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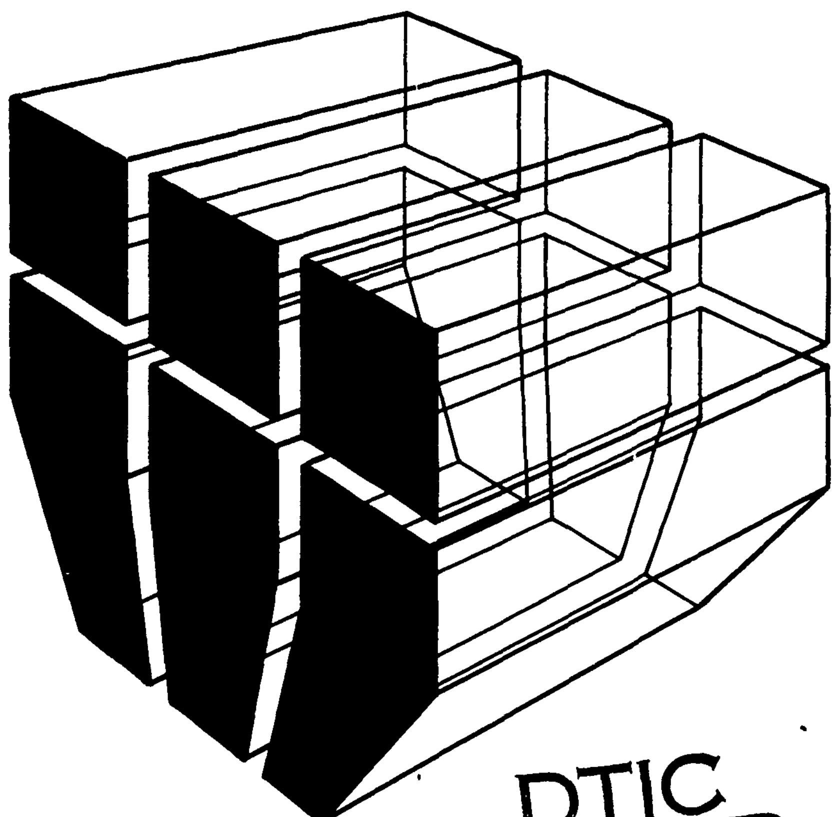
EFFECTS OF TRACKED VEHICLE ACTIVITY ON HIGHER VERTEBRATE POPULATIONS AT ARMY INSTALLATIONS

by
William D. Severinghaus



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Recent trends in environmental analysis require quantification of impact estimates. This manuscript presents the results of research conducted to establish cause/effect relationships between Army activities and their impacts on ecosystems and describes initial results of the first phase of the basic research effort. The material is contained in two papers. "Effects of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, Kentucky" appeared in Trans. Ky Acad. Sci., 41(1-2), 1980, 15-26. "Effects of Tracked Vehicle Activity on Bird Populations" appeared in

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Environmental Management, Vol. 6, No. 2, pp. 163-169. Further significant research is focusing on quantification of impacts on soil, water, and attributes.

FOREWORD

This work was performed for the Chief of Engineers under Project 4A161102AT23, "Basic Research in Military Construction"; Task Area C, "Environmental Quality"; Work Unit 001, "Interdependency of Elements in Ecological Systems."

This investigation was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (USA-CERL). Dr. R. K. Jain is Chief of USA-CERL-EN.

"Effects of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, Kentucky" is reprinted with permission of Eastern Kentucky University. "Effects of Tracked Vehicle Activity on Bird Populations" is reprinted with permission of Springer-Verlag New York, Inc.

COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

Trans. Ky. Acad. Sci., 41(1-2), 1980, 15-26

Effects of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, Kentucky

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ABSTRACT

A field study was conducted at Fort Knox, Kentucky, to investigate the effects of Army tracked vehicle training on terrestrial birds and mammals. Intensive studies were conducted at 3 sites representative of a long-term training area, a short-term training area, and a control area. This report describes the survey procedures used and provides preliminary indications of ecological differences between Army tracked vehicle training areas and areas representing pretraining (no training) conditions. Principal changes were caused by clearing and compacting the soil, vegetational disturbance, and resultant erosion in the training areas.

INTRODUCTION

Recent trends in environmental impact analysis require quantification of impact estimates. This paper presents the results of research conducted to establish cause/effect relationships between Army activities and their impacts on ecosystems and describes initial results of the first phase of the basic research effort. Further significant research is focusing on quantification of impacts on soil, water, and other attributes.

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METHODS

Fort Knox lies in the Muldraughs Hill section of north-central Kentucky (Wharton and Barbour 1973), an area in which there is a variety of topographic and edaphic sites, that range from mesophytic deep depressions and sheltered slopes to dry uplands over shallow soils. Vegetationally, the area is within the western mesophytic forest region of the Deciduous Forest Formation of eastern North America (Wharton and Barbour 1973). Mixed mesophytic communities with sugar maple, tulip poplar, and a rich assortment of associated species occupy the depressions and sheltered slopes, while mixed oak and oak-hickory communities dominate the drier slopes and ridges.

Three study sites were selected in the Otter Creek watershed west of the cantonment (Fig. 1) in Meade County, Kentucky, for the bird and small mammal surveys. The northernmost site, northwest of Carlson Lake, is an area of 4.4 ha that has been used heavily since 1942, and nearly all arborescent vegetation has been destroyed or removed. Erosion has been so severe in the past that some chert beds were exposed. Baxter silt loam surrounded most of that area. The bulk of the exposed soil was classified as gullied land, and the original soil profile had been destroyed. In locating the mammal and bird grids in that area, an effort was made to exclude sinkholes and to maintain a buffer zone between the grids and the surrounding area which had undergone little or no noticeable usage. That long-term impact grid was being used both day and night on a continuous basis for training maneuvers.

A second impact area of 12.1 ha was southwest of Snow Mountain and east of Pinwheel Road. It has been used for

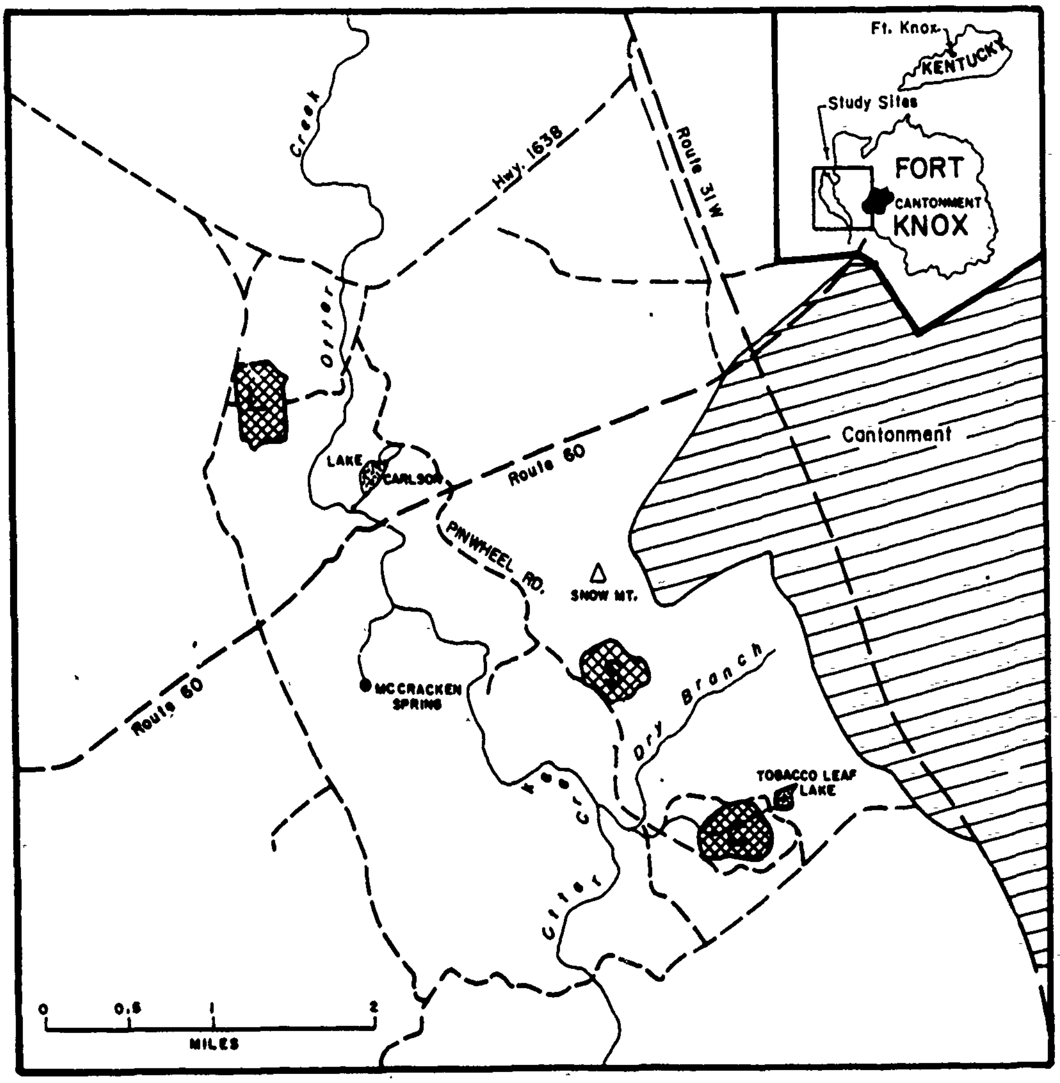

FIG. 1. Locations of the 3 study areas at Fort Knox, Kentucky. L = long-term, S = short-term, and C = control areas. Inset shows locations of Fort Knox and cantonment in Kentucky.

tracked vehicle maneuvers since early spring 1978 and is part of a large tract of land that had been opened recently for tracked vehicle training purposes. To develop required training conditions, all vegetation under 3 inches (76 mm) in diameter was cleared for 1,600 ft (480 m) east and west of Pinwheel Road. As a mitigation procedure, all the vegetation cleared was bulldozed into gullies, sinkholes, and other topographical locations of significance to reduce erosion.

Although herbaceous vegetation had not been disturbed intentionally, most of the ground cover was disrupted during site preparation. The whole area was then reseeded with rye and fescue grasses that were only beginning to germinate at the time of the study. It should be noted that trees considerably larger than 3 inches (76 mm) in diameter were removed and that some erosion was already evident. Baxter cherty silt loams and Crinder silt loam occupied this area. That

TABLE 1.—NUMBERS OF 7 SPECIES OF SMALL MAMMALS CAPTURED, ALONG WITH ESTIMATES OF POPULATION SIZE PER HECTARE WHERE POSSIBLE, ON EACH OF 3 STUDY AREAS AT FORT KNOX, KENTUCKY. C = CONTROL STUDY AREA, S = SHORT-TERM STUDY AREA, L = LONG-TERM STUDY AREA. AN ASTERISK (*) INDICATES SIGNIFICANCE AT THE 0.05 LEVEL

Species		Observations		Estimated population (Schnabel)	t-test of means (probability)		Total observations		Index value		Population change (%)	
		Individuals	Total		C/S	C/L	Grid + brush	Sinkholes	Grid + brush	Sinkholes	S/C	L/C
Short-tailed shrew	C	5	5	3.0	0.021*	0.021*	14	—	3.88	—	−90.7	−100.0
	S	0	0	—			1	—	0.36	—		
	L	0	0	—			0	—	—	—		
Eastern chipmunk	C	7	15	5.22	0.004*	0.001*	17	1	4.72	7.04	−69.3	−100.0
	S	3	3	0.0			4	—	1.45	—		
	L	0	0	—			0	1	—	4.55		
Southern flying squirrel	C	0	0	—	0.329	0.329	0	—	—	—	Insufficient data	
	S	1	1				1	—	0.36	—		
	L	0	0	—			0	—	—	—		
White-footed mouse	C	0	0	—	0.001*	0.010*	2	3	0.55	21.13	+3,089.1	+1,652.7
	S	11	31	11.24			47	—	16.99	—		
	L	9	22	8.38			22	2	9.09	9.09		
Prairie vole	C	1	2	1.0	0.162	0.715	3	—	0.83	—	−100.0	+149.4
	S	0	0	—			0	—	—	—		
	L	2	3	2.0			3	—	1.24	—		
Pine vole	C	11	14	10.0	0.002*	0.001*	21	1	5.83	7.04	−87.7	−100.0
	S	1	1	0.0			2	—	0.72	—		
	L	0	0	—			0	—	—	—		
House mouse	C	0	0	—	0.042*	1.00	0	—	—	—	+	—
	S	1	4	1.0			4	—	1.45	—		
	L	0	1	—			0	—	—	—		

short-term study site was set up, as was the long-term site, by avoiding sinkholes and maintaining the buffer zone between the grids and unimpacted areas. Training was observed frequently during the study.

The control site of 4.2 ha was west of Tobacco Leaf Lake. More than the disturbed sites, it was a mosaic of different aged communities having varied histories and a variety of edaphic and slope conditions. This site was bordered on the northwest by recently cleared areas contiguous with the short-term site. Evidence suggested that this area was used periodically for training, although it did not get heavy use by tracked vehicles. Especially evident were several overgrown tracked vehicle trails that traversed the site. One community in the control area, however, had not been penetrated by vehicles and apparently never had been cleared.

The mammal and bird studies were conducted during April and May 1978 with additional data obtained during late June and early July.

A 1-hectare grid was located within each of the long-term, short-term, and control areas. Standard capture–recapture methods were used in which the animals were toeclipped for marking purposes. The grids were run for 19 to 21 consecutive nights to obtain sufficient data for estimating the populations with the Schnabel method (Smith 1974). The live traps were baited with a mixture of rolled oats, peanut butter, and cracked corn. Cotton was supplied for nest material and insulation. Additional data were obtained by trapping small mammals both around the sinkholes on the control and long-term grids and in the brush piles on the control and short-term grids.

The grids used in the bird study were of variable size. There was a problem finding areas of apparent original equivalency while still maintaining buffer zones between areas that were different naturally and/or in terms of human use patterns. All 3 grids were observed 15 times from 17 April to 11 May and from 29 June to 2 July. Observation periods varied among early morning, late morning, or early afternoon and were rotated daily to equalize the number of hours per interval spent on each grid for a total of 45 hours apiece.

RESULTS

The data from the mammal grid (Table 1) were analyzed using the Schnabel method where possible. Because of the inability to capture, mark, release, and recapture some species, that method did not produce consistently effective results, but will be discussed where applicable. A Student's *t*-test of means was used to compare the daily observations of each species on the control grid and the long- and short-term grids (Table 1). A second measure of comparison between the populations of the 3 areas is a capture index, defined as the number of individuals of each species captured divided by the number of trapnights multiplied by 1,000.

The short-tailed shrew *Blarina brevicauda* does not survive well in a livetrap situation; therefore, the capture-recapture data were of little use. The *t*-test indicated a significant difference in the number of shrews ($P = 0.021$) between the 2 impact areas and the control site. The index value indicated that approximately 90 percent of the population was lost initially when the sites are prepared for training, and the remainder was lost as training progressed. Loss of cover, erosion, and soil compaction probably are the most significant factors that affect that species.

The eastern chipmunk *Tamias striatus* that prefers deciduous woods with brushy areas, showed a 69 percent loss to short-term activities and a 100 percent loss in the heavy, continuous use area. Observations on the grids indicated a significant difference between populations in the control area and in the long- and short-term areas ($P = 0.001$ and $P = 0.004$, respectively). No recaptures of marked animals were recorded for the short-term grid so comparison is not possible. The lower population in the short-term area probably was caused by a combination of the change in habitat (concentration of brush to reduce erosion), the chipmunk's innate intolerance of other individuals of the same species, and its preference for staying on or below the surface and not climbing vertically in the brush piles.

Data on the southern flying squirrel *Glaucomys volans* were insufficient for analysis. Only one was captured and released on the short-term grid. It can reasonably be assumed that that species inhabits the control area, but the lack of trees and most other vegetation precludes its existence within the long-term area.

The white-footed mouse *Peromyscus leucopus* was the most common small mammal observed. Relatively high populations were found in the short- and long-term areas in comparison to the control area (Table 1). The Schnabel method indicated a ratio of 0:11:8 mice per hectare for the control, short-term, and long-term sites. The *t*-test on observations indicated a significant difference (P = 0.001 and P = 0.010) between the control site and the short- and long-term sites. The index value showed 31-fold and 17-fold increases, respectively, for the short- and long-term sites over the control. The reason for the increase is complex. It appears that the white-footed mouse has replaced the eastern chipmunk in the short-term areas because the mouse is more tolerant of conspecifics and because its movements are vertically, as well as horizontally, inclined. The presence of the white-footed mouse in the long-term study area was unusual. At the beginning of the study, none were taken on the grid. Toward the middle of the study scrotal males were being captured along the erosion gullies in the long-term area. When released, those animals would enter the gullies immediately and leave the grid area. The increase in the number of mice on the long-term grid coincided with a noticeable increase in the number of scrotal males in the short-term grid. It is entirely possible that the increase in the white-footed mouse population on the long-term grid was due to the increased wandering of reproductive males.

Data on the prairie vole *Microtus ochrogaster* are minimal; only 3 were taken on the grids, 1 from the control area and 2 from the long-term area, with a total of only 6 observations. That species' habitat preference should have excluded them from all grids, since they prefer open, grassy fields. The individuals captured on the control grid were taken along an overgrown road with some grass and small saplings. The individuals captured on the long-term grid were taken at a point on the grid's periphery where a large tree had been pushed over. The tree was dead and was large enough that it protected a small area adjacent to the grid from vehicular activity and erosion. The species could not be expected in the short-term area, since no ground cover was left after the area had been cleared.

A fairly substantial population of pine voles *Microtus pinetorum* was found at the control site. This was expected, since they prefer a forest floor with a layer of decaying organic material. The *t*-test on the observations indicated a significant difference between the control and the short- (P = 0.002) and long- (P = 0.001) term areas. The index value showed an 88 percent loss of pine voles at the short-term site and a 100 percent loss at the long-term site. The reason for that difference is the lack of vegetation and the presence of erosion in the long-term and the scraping of the soil in the short-term area during clearing operations.

The house mouse *Mus musculus* was observed only in the short-term area. The difference between the control and short-term areas was significant (P = 0.042). The lack of that species in the long-term area probably is due to the lack of sufficient vegetation for cover and food.

The presence of other mammals in the study area was evidenced by sight and/or sign. Raccoon, opossum, and deer were observed in all 3 areas. Fox tracks were seen in the short-term area, and signs of dogs and gray squirrels were seen in the control area.

The information on small mammals

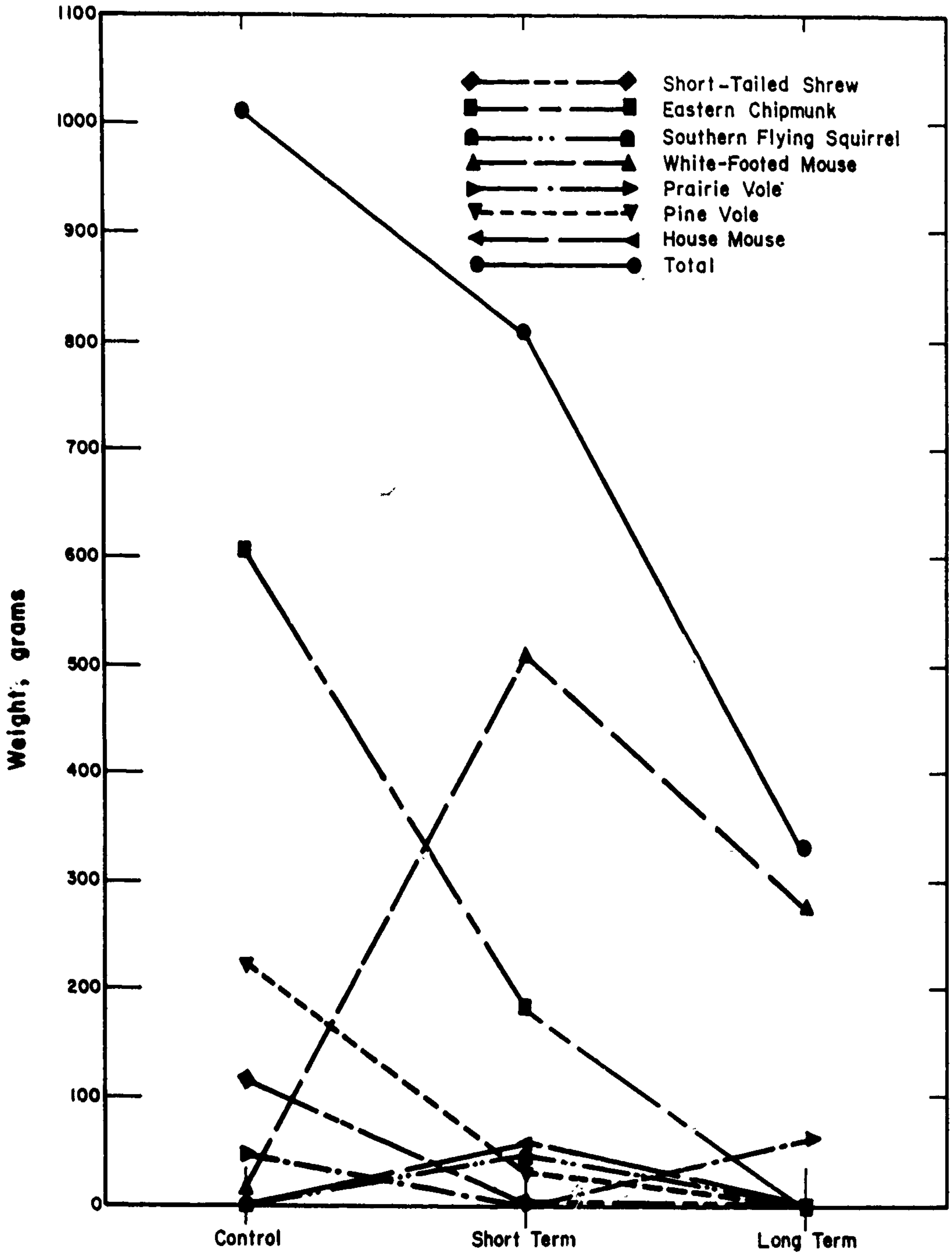

FIG. 2. Biomass of mammals in long-term, short-term, and control areas, Fort Knox, Kentucky.

that inhabit the sinkhole areas indicated that those areas provide local refuge for chipmunks and white-footed mice. If training were terminated and/or the area refurbished, there would appear to be ample opportunity for reinvasion of those areas by small mammals.

With 1 exception, all mammals cap-

TABLE 2.—BIOMASS (G) OF SMALL MAMMALS IN EACH OF 3 STUDY AREAS OF FORT KNOX, KENTUCKY, ALONG WITH PERCENTAGE CHANGES IN BIOMASS BETWEEN STUDY AREAS. +% INDICATES PERCENTAGE LOSS, × INDICATES INCREASE (3× = 3-FOLD INCREASE)

Species	Control	Short-term	Long-term	Change from control to short-term	Change from short-term to long-term
Short-tailed shrew	58.2–116.4[1]	5.4–10.8	0	90.7%	100.1%
Eastern chipmunk	349.38–608.88	107.3–187.05	0	69.3%	100.0%
Southern flying squirrel	0	25.2–35.28	0	—	—
White-footed mouse	9.35–16.5	288.83–509.7	154.53–272.7	30.9×	16.5×
Prairie vole	30.71–39.84	0	43.88–59.52	100.0%	1.4×–1.5×
Pine vole	128.26–227.37	15.84–28.05	0	87.7%	100.0%
House mouse	0	26.1–43.5	0	—	—
Totals	575.8–1,008.99	468.67–814.41	198.41–332.22	18.6–19.3%	65.5–67.1%

[1] Based on Index value and weight range (g) from Barbour and Davis (1974).

tured on the short-term grid were taken in the brush piles placed in gullies to reduce erosion; the southern flying squirrel was taken at the base of a tree away from the brush piles. All mammals taken on the long-term grid were captured within 2 m of the gullies except for the prairie voles that were taken in the downed tree area.

The last measure used to examine small mammal populations in the 3 study areas was biomass.

The impact on small mammal populations was generally negative (Fig. 2), since there was an 18 to 20 percent reduction in biomass from the control area to the short-term area and a 65 to 68 percent reduction from the control area to the long-term area (Table 2). It appears that the clearing of hardwood forests to simulate western European conditions will result in an immediate loss of approximately 20 percent of the area's capacity to sustain small mammal life. In addition, extensive and long-term use of such areas can result in a biomass loss that approaches 65 percent. This information does not consider the desirability of the various species but can approximate the area's abilities to sustain small mammal populations and will have additional significance when considering the area's trophic structure.

Shrews, voles, and chipmunks all lost large amounts of biomass. Shrews and voles are exclusively surface dwellers that inhabit nests or dens either on the surface or below ground close to the surface. Chipmunks are somewhat similar; they prefer to stay on the ground, although they will climb occasionally. All 3 groups would have suffered some loss of food resources with loss to the voles being most severe. On the other hand, mice showed a distinct increase, since their preference for climbing and seeds (as compared to grass eaters) allowed them to replace the voles and chipmunks.

Fifty-four species of birds were seen at the study sites during the 15-day survey. They were divided into 3 groups in the manner of Vogl (1973): "resident" (present throughout the study period), "transient" (departed from or arrived in the study area during the study period), and "occasional" (birds sighted 5 times or less) (Tables 3, 4, 5). The adjusted figures in the second column under each grid heading take into account the area surveyed and the number of hours of observation accumulated for each area.

Nineteen species were considered "residents" during the time of the survey (Table 3). Eight of those species showed a significant difference at the $P = 0.05$ level when comparing control and short-term areas, while 11 were significantly different when comparing the long-term and control areas. Seventeen of the 19 species were observed more frequently in the control area than in the short-term area as well as in the long-term area.

TABLE 3.—NUMBERS OF RESIDENT BIRDS RECORDED IN THE 3 STUDY AREAS AT FORT KNOX, KENTUCKY. THE ADJUSTED FIGURES TAKE INTO ACCOUNT THE AREA SURVEYED AND THE TIME SPENT IN OBSERVATION. FIGURES MARKED WITH AN ASTERISK (*) ARE SIGNIFICANTLY (0.05 LEVEL) DIFFERENT THAN THE CONTROL AREA

	Control		Short-term		Long-term	
Species	Observed	Adjusted	Observed	Adjusted	Observed	Adjusted
Mourning dove	6	6.2	4	14	0	0*
Common flicker	4	38	5	17	0	0
Downy woodpecker	3	29	3	10	0	0
Eastern kingbird	3	29	3	10	5	47
Blue jay	64	614	34	116*	6	56*
Common crow	8	77	9	30	0	0*
Carolina chickadee	12	115	3	10*	0	0*
Tufted titmouse	8	77	1	3*	0	0*
Gray catbird	6	58	6	20	0	0
American robin	14	134	0	0*	0	0*
Wood thrush	17	163	1	3*	0	0*
Red-eyed vireo	43	413	11	37*	0	0*
Prothonotary warbler	8	77	0	0*	0	0*
Prairie warbler	16	154	0	0*	0	0*
Red-winged blackbird	1	10	8	27	1	9
Scarlet tanager	6	58	2	7	0	0*
Cardinal	5	48	7	24	0	0
Indigo bunting	0	0	6	20	0	0
Rufous-sided towhee	4	38	15	51	0	0
	228	2,194	118	399	12	112

Five species were considered "transient" during the time of the survey (Table 4). Three species showed a significant difference when control and short-term areas were compared; 5 showed a significant difference between the control area and the long-term area. All 5 species were observed more frequently on the control site than in either the short-term or long-term areas.

Twenty-five of the species observed were considered "occasionals" (Table 5). The number of individuals of each species observed did not allow for statistical analysis, but it should be noted that 19 of the 25 were seen more frequently in the control area than in either the short- or long-term areas; 7 were observed more frequently in the short-term area; 1 was observed more frequently in the control than in the long-term area.

Some of these results can be explained by examining the habitat preferences of the "resident" species that did not show

TABLE 4.—NUMBERS OF "TRANSIENT" BIRDS RECORDED IN THE 3 STUDY AREAS OF FORT KNOX, KENTUCKY. THE ADJUSTED FIGURES TAKE INTO ACCOUNT THE AREA SURVEYED AND THE TIME SPENT IN OBSERVATION. FIGURES MARKED WITH AN ASTERISK (*) INDICATE POPULATIONS THAT ARE SIGNIFICANTLY DIFFERENT ($P < 0.005$) THAN CONTROL

	Control		Short-term		Long-term	
Species	Observed	Adjusted	Observed	Adjusted	Observed	Adjusted
Yellow-bellied sapsucker	11	96	0	0*	0	0*
Ruby-crowned kinglet	36	346	6	20*	1	9*
Black-and-white warbler	7	67	0	0*	0	0*
Yellow-rumped warbler	9	87	5	17	0	0*
White-throated sparrow	41	394	103	350	0	0*
	103	980	110	373	1	9

TABLE 5.—NUMBERS OF "OCCASIONAL" BIRDS RECORDED IN 3 STUDY AREAS AT FORT KNOX, KENTUCKY. THE ADJUSTED FIGURES TAKE INTO ACCOUNT THE AREA SURVEYED AND THE TIME SPENT IN OBSERVATION

Species	Control		Short-term		Long-term	
	Observed	Adjusted	Observed	Adjusted	Observed	Adjusted
American woodcock	2	19	0	0	0	0
Common nighthawk	2	19	0	0	0	0
Belted kingfisher	3	29	0	0	0	0
Pileated woodpecker	0	0	1	3	0	0
Hairy woodpecker	0	0	5	17	0	0
Great crested flycatcher	2	19	0	0	0	0
Eastern wood pewee	1	10	0	0	0	0
Rough-winged swallow	1	10	1	3	0	0
Purple martin	0	0	1	3	0	0
White-breasted nuthatch	0	0	1	3	0	0
Red-breasted nuthatch	2	19	2	7	0	0
Brown thrasher	2	19	1	3	0	0
Veery	1	10	0	0	0	0
Black-throated green warbler	4	38	0	0	0	0
Palm warbler	2	19	2	7	0	0
Kentucky warbler	2	19	1	3	0	0
Canada warbler	0	0	2	7	0	0
Northern oriole	2	19	0	0	0	0
Common grackle	1	10	0	0	0	0
Brown-headed cowbird	2	19	1	3	0	0
Summer tanager	2	19	0	0	0	0
Rose-breasted grosbeak	5	48	0	0	0	0
American goldfinch	4	38	0	0	0	0
Dark-eyed junco	0	0	1	3	0	0
Song sparrow	1	10	0	0	0	0
	41	393	19	62	0	0

significant differences or were not observed more frequently at the control site. The eastern kingbird *Tyrannus tyrannus* prefers open, widely spaced trees and mature woodlands. The control area is not an open woodland. The short-term area is an open woodland but does not contain suitable understory for insect proliferation. The long-term area had an unusually high population of kingbirds who would leave the woods to feed in the open areas. The red-winged blackbird *Agelaius phoeniceus* prefers open country, ponds, marshes, and meadows, characteristics that more closely depict the short-term area. The indigo bunting *Passerina cyanea* will feed in any area from fields to deep woods but nests in brushy, weedy areas like the short-term site. The rufous-sided towhee *Pipilo erythrophthalmus* prefers brushy fields and open woodlands.

The red-tailed hawk *Buteo jamaicensis* and the turkey vulture *Cathartes aura* were observed in the study areas, but none of the areas incorporated enough acreage to include 5 or more individual territories; therefore, those data are not being considered in this analysis. Rock doves *Columba livia* were seen flying over the short-term area. Their presence could be attributed to the existence of an abandoned cluster of buildings on Snow Mountain approximately 1,000 m from the area. Several bobwhites *Colinus virginianus* were seen at the control area. Fort Knox has an active wildlife management program, and it was assumed that these animals were part of a group that had been pen raised and recently released, since researchers could approach within 1 m of them before they would seek cover.

To determine the impact of tracked vehicle training on bird populations in general, the data were converted to biomass per species (Table 6). Species weights were then determined (Poole 1938, Bald-

TABLE 6.—ESTIMATED BIOMASS OF EACH SPECIES OF BIRD RECORDED IN EACH OF 3 STUDY AREAS AT FORT KNOX, KENTUCKY, ALONG WITH THE ESTIMATED TOTAL BIOMASS AND PERCENTAGE COMPUTED BY EACH AREA. ALL WEIGHTS ARE IN GRAMS

Species	Control	Short-term	Long-term
Red-tailed hawk	—	—	19,462.11
Turkey vulture	—	69,360.00	47,430.00
Bobwhite	12,206.0	—	—
American woodcock	3,811.0	—	—
Rock dove	—	17,423.232	—
Mourning dove	8,545.68	2,533.0272	—
Common nighthawk	1,742.016	—	—
Belted kingfisher	3,841.92	—	—
Common flicker	5,151.744	3,101.7792	—
Pileated woodpecker	—	2,272.696	—
Yellow-bellied sapsucker	4,896.0	—	—
Hairy woodpecker	—	1,513.6664	—
Downy woodpecker	775.296	373.4342	—
Eastern kingbird	1,070.496	515.6222	2,938.2885
Great crested flycatcher	722.88	—	—
Eastern wood pewee	132.672	—	—
Rough-winged swallow	151.2	72.828	—
Purple martin	—	198.832	—
Blue jay	51,240.96	13,111.8144	7,911.34
Common crow	37,747.2	20,454.264	—
Carolina chickadee	1,036.8	124.848	—
Tufted titmouse	1,691.136	101.8205	—
White-breasted nuthatch	—	97.0578	—
Red-breasted nuthatch	307.008	147.8755	—
Gray catbird	2,058.048	991.2931	—
Brown thrasher	1,334.016	321.2755	—
American robin	10,477.824	—	—
Wood thrush	8,486.4	240.448	—
Veery	314.4	—	—
Ruby-crowned kinglet	2,325.888	186.7171	106.4013
Red-eyed vireo	7,422.144	914.5347	—
Black-and-white warbler	710.304	—	—
Prothonotary warbler	1,013.76	—	—
Yellow-rumped warbler	84.768	163.3197	—
Myrtle warbler	1,117.44	67.2792	—
Black-throated green warbler	364.8	—	—
Prairie warbler	1,113.6	—	—
Palm warbler	158.4	76.296	—
Kentucky warbler	272.216	65.7905	—
Canada warbler	—	40.46	—
Red-winged blackbird	672.0	2,589.44	1,106.7
Northern oriole	1,344.0	—	—
Common grackle	1,174.08	—	—
Brown-headed cowbird	806.4	194.208	—
Scarlet tanager	1,854.72	297.7856	—
Summer tanager	806.4	—	—
Cardinal	2,028.0	1,367.548	—
Rose-breasted grosbeak	2,294.4	—	—
Indigo bunting	—	360.672	—
American goldfinch	514.944	—	—
Rufous-sided towhee	1,588.608	2,869.4232	—
Dark-eyed junco	—	96.7803	—
White-throated sparrow	10,839.744	13,116.5309	—
Song sparrow	199.104	—	—
Total	196,447.824	155,362.6082	78,954.8238
Percent		20.914	59.8088

win and Kendeigh 1938, Norris and Johnston 1958, and Graber and Graber 1962).

As expected, the overall impact of short- and long-term areas was negative. There was a 20 percent reduction in biomass at the short-term area and a 60 percent reduction at the long-term area.

Discussion

The results of this study indicated that there is generally a modest impact on small mammals when areas are prepared for tracked vehicle training and a severe impact when these areas are used extensively and over a long time. There was also ample indication that mammals that spend their entire lives on or below, but near, the surface, are severely impacted by such training activities in comparison to those that climb in brush and trees during at least part of their existence. The major cause–effect relationships appear to be disturbance of the soil surface by the compacting and scraping activities of clearing, and the soil compaction, vegetational disturbance, and resulting erosion caused by training. The primary parameters affected are the reduction of food resources and the removal of or damage to the nesting and cover.

Study results showed that the methods and results of preparation for tracked vehicle training cause a moderate (20%) reduction in bird populations. This information in itself indicates a total reduction in biotic productivity, but detailed examination of each "resident" species is necessary to understand the causes of the reduction. Data show that populations of woodland species are severely reduced (wood thrush *Hylocichla mustelina*, tufted titmouse *Parus bicolor*, red-eyed vireo *Vireo olivaceus*, and Carolina chickadee *Parus carolinensis*), while populations of species that prefer an open woodland or forest edge habitats are moderately reduced (cardinal *Cardinalis cardinalis*, common flicker *Colaptes auratus*, common crow *Corvus brachyrhynchos*, gray catbird *Dumetella carolinensis*, and mourning dove *Zenaida macroura*). Populations of species that prefer open, bushy habitats were actually impacted positively (rufous-sided towhee and red-winged blackbird). It also appears that insectivorous species such as the vireos and warblers are reduced much more severely than seed eating species such as the cardinal. The main disturbance parameters appear to be reduction of understory, disruption of vegetational stratification, and disturbance of soil surface.

The virtual 100 percent reduction in most "resident" species in the long-term area is indicative of the severely eroded and denuded terrain. The species found most frequently in the long-term impact area were the red-tailed hawk, turkey vulture, and eastern kingbird, and it is probably easier for these species to capture prey, locate carrion, and glean insects, respectively, in the open area.

Conclusions

The major cause–effect relationships of tracked vehicle training activities appear to be disturbance of the soil surface by the compacting and scraping activities of clearing and the compaction, vegetational disturbance, and resultant erosion caused by training. With mammals, it appears as though clearing is not as severe as the actual training and that dens, nesting sites, cover, and food resources suffer somewhat equal losses. The main disturbance parameters that affect birds appear to be reduction of understory, disruption of vegetational stratification, and disturbance of soil surface.

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Effects of Tracked Vehicle Activity on Bird Populations

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ABSTRACT / This study was initiated to develop cause and effect relationships between Army training activities and bird populations throughout the continental United States. Installations in Kentucky, Louisiana, Texas, and Washington were selected as representative of diverse ecosystems and of extent of training. Birds were separated into 31 guilds to assist in the analysis between different ecosystems. The results showed that (1) guild theory can be useful in impact analyses within and between ecosystems, (2) tracked vehicles disturb bird populations because of habitat alteration and reduction, (3) the change in biomass ranged from 20.9 to −55.3 percent and is dependent on the extent of training and ecosystem type, and (4) species replacement should be a major concern, with nine endemic species being replaced by three endemic and two introduced species. Because of similarities between tracked vehicle training and some construction activities, much of this information may be useful for analysis of civilian activities as well as military.

The literature on the effect of off-road vehicular (ORV) traffic on the environment has dealt with only recreational type vehicles and primarily with vegetation and soils, although some faunal studies do exist (Berry 1980). Few studies on bird populations have been published, with some quantifying ORV effects (Bury and others 1977, Weinstein 1978) and others describing general effects (Stebbins 1974). No studies have yet reported the unique effects of tracked vehicles on bird populations or compared those effects between different ecosystems.

The purpose of this research is to examine cause and effect relationships between Army training activities and bird populations and to obtain an overview of these relationships in the continental United States. This research program obtained field data on four ecologically diverse installations under diverse levels of training. The problem of diversity of bird species and their functional relationships to environmental resources was reduced by utilizing guild theory. Installations were selected from areas of the country that had the maximum breeding activity at different times so that more than one installation could be surveyed during a calendar year.

Study Areas

The sites used during this survey varied from light use to light-moderate, moderate, and extreme. The classification of tracked vehicle usage was based primarily on qualitative ground observations of the study sites, combined with similar estimates from aerial photographs and helicopter-based observations; it represents a relative classification scheme. Four U.S. Army installations study locations, which represented a diversity of ecosystems and level of tracked vehicle training, were chosen for the study (Figure 1).

The Peason Ridge portion of Fort Polk is located in the southern coniferous forest region approximately 16 km north of Leesville, Vernon Parish, Louisiana. Tracked vehicle training is limited primarily to within 100 meters of the roads and should be considered light to moderate, as much of the maneuvering is done on the roads. Test and control grids were gently rolling forests, consisting predominantly of loblolly (*Pinus taeda*) and long-leaf (*P. australis*) pines and several species of oak such as bluejack (*Quercus cinerea*), blackjack (*Q. marilandica*), southern red (*Q. rubra*), and post oak (*Q. stellata*). Both areas had little undergrowth. The test grid comprised an area of 10 ha bordered by a major tank trail. Tank trails of various ages, from fresh to almost obliterated by invading vegetation criss-crossed the test grid. Throughout this study, the major trail bordering the test grid was used by tracked vehicles and jeeps; however it was infrequent that more than a few vehicles were observed on the road during any observation period. There was some use of the grid area itself for training activities, as indicated by the presence of fresh tank, armored personnel carrier, and jeep tracks. The control grid was 8.4 ha in area and was located 14 km ENE of the test grid. Little evidence of vehicular activity was visible except for a relatively fresh tank trail intruding into the border of the area for several

KEY WORDS: Tracked vehicle; Impact; Birds; Guilds; Biomass

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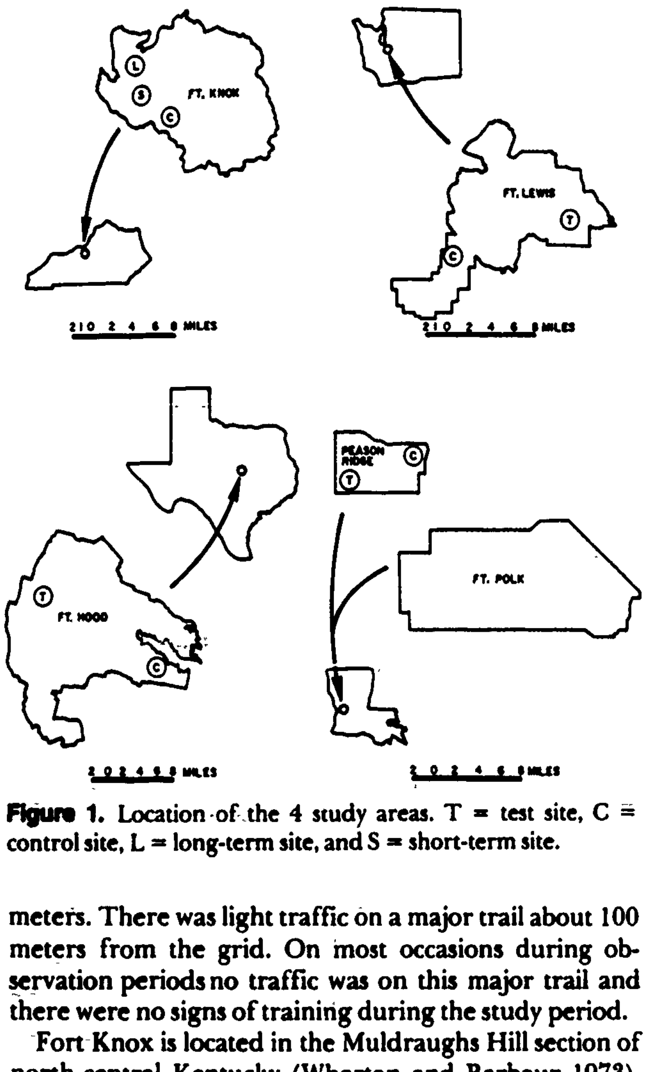

Figure 1. Location of the 4 study areas. T = test site, C = control site, L = long-term site, and S = short-term site.

meters. There was light traffic on a major trail about 100 meters from the grid. On most occasions during observation periods no traffic was on this major trail and there were no signs of training during the study period.

Fort Knox is located in the Muldraughs Hill section of north-central Kentucky (Wharton and Barbour 1973), an area ranging from mesophytic deep depressions and sheltered slopes to dry uplands over shallow soils. Mixed mesophytic communities with sugar maple and tulip poplar occupy the depressions and sheltered slopes, while mixed oak and oak-hickory communities dominate the dryer slopes and ridges. The long-term use site had been heavily used since 1942, and nearly all arborescent vegetation had been destroyed or removed. Erosion was so severe in the past that some chert beds were exposed. This heavy-sustained impact grid was being used continuously for training maneuvers. A short-term use site has been used for tracked vehcile maneuvers since the early spring of 1978. All vegetation under 7.5 cm in diameter had been cleared and was bulldozed into gulleys, sinkholes, and other topographical locations of significance to reduce erosion. Although herbaceous vegetation had been disturbed unintentionally, most of the ground cover was disrupted during site preparation. The whole area was then reseeded with rye and fescue which was only beginning to germinate at the time of the study. It should be noted that trees considerably larger than 7.5 cm in diameter were removed and that some erosion was already evident. Training was frequently observed during the study. The control site was used occasionally for training, although not by tracked vehicles. Several overgrown tracked vehicle trails weaved through the site. One area, however, had not been penetrated by vehicles and apparently never had been cleared.

Fort Hood is located in Bell and Coryell Counties of north-central Texas. The reservation lies in the southern portion of the Cross Timbers and Prairies vegetation area near the Blackland Prairie and Edwards Plateau region (Gould 1975). The reservation is part grassland and savannah and part woodland and scrub. The woody vegetation is primarily rock cedar (*Juniperus ashei*), live oak (*Quercus fusiformis*), and Texas oak (*Q. texana*). The control site vegetation consisted of typical upland woodland dominated by rock cedar and live oak. Topography is rolling with a combination of level ridge tops and both east- and west-facing slopes. A few cedars have been cut for posts, and a few old vehicle trails pass through the area, but this is true of much of the upland forest observed at Fort Hood. The test site vegetation consisted of islands of trees surrounded by heavily used tracked vehicle trails. Plant species composition conforms to the typical rock cedar-live oak type. Soil topographies are very similar to the control area except that much of the topsoil has eroded away, exposing the very light-colored, gravelly clay subsoil.

Two sites were selected to study the impact of tracked vehicles on Fort Lewis which is located southwest of Tacoma, Washington. The test site was on a flat gravel outwash approximately 2 km in diameter. The prairie had scattered clumps of Oregon white oak (*Quercus garryana*) and scotch broom (*Cytisus scoparius*).The control site was a slightly undulating plain with a relatively unbroken cover of vegetation. There were no woody perennials on the site, but there were scattered clumps of the introduced scotch broom.

Methods

Standard bird census methods were utilized. Forts Polk and Knox were surveyed by alternating morning and evening observations on test and control sites. Obser-

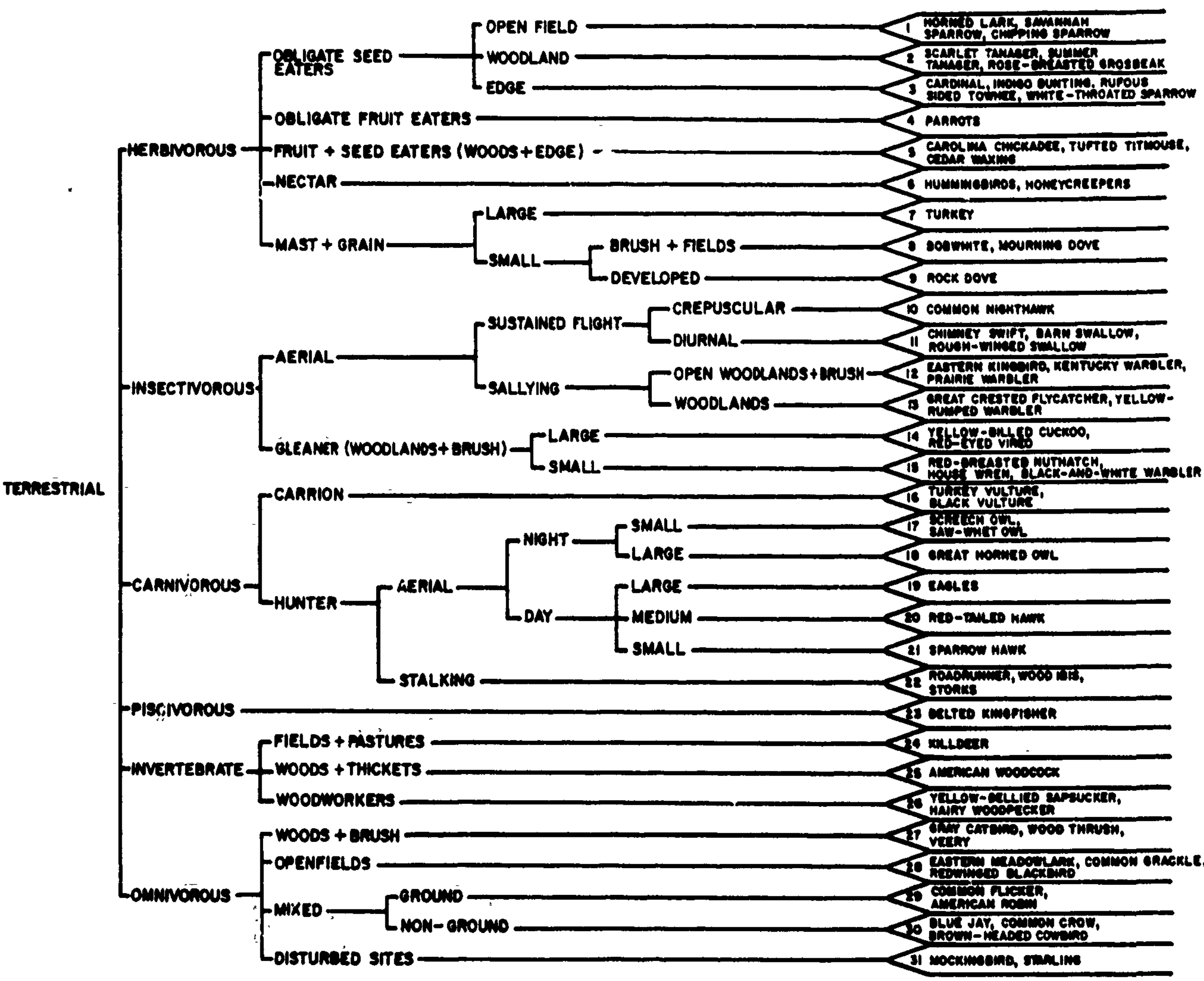

Figure 2. Guilds of predominantly terrestrial dwelling birds inhabiting the contiguous United States (from Severinghaus *Envir. Manag.*, 5:187–190).

vation hours totaled 46 hours from June 7–26, 1977 for Polk and 135 hours from April 17–May 11, 1978 for Knox. Methods of observations and analysis follow Kendeigh (1944). Line transect methods following Emlen (1971, 1977) and Balph and others (1977) were utilized at Forts Hood (April 22–30, 1979) and Lewis (June 7–16, 1979). Biomass information was obtained by combining the information presented in Norris and Johnston (1958), Behle (1943), Graber and Graber (1962), Esten (1931), Baldwin and Kendeigh (1938), Poole (1938), Amadon (1943), and Oberholser (1974). This was then analyzed using a 2 × 2 contingency table with X^2. To reduce the potential differences between methods of bird density estimation, percentages were used.

Results and Discussion

The use of guild theory for applied environmental analyses has been suggested, along with the delineation of mammal and bird guilds (Figure 2). Data analysis and habitat preference indicate that the horned lark should be placed in a separate guild (Table 1). A total of 89 species was observed on 9 different study sites which represent 116 observation periods. In Table 1, the

Table 1. Bird guilds observed.[1]

Guild	Primary characteristics	Representative members[2]
1A	Seedeating, bare ground	Horned lark
1B	Seedeating, open field	Savannah sparrow, chipping sparrow
2	Seedeating, woodland	Scarlet tanager, summer tanager, rose-breasted grosbeak
3	Seedeating, edge	Cardinal, indigo bunting, rufous-sided towhee, white-throated sparrow
5	Fruit and seedeating, woods and edge	Carolina chickadee, tufted titmouse, cedar waxwing
6	Nectar	Ruby-throated hummingbird
7	Mast and grain, woodland, open	Turkey
8	Mast and grain, small, brush and field understory	Bobwhite, mourning dove
9	Mast and grain, small, developed	Rock dove
10	Insectivorous, aerial, crepuscular	Common nighthawk
11	Insectivorous, sustained, diurnal	Chimney swift, barn swallow, rough-winged swallow
12	Insectivorous, sallying, open	Eastern kingbird, Kentucky Warbler, prairie warbler
13	Insectivorous, sallying, woodland	Great crested flycatcher, yellow-rumped warbler
14	Insectivorous, gleaner, larger	Yellow-billed cuckoo, red-eyed vireo
15	Insectivorous, gleaner, small	Red-breasted nuthatch, house wren, black-and-white warbler
16	Carnivorous, carrion	Turkey vulture, black vulture
18	Carnivorous, hunter, night, large	Great horned owl
23	Piscivorous	Belted kingfisher
24	Invertebrate, pastures and fields	Killdeer
25	Invertebrate, woods and thickets	American woodcock
26	Invertebrate, woodworker	Yellow-bellied sapsucker, hairy woodpecker
27	Omnivorous, woods and brush	Gray catbird, wood thrush, veery
28	Omnivorous, openfield	Eastern meadowlark, common grackle, redwinged blackbird
29	Omnivorous, mixed, ground	Common flicker, American robin
30	Omnivorous, mixed, non-ground	Blue jay, common crow, brown-headed cowbird
31	Omnivorous, disturbed sites	Mockingbird, starling

[1] Adapted from Severinghaus (1981).
[2] Species listed are not all studied, but are examples.

significant guild characteristics are given in the second column and take the form of the general feeding strategy and the feeding habitat. Table 2 gives the results of the surveys in terms of biomass per guild.

Five major factors contribute to the altering of bird populations by tracked vehicle training activities:

(1) *Opening of the Woodlands.* In coniferous forests and areas of young deciduous growth, tracked vehicles open the canopies by physically riding trees down, breaking or uprooting them, or by injuring them sufficiently to allow disease or pest infestations. In mature coniferous and deciduous forests, trees are damaged and eventually die due to physical injury or compaction of the soil causing root damage. Opening the canopy of the woodlands allows the understory and/or ground cover to develop towards edge or open field habitat and results in a biomass reduction of woodland bird species and an increase in edge or open field species. This is not a 1:1 replacement in biomass as the total is reduced.

(2) *Reduction of Understory.* Many woodland and edge species rely on the understory which is highly susceptible to tracked vehicles because there is repetitive contact. Damage to this stratum is not restricted to contact and scraping but also includes soil compaction, wind and water erosion.

(3) *Soil and Duff Scraping.* This problem is twofold as initially, in site preparation, bulldozers push over trees which are then pushed into gullies and sinkholes, removing ground cover and duff. This bares the top soil resulting in erosion. Secondly, the tracked vehicles (bulldozers) compact the soil, damaging or destroying the ground cover vegetation. This, combined with the action of the tread cleats breaking the top few inches of vegetation and humus, eventually allows erosion to

Table 2. Bird biomass per guild[1].

	Polk		Knox			Hood		Lewis	
Guild	Test	Control	Long	Short	Control	Test	Control	Test	Control
1A								2642.5	
1B	91.0					66.3		6531.0	7536.9
2	137.0	882.4		394.6	4955.5	145.2	1211.1		
3	520.0	833.8		17714.1	15170.3	8390.0	7542.4		227.0
5	78.0	296.0		226.6	2727.9	840.3	2953.8		
6							149.7		
7						(6000.0)			
8	1240.0			2533.0	20751.9	2815.0	1981.0		
9				17423.2				(1727.0)	
10	116.0	80.6			1742.0				
11		125.1		271.6	151.2		641.4	29.4	52.5
12	35.0		2938.3	698.2	2615.7	501.6	40.0		
13	66.0	133.4	106.4	417.3	5762.2	58.5	687.2		
14	480.0	340.5		974.5	7422.1	541.3	243.0		
15	31.0	389.1		245.0	1017.3	151.1	424.3		
16	(6600.0)	(3057.1)	(47430.0)	(69360.0)		(1100.0)	(21960.0)		
18							(11620.0)		
23					(3841.9)				
24						171.0			
25					3811.2				
26				4159.8	5671.3		21.6		
27				1553.0	13536.8		953.7		
28			1106.7	2589.4	1846.1	451.0	1625.8	3753.4	4478.6
29				3101.8	15629.5			1208.9	6831.3
30	1150.0	40.3	7911.3	33760.3	89794.6	5197.5	4297.5		537.6
31						2570.0		1516.0	
TOTAL	3944.0	3121.1	12062.7	86062.4	192605.6	22998.8	44732.5	15682.1	19663.9
% Change	+20.9		−93.7	−55.3		−48.6		−20.2	

[1] Biomass in grams, see text and Table 1 for explanation.

remove most of the ground cover, duff, and top soil. In either case, continued vehicle maneuvering with the lack of erosion control or other mitigation measures perpetuates or even magnifies the problem.

(4) *Loss of Food Resources.* This is caused by one of the first three factors, which reduces biomass of the primary consumers (insects, small mammals, or small birds) and is accompanied by a similar loss in the next trophic level (insectivorous or carnivorous birds).

(5) *Degradation of Existing Conditions.* When tracked vehicle activity does not alter the existing vegetational stratification, it may still reduce the productivity of the existing community. The prairies at Fort Lewis were still prairies, but most of the more sensitive species were lost and surviving vegetation was much shorter and sparser. Compaction of the soil and the cutting and tearing by the cleats is probably the most severe problem, with erosion taking place in areas of sufficient slope and susceptible substrate.

Total biomass changes resulting from tracked vehicle training activity depends on the type of training, the extent of off-road maneuvers, and natural conditions such as erodibility, climate, natural vegetation, and vegetational resiliency. These changes indicate a negative trend as training progresses. The light training on the prairies at Fort Lewis is not significantly altering the existing prairie strata but it is reducing its productivity (Table 3). The moderate training at Fort Hood and extreme or heavy training at Fort Knox on the long-term site also fit this trend. The positive change at Fort Polk may have occurred because the closed-canopy forests were being opened to a more productive, mixed coniferous-deciduous community. The low level of negative change for the Fort Knox short-term site was

Table 3. Change in biomass in relation to the amount of tracked vehicle usage.

Tracked Vehicle Usage	Installation	Biomass Change
Light	Ft. Lewis	−20.2
Light to moderate	Ft. Polk	+18.8
Moderate	Ft. Hood	−49.9
Moderate	Ft. Knox-Short Term	−20.9
Extreme	Ft. Knox-Long Term	−59.8

probably a result of the recent site preparation work with much of the vegetation being pushed into gullies and other potential erosion corridors.

Although there can be anywhere from a slightly positive to a strongly negative impact on total biomass, there can be a significant change in species composition (Table 4). The change in species diversity can be compared by examining control only and test only data. The net change at Fort Polk was +1 (7–6) while the change at Fort Knox was −10 (9−19) with the average being −3.5 or a 10.6 percent reduction in diversity. These figures for both levels of use indicate that training can be a problem in the context of species replacement. This would be particularly evident in areas of critical habitat for species whose local survival is in question.

Another problem with species replacement involves species themselves. Table 5 summarizes the species observed in sufficient numbers and/or frequency to be considered common or abundant on the study sites within their geographic ranges. The most striking observation was that the more secretive species (ruby-throated hummingbird, Swainson's thrush, veery, black-and-white warbler, and rose-breasted grosbeak) were found in the control sites only, less secretive species (bobwhite, yellow-rumped warbler, brown-headed cowbird, cardinal, and white-throated sparrow) were found on both test and control sites, and the more tolerant less desirable species (rock dove, horned lark, or mockingbird, and starling) were found only on the test sites.

Conclusions

Analysis suggests that five major aspects of avian habitat were affected: (1) woodlands were opened; (2) there was a general reduction in the understory; (3) the surface soil and duff were scraped or loosened sufficiently to cause their eventual loss; (4) there was a loss of food resources for secondary consumers; and (5) when there is no major alteration of habitat, a general degradation of the existing conditions occur.

Further analysis of biomass and species replacement indicates that tracked vehicle training caused a significant reduction in biomass except in well-developed, predominantly coniferous forests, where a slightly positive effect resulted and many sensitive, secretive, and endogenous species were replaced with tolerant and/or introduced species.

The characteristics of tracked vehicle training are similar to those of the various stages of clearing, preparation, and use of sites for construction, whether military or civilian. The preparation for training at Fort Knox was visually very similar to activities conducted during preparation for housing developments in many parts of the country. During construction, the trees are thinned to allow movement of construction vehicles, equipment, and supplies. The surface is scraped free of top soil and duff to be used as fill-in for low places. Moderate-use sites are similar to the construction and eventual refurbishing of minor roadways, recreational

Table 4. Species composition change.

		Polk	Knox-short	Hood	Lewis	Average[1]	Knox-Long
Test only	%	28.0	17.0	29.5	20.0	23.6	4.4
	N	7	9	13	2	7.8	2
Control only	%	24.0	35.8	36.4	40.0	34.1	86.7
	N	6	19	16	4	11.3	39
Test and control	%	48.0	47.2	34.1	40.0	42.3	8.9
	N	12	25	15	4	14.0	4
Total	N	25	53	44	10	33.0	45

[1] Knox long-term site data not included as it does not represent a normal condition of training area usage.

Table 5: Commonly to abundantly observed species of bird and their site preference.

Control only	Prefers control	Both control and test	Prefers test	Test only
Ruby-throated hummingbird	Common flicker	Bobwhite	Mourning dove	Rock dove
Swainson's thrush	Great-crested flycatcher	Yellow-rumped warbler	Eastern kingbird	Horned lark
Veery	Blue jay	Western meadowlark	White-eyed vireo	Mockingbird
Black-and-white warbler	Carolina chickadee	Brown-headed cowbird	Redwinged blackbird	Starling
Prothonotary warbler	Tufted titmouse	Cardinal	Rufous-sided towhee	Chipping sparrow
Hooded warbler	Carolina wren	Savannah sparrow		
Northern oriole	American robin	White-throated sparrow		
Rose-breasted grosbeak	Ruby-crowned kinglet			
American goldfinch	Red-eyed vireo			
	Eastern meadowlark			
	Summer tanager			

areas, and small industrial parks in which islands of various size and continuity remain available for inhabitation by wildlife. The heavy-use areas are biologically similar to the end products of the construction of multilane highways, major industrial parks, large shopping centers, and even agricultural lands. Because of these similarities, some, if not all, of the information reported should be of importance to biologists attempting to understand the impact of civil construction.

Acknowledgments

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