of the path. Walking increased the depth of trail somewhat; the trend was statistically significant on the light shoes segment. There was a significant decrease in mean measured trail width on the light shoes segment and less pronounced decrease on the heavy shoes segment and control segments. The decrease in width was probably due to investigator error or seasonal changes in leaf litter distribution.

Table 1. Regression models for surface compaction (Y) against number of passes (X) for the footpath.

Horse: $Y = 1.53 - .0393\ X + .0027\ X^2$, $F^2_{57} = 11.393$, $P < .001$

*Heavy Shoes: $Y = 1.81 - .06529\ X + .00245\ X^2 - .0004\ X^3 + .0000\ X^4$, $F^4_{55} = 3.323$, $P < .05$

Light Shoes: $Y = 2.33 - 0.1462\ X$, $F^1_{58} = 15.21$, $P = .0001$

*Quartic term too small to show on computer printout.

Table 2. Mean width and depth measurements on the foot path before and after 100 passes, with standard deviations and paired t statistics on the mean difference.

	WIDTH			DEPTH		
	Before	100 passes	Difference	Before	100 passes	Difference
HORSE						
Mean	42.95	57.42	+14.47*	5.05	7.05	+2.00*
SD	15.29	20.27	5.41	2.80	4.25	0.94
	t = 2.68, df = 18			t = 2.13, df = 18		
HEAVY SHOES						
Mean	43.89	40.63	-3.26	3.16	4.16	+1.00
SD	31.13	9.70	5.47	2.52	2.63	0.93
	t = 0.60, df = 18			t = 1.07, df = 18		
LIGHT SHOES						
Mean	42.47	35.68	-6.79**	4.47	5.89	+1.42*
SD	7.55	6.82	1.92	3.22	2.88	0.55
	t = 3.53, df = 18			t = 2.58, df = 18		
CONTROL MEAN						
Mean	55.94	50.72	-5.22	4.00	4.28	+0.28
SD	25.09	25.32	5.40	2.40	3.01	0.44
	t = 0.97, df = 17			t = 0.63, df = 17		

* .05 > P >.01

**.01 > P

The horse segment was badly eroded the following spring. A gully up to four inches deep runs along the center of the path. Many rocks and pebbles on the surface which had been dug up by the horse's hooves were exposed by the subsequent erosion. The other segments did not show conspicuous deterioration. Figures 5 and 6 show a representative section of the path before and immediately after 100 horse passes.

Foot and Horse Trail

(1) Mesic Forest

Walking in heavy shoes decreased overall compaction slightly and tended to decrease the average depths of leaf litter, although this difference was not statistically significant at the $P < .05$ level ($t_9 = 2.30$, $P < .05$), due largely to removal of leaf litter. Observed increases in depth and number of loose rocks were not statistically significant. The amount of exposed root was not affected (Table 3).

Riding further decreased leaf litter and significantly reduced surface compaction ($t_9 = 2.61$, $P < .05$). Trail depth and amount of exposed root were increased, although this was not statistically significant. There was a slight decrease in the area of exposed rock. Some rocks were

Table 3. Mean values for all measurements on hiking - horse trail (mesic forest)

	Before testing	After 100 foot passes	After 88 horse passes
Exposed rock (centimeters)	91.0	150.2	142.5
Loose rocks (number)	11.9	14.1	15.8
Exposed root (centimeters)	82.4	83.1	96.4
Surface compaction (kilograms per square centimeter)	2.64	1.94	0.89
Depth of leaf litter (centimeters)	2.10	1.00	0.50
Width (centimeters)	158.6	143.1	164.6
Depth (centimeters)	8.8	9.7	12.9

Table 4. Mean values for all measurements on hiking - horse trail (xeric forest)

	Before testing	After 100 foot passes	After 88 horse passes
Exposed rock (centimeters)	4.1	4.3	4.5
Loose rocks (number)	1.2	4.1	5.7
Exposed root (centimeters)	31.5	81.4	82.9
Surface compaction (kilograms per square centimeter)	1.86	2.46	0.69
Depth of leaf litter (centimeters)	1.80	0.75	0.25
Width (centimeters)	146.3	143.3	144.4
Depth (centimeters)	8.1	7.7	6.5

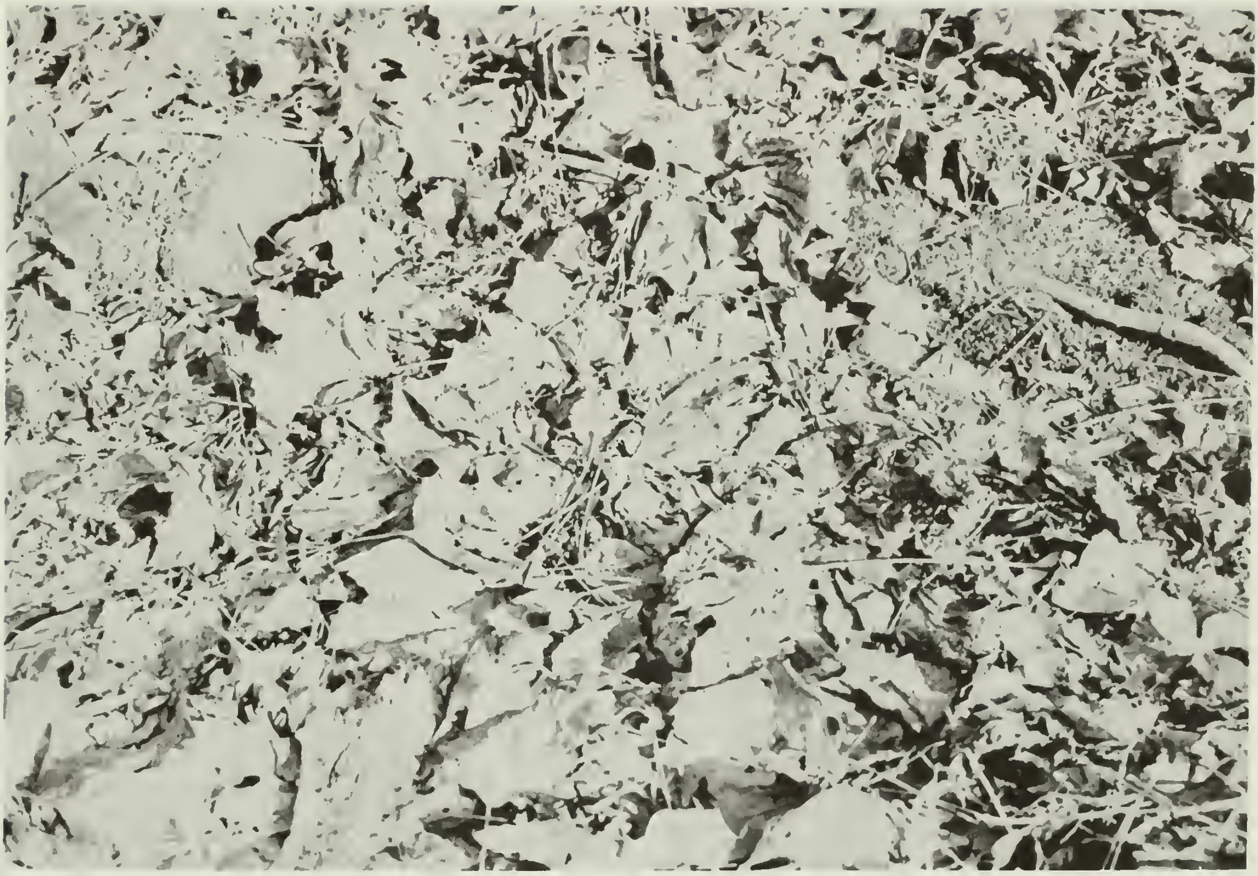

Figure 5. Closeup of trail surface on foot path before experimentation.

Figure 6. Same location as Figure 5 after 100 horse passes.

"dug up" by the horse's hooves and subsequently were classed as "loose" rather than "exposed". At times the horse went off the trail to avoid the mud, increasing the trail's width in some places.

(2) Xeric Forest

Walking resulted in a significant increase in the area of exposed roots (t_9 = 2.37, $P < .05$), a slight increase in surface compaction and a very significant decrease in depth of leaf litter (t_9 = 2.85, $.025 > P > .01$). There were many small rocks lying on or near the trail and consistent counts were impossible. Trail width and area of exposed rock were not affected (Table 4).

Riding significantly reduced surface compaction from an average of 2.46 kilograms per square centimeter to 0.69 kilograms per square centimeter (t_9 = 3.82, $P < .005$). Leaf litter depth was reduced by about two-thirds; due to the large number of sites without litter, difference was not statistically significant.

Some erosion damage was evident the following spring in both forest types but the trail was still in fair condition.

DISCUSSION

Tables 5 and 6 summarize and compare the results of the three different types of use on the pasture and foot path.

On the pasture, walking caused flattening of vegetation and compaction of the underlying soil. The type of shoe did not make a great deal of difference; heavy shoes resulted in definite surface compaction, whereas the measurements taken for the light shoe transect were ambiguous. Average compaction on the light shoe transect was much higher before testing than on the other two transects and was not significantly affected. The total variance of the measurements on this transect was also high (Appendix Table 1). On both walking transects the position of the strip accounted for more of the overall variance in surface compaction than the number of passes (Appendix Table 1), 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 the strip (see Appendix).

Table 5. Impacts of three types of use on the pasture.

Heavy Shoes	Light Shoes	Horse
Reduction of vegetation (85 percent)	Reduction of vegetation (85 percent)	Reduction of vegetation (95.7 percent)
Increase in surface compaction (137 percent)	Increase in surface compaction	Initial increase in surface compaction, followed by decrease
		Disruption of root systems
		Mud along most of strip
		Impact distributed over a wider area

Table 6. Impacts of three types of use on the footpath.

Heavy Shoes	Light Shoes	Horse
Compaction and redistribution of leaf litter	Compaction of leaf litter	Redistribution of leaf litter, mixing into soil
Fluctuations in surface compaction	Decrease in surface compaction (62.6 percent)	Decrease in surface compaction (82 percent)
Increase in trail depth (32 percent)	Increase in trail depth (32 percent)	Increase in trail depth (40 percent)
No increase in trail width	No increase in trail width	Increase in trail width (33.7 percent)
		Trampling of vegetation alongside trail
		Surface erosion damage

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. This behavior is probably typical of park visitors who go hiking in lightweight shoes. Leaf litter was compacted against the ground, resulting in a linear decrease in overall depth. When wearing heavy shoes, the investigator paid little attention to where he stepped (except to avoid large rocks) and tended to kick or step horizontally. Leaf litter was redistributed along the trail as well as compacted, resulting in some places where the trail was bare of litter and others where it was deeper than before.

The horse churned the trail surface into mud, trampled and uprooted herbaceous vegetation beside the trail, and mixed the leaf litter into the soil. These impacts are reflected in the increase in trail width and marked decrease in surface compaction.

Impacts of walking and riding on the hiking - horse trail are summarized in Tables 7 and 8. The impacts on the trail through the mesic forest were similar to those observed on the footpath. After 88 passes of the horse, the trail was in such poor condition that the horse balked. The trail through the xeric forest was

Table 7. Impacts of walking (heavy shoes) and riding on the hiking - horse trail (mesic forest).

Heavy Shoes	Horse
Compaction and redistribution of leaf litter	Redistribution of litter, mixing into soil
Decrease in surface compaction (26.5 percent)	Further decrease in surface compaction (54 percent)
Rocks exposed due to redistribution of leaf litter	Smaller rocks "dug up" and left on surface
Impact limited to maintained trail surface	Trampling of vegetation alongside trail
Trail became somewhat slippery	Trail became so muddy the horse was unwilling to continue

Table 8. Impacts of walking (heavy shoes) and riding on hiking - horse trail (xeric forest)

Heavy Shoes	Horse
Reduction in depth of leaf litter (58 percent)	Further reduction of litter cover (67 percent)
Surface compacted (32 percent increase)	Surface softened (72 percent decrease in compaction)
Small roots exposed by removal of leaf litter	Roots already exposed

less severely impacted. The soil was much more resistant to the gouging action of the horse's hooves and, although somewhat slippery in the steep part, the trail was not nearly as treacherous as that in the mesic forest environment.

Some notable differences were found between the surfaces investigated. Trampling on the pastures tended to increase compaction, at least initially, and then, in the case of horse use, to decrease it. Compaction on the foot trail tended to decrease steadily for all types of use. One hundred passes over vegetation, even of the more resilient successional variety, resulted in a reduction of height by 85 to 95 percent. The effect of trampling on the leaf litter on a trail was less radical. One hundred passes reduced the depth of litter by 50 percent 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 sampling 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). 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 ten horses may noticeably loosen the trail surface. Note that, in Figure 4, 10 passes by a horse dropped the surface compaction from 1.7 kilograms per square centimeter to less than 1.0 kilogram per square centimeter. 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. Figure 4 indicates that 10 to 20 passes on a horse may loosen 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 three to four times as much weight per foot as a hiker and distributes the weight over the relatively small surface area of metal horse shoes. A horse with rider weighs 400 to 600 kilograms, whereas most hikers weigh less than 100 kilograms. Just on a weight basis, a party of 20 horses is at least equal tc a party of 100 adult hikers, so these differences in impact are to be expected.

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 investigator weighs 150 pounds). 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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APPENDIX

Table 1. Analysis of variance (sum of squares, degrees of freedom in parentheses) for surface compaction measurements on pasture. Sources: 4 terms of polynomial regression calculated by BMD OSR, position on the transect and error.

Source	Heavy Shoes	Light Shoes	Horse
PASSES	1.811 (1)*	.810 (1)	.002 (1)
$PASSES^2$	.007 (1)	.007 (1)	1.580 (1)
$PASSES^3$	.001 (1)	.044 (1)	2.616 (1)
$PASSES^4$	.180 (1)	1.134 (1)	.058 (1)
POSITION	9.783 (1)***	9.259 (1)**	2.284 (1)
ERROR	14.32 (54)	45.569 (54)	23.025 (44)

*.01 > P > .01

**.01 > P > .001

***.001 > P

Probability values (P) based on F-test

"$Pasees^2$" etc. indicates the degree of the polynomial

Table 2. Analysis of variance for linear and inverse linear regression models of vegetation height against number of passes on pasture, and inverse linear models.

Source	Heavy shoes	Light shoes	Horse
PASSES (Linear)	234 (1)***	685 (1)***	1,110 (1)***
POSITION (Linear)	34 (1)	14 (1)	45 (1)
ERROR (Linear)	919 (57)	881 (57)	733 (47)
PASSES (Inverse)	361 (1)***	817 (1)***	1,577 (1)***
POSITION (Inverse)	31 (1)	14 (1)	43 (1)**
ERROR (Inverse)	795 (57)	748 (57)	268 (47)
Inverse Linear Model:	H = 4.4 + 9.0 (INPASS)	H = 3.8 + 10.1 (INPASS)	H = 1.9 + 14.4 (INPASS)

*.01 > P > .01

**.01 > P > .001

***.001 > P

Probability values (P) based on F-test

Table 3. Analysis of variance for leaf litter measurements along footpath.

Source	Heavy Shoes	Light Shoes	Horse
PASSES	2.103 (1)	6.157 (1)*	1.850 (1)
$PASSES^2$	1.151 (1)	.057 (1)	.318 (1)
$PASSES^3$	.151 (1)	.523 (1)	2.576 (1)
$PASSES^4$	.475 (1)	.022 (1)	.274 (1)
POSITION	.033 (1)	2.745 (1)	4.182 (1)*
ERROR	35.042 (54)	60.479 (54)	37.033 (54)

Table 4. Analysis of variance for surface compaction measurements along footpaths.

Source	Heavy Shoes	Light Shoes	Horse
PASSES	2.544 (1)	15.821 (1)***	11.092 (1)***
$PASSES^2$	.263 (1)	.155 (1)	3.976 (1)***
$PASSES^3$	.791 (1)	.001 (1)	.067 (1)
$PASSES^4$	5.556 (1)	2.152 (1)	.377 (1)
POSITION	2.384 (1)	6.761 (1)	1.446 (1)
ERROR	35.504 (54)	51.26 (54)	35.804 (54)

*.01 > P > .01

**.01 > P > .001

***.001 > P

Probability values (P) based on F-test

"$Passes^2$" etc. indicates the degree of the polynomial