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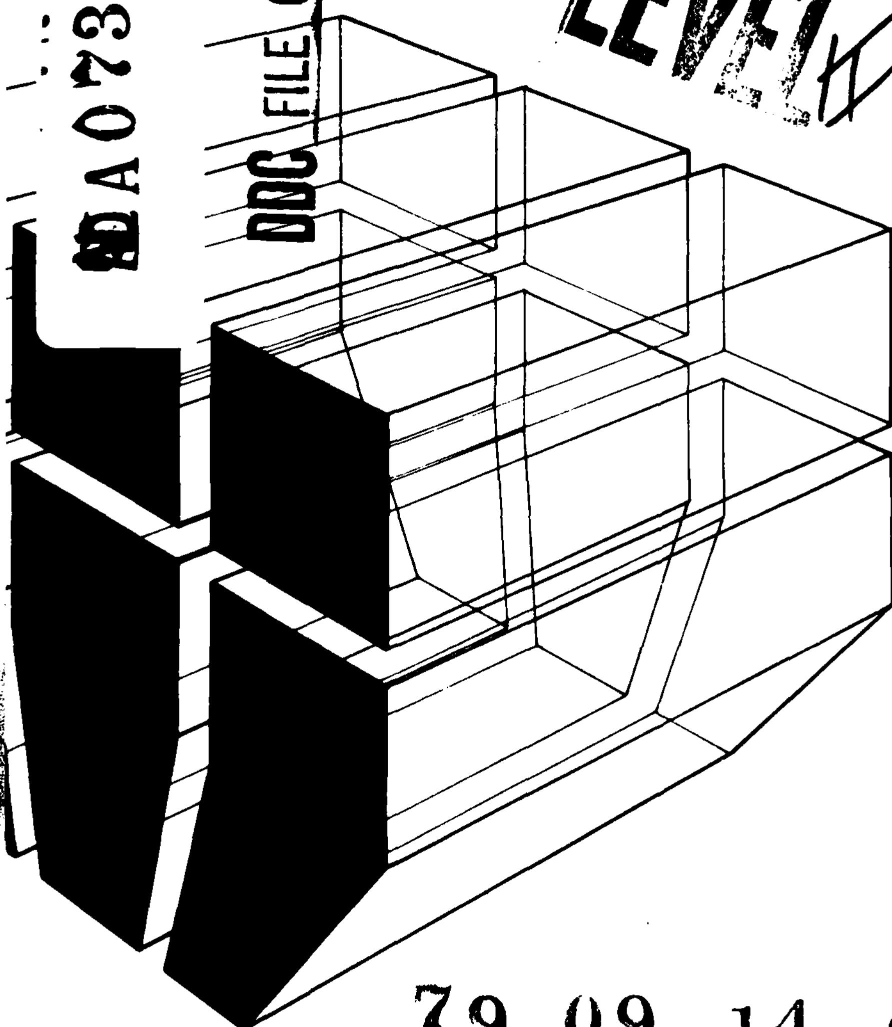
SPECIAL REPORT N-77
July 1979

(12)

EFFECTS OF TRACKED VEHICLE ACTIVITY ON TERRESTRIAL MAMMALS, BIRDS, AND VEGETATION AT FORT KNOX, KY



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79 09 14 057

CERL

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: CERL-SR-N-77
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY
5. TYPE OF REPORT & PERIOD COVERED: SPECIAL
6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): W. D. Severinghaus, R. E. Riggins, W. D. Goran
8. CONTRACT OR GRANT NUMBER(s): ILIR
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY, P.O. Box 4005, Champaign, IL 61820
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS
12. REPORT DATE: July 1979
13. NUMBER OF PAGES: 64
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)
18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service
Springfield, VA 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

mammals
birds
vegetation
Ft. Knox, KY
tracked vehicles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A field study was conducted at Fort Knox, KY, to investigate the effects of Army tracked vehicle training on terrestrial birds, mammals, and vegetation. Intensive studies were conducted at three 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 pre-training (no training) conditions.

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SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

FOREWORD

This investigation was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL) under the In-Laboratory Independent Research (ILIR) program. Vegetation studies were conducted under the direction of Mr. Steven Apfelbaum, Botany Department, University of Illinois.

Dr. R. K. Jain is Chief of EN. COL J. E. Hays is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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EFFECTS OF TRACKED VEHICLE ACTIVITY ON TERRESTRIAL MAMMALS, BIRDS, AND VEGETATION AT FORT KNOX, KY

1 INTRODUCTION

Background

Recent trends in environmental impact analysis require quantification of impact estimates. One effective way of insuring quantified environmental analysis is the use of analytical models. Since cause/effect relationships are a prerequisite for modeling, ecological modeling is not currently feasible, because appropriate cause/effect relationships have not yet been established. This report is the first of a series which will document basic ecological research conducted to establish cause/effect relationships between Army activities and their impacts on ecosystems. This report describes initial results of the first phase of the basic research effort. Further significant findings will be documented as they occur during the course of the research, which will study quantification of impacts on soil, water, etc.

Objective

The objectives of this report are (1) to describe preliminary indications of ecological differences between selected Army tracked vehicle training areas and areas representing pre-training (no training) conditions, (2) to document the procedures used to obtain this information, and (3) to study the guild concept for determining ecological impacts on mammals.

Approach

Intensive surveys were conducted at selected sites at Fort Knox, KY, to establish the effects of tracked vehicle training on birds, small mammals, and vegetation.

2 GENERAL SITE DESCRIPTION

Fort Knox is located in the Muldraughs Hill section of north-central Kentucky,[1] an area in which there is a variety of topographic and edaphic sites, ranging from mesophytic deep depressions and sheltered slopes to dry uplands over shallow soils. Vegetationally, this area is within the western Mesophytic forest region of the Deciduous Forest Formation of eastern North America.[2] 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.

The vegetational history of this area is much the same as that of the surrounding Ohio Valley and is briefly introduced here to provide the necessary background for understanding the current dynamic changes occurring in the study area forests. The impact of tracked vehicles and the associated modification of the forest for training purposes can only be understood in the context of succession resulting from prior disturbances.

Most of the study area was cleared of all trees and much of it was cultivated prior to this century, as evidenced by the growth patterns of older trees, the species composition of present communities, and the present soil conditions. Most communities identified in the study were judged to be younger than 80 years.

During the first few years after intensive cultivation and/or pasture use of soils is abandoned, perennial herbs become established, including asters, goldenrods, poverty grass, and dozens of associated species. If soil disturbance immediately precedes abandonment, annual herbs such as camphor weed, ragweed, foxtail, and several other species of grasses often occupy sites before the perennial herbs become well established.

Depending on the site and seed sources, several species of trees become established on disturbed sites within the matrix of herbaceous vegetation. In this part of Kentucky, the most important species are eastern red cedar, persimmon, sassafras, and dogwood; in addition, shingle oak and other woody plants sometimes become established. These early invaders gradually decrease the herbaceous vegetation as they mature and the canopy closes. Closed canopy conditions lead to an amelioration of the environment, and the more mesic tree species become established, especially oaks and hickories on the upland sites and sugar maple and tulip poplar on the deeper, more fertile soils. In time,

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1 May E. Wharton and R. W. Barbour, Trees and Shrubs of Kentucky (University of Kentucky, 1973), p 4.

2 Wharton and Barbour, pp 15-18.

often 100 or more years, the early woody invaders are replaced by woody plants that become established beneath them; this gives rise to a forest community in which each species reproduces, and conditions are stabilized. During this successional process, soils develop to resemble their original condition before the clearing activities.

Soils underlying the study area are primarily silt loams and cherty silt loams of the Baxter and Crinder series.[3] Soils of these series are generally deep and well-drained, but when cleared, present severe erosion hazards. Baxter soils occupy the sides of depressions and are characterized by a high percentage of chert at 2 to 3 dm. Baxter cherty silt loam occupies some ridges and the slopes, whereas Crinder silt loam occurs on other ridges. Crinder soils, like the Baxter series, are subject to extreme erosion, but are deeper and potentially more fertile. Crinder soils form over limestone in loess deposits and lack chert in the subsoil.

Three study sites were selected in the Otter Creek watershed west of the cantonment (Figure 1) in Meade County, KY, for the bird, small mammal, and vegetation surveys. The northern-most site, located northwest of Carlson Lake (Figure 2), is an area that has been heavily used 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 this 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 this area, an effort was made to exclude sink holes and maintain a buffer zone between the grids and the surrounding area which had undergone little or no noticeable usage. This long-term impact grid was being used both day and night on a continuous basis for training maneuvers.

A second impact area was located southwest of Snow Mountain and east of Pinwheel Road. This area has been used for tracked vehicle maneuvers since the early spring of 1978 and is part of a large tract of land that had been opened recently for tracked vehicle training purposes. To simulate western European conditions, all vegetation under 3 in. (76 mm) in diameter was cleared for 1600 ft (480 m) east and west of Pinwheel Road. As a mitigation procedure, all the vegetation cleared was bulldozed into gullies, sink holes, 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 which was only beginning to germinate at the time of the study. Clearing was formerly completed by burning all brush and cleared vegetation, and

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[3] Soil maps provided by Meade County Conservation Service, Brandenberg, KY.

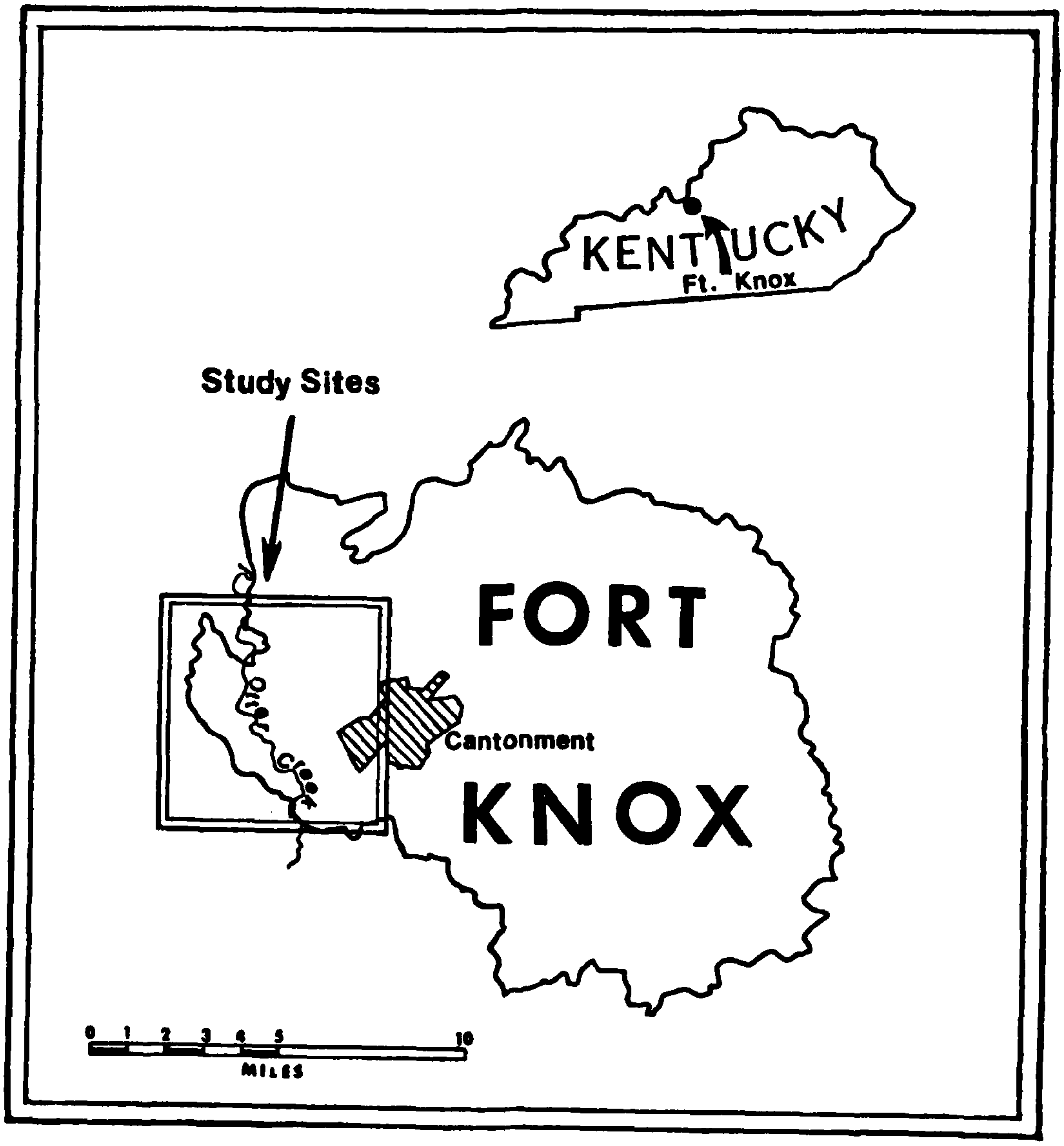

Figure 1. Location of Fort Knox in Kentucky and location of study area within Fort Knox.

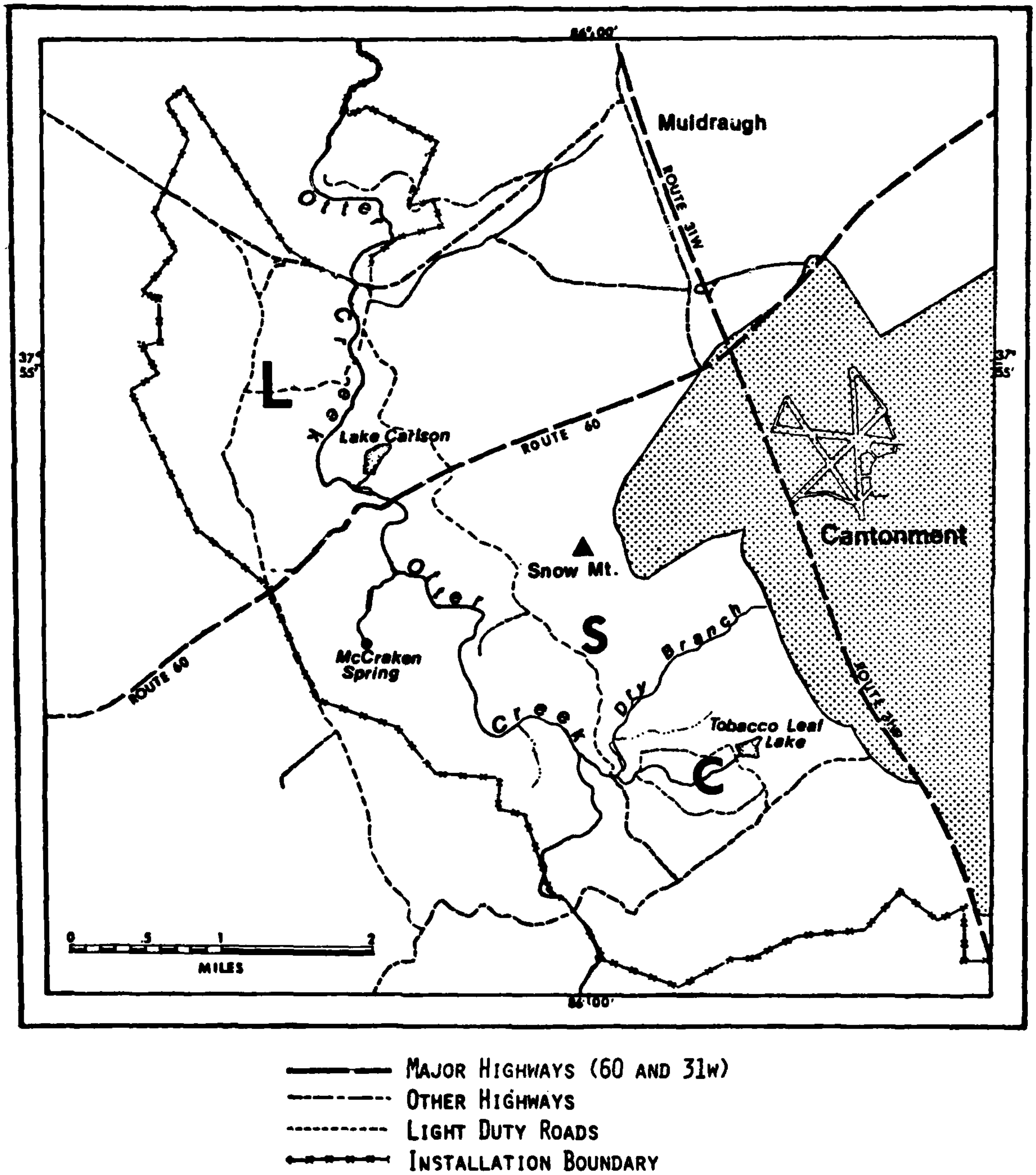

Figure 2. Study sites. Small mammals, birds, and vegetation were studied at sites marked C, S, and L.

reseeding was generally not done. It should be noted that trees considerably larger than 3 in. (76 mm) in diameter were removed and that some erosion was already evident. Baxter cherty silt loams and Crinder silt loam occupied this area. This short-term study site (see Figure 2) was set up, as was the long-term site, by avoiding sink holes and maintaining the buffer zone between the bird grid and impacted areas. Training was observed frequently during the study.

The control site (see Figure 2) was located 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 conditions and slope conditions. This site was bordered on the northwest by recently cleared areas that were continguous with the short-term site. Evidence suggested that this area was used periodically for training, although it was not heavily used by tracked vehicles. Especially evident were several overgrown tracked vehicle trails weaving through the site. One community in the control area, however, had not been penetrated by vehicles and apparently never had been cleared.

3 METHODS

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

Mammals

Three 1-hectare grids were located within long-term, short-term, and control areas. Standard capture-recapture methods were used in which the animals were toe-clipped for marking purposes. The grids were run for 19 to 21 consecutive nights to obtain sufficient data for estimating the populations using the Schnabel method.[4] 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 sink holes near the control and long-term grids and in the brush piles on the control and short-term grids.

Birds

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 three grids were observed 15 times during the periods 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.

Vegetation

All vascular vegetation was sampled in each of the three study sites. The percentage of the ground covered and the number of rooted stems of herbs and woody plants less than 2 m tall were enumerated from randomly placed 1/32-m^2 quadrats. Diameter at breast height (dbh) tallies by species were recorded for woody vegetation in 4 m x 50 m quadrats established along randomly located transect lines. Fifty-meter line intercepts and the transect lines were used to estimate cover by woody vegetation that was more than 2 m tall. Increment cores were taken from random trees of each species tallied in the 4- x 50-m quadrats except the diffuse porous species (sumac, dogwood, maple). Prism samples were taken at 25-m intervals along transects to estimate basal

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[4] R. L. Smith, Ecology and Field Biology (Harper and Row, 1974), p 718.

area. Frequency was estimated by expressing the percent occurrence of each rooted species in the appropriate quadrat over the total number of samples taken in each site. Relative density (D), cover (C), and frequency (F) were calculated for each species sampled. These values were then summed to derive an importance value (IV) for each species. Age, size relationships, and size-class frequency distribution for the more important trees were estimated, using dbh and tree age data. The latter information was also useful for determining each site's vegetational history.

Vegetational communities and maps showing the percentage of the ground covered by woody vegetation greater than 2 m in height and the percentage covered by vegetation less 2 m in height were prepared for each site. Community designations are based on importance value,[5] a method of quantifying dominance.[6] Community maps were prepared from 1:5000 scale aerial photographs, 1:24,000-scale U.S. Geological Survey topographic maps, the results of transect sampling, and additional field checking. Maps depicting the percentage of ground cover were prepared, using the species intercept data and the percent bare ground estimates made in the herb quadrats. The four cover classes used in mapping were: less than 25 percent, 25 to 50 percent, 50 to 75 percent, and greater than 75 percent. Peripheral communities that were not sampled were subjectively mapped relative to the results obtained from sampling other communities. Soils were examined in each community and soil compaction was estimated to the 2.5-cm depth, using an Army hand-held soil penetrometer.

All plants encountered in sampling and reconnoitering were identified. The less common species were collected and deposited in herbaria at Warren Wilson College, Swannanoa, NC. All nomenclature follows Gleason and Cronquest.[7] Soil compaction was considered when establishing community delineations.

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[5] John T. Curtis, The Vegetation of Wisconsin: An Ordination of Plant Communities (University of Wisconsin, Madison, 1959).

[6] Robert H. Whittaker, Communities and Ecosystems, 2nd ed. (MacMillan Publishing Co., 1975).

[7] Henry A. Gleason and Arthur Cronquest, Manual of Vascular Plants in the Northeastern United States and Adjacent Canada (D. Van Nostrand Co., Inc., 1963).

4 RESULTS

Mammals

The grid data (Table 1) were analyzed using the Schnabel method.[8] Because of the inability to capture, mark, release, and recapture some species, this method did not produce consistently effective data 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 (see Table 1). A second measure of comparison between the populations of the three areas is a capture index, which is defined as the number of individuals of each species captured divided by the number of trap-nights multiplied by 1000.

The short-tailed shrew does not survive well in a live trap 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 two impact areas and the control site. The index value indicated that approximately 90 percent of the population is initially lost when the sites are prepared for training, and the remainder is lost as training progresses. Loss of cover, erosion, and soil compaction are probably the most significant factors affecting this species.

The eastern chipmunk, which 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 areas. 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 resulted from 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 were insufficient for analysis. Only one was captured and released on the short-term grid. It can be reasonably assumed that this species inhabits the control area, but the lack of trees and most other vegetation precludes its existence within the long-term area.

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[8] R. L. Smith, Ecology and Field Biology (Harper and Row, 1974).
* p = probability.

Table 1

Mammal Grid Data

Species		Observation Individuals	Observation Total	Estimated Population Per Hectare (Schnabel)	t-Test of Means C/S	Probability C/L	Total Observations Grid+Brush	Total Observations Sink Holes	Index Value Grid+Brush	Index Value Sink Holes	Population Change (%) S/C	Population Change (%) L/C
Blarina brevicauda	C	5	5	3.0	0.021*	0.021*	14	---	3.88	---		
(Short-tailed shrew)	S	0	0	---	0.021*	0.021*	1	---	0.36	---	-90.7	-100.0
	L	0	0	---			0	---	---	---		
Tamias striatus	C	7	15	5.22			17	1	4.72	7.04		
(Eastern Chipmunk)	S	3	3	0.0	0.004*	0.001*	4	---	1.45	---	-69.3	-100.0
	L	0	0	---			0	1	---	4.55		
Glaucomys volans	C	0	0	---			0	---	---	---		
(Southern Flying Squirrel)	S	1	1		0.329	0.329	1	---	0.36	---	insufficient data	
	L	0	0	---			0	---	---	---		
Peromyscus leucopus	C	0	0	---			2	3	0.55	21.13		
(White-Footed Mouse)	S	11	31	11.24	0.001*	0.010*	47	---	16.99	---	+3089.1	+1652.7
	L	9	22	8.38			22	2	9.09	9.09		
Microtus ochrogaster	C	1	2	1.0			3	---	0.83	---		
(Prairie Vole)	S	0	0	---	0.162	0.715	0	---	---	---	-100.0	+149.4
	L	2	3	2.0			3	---	1.24	---		
Microtus pinetorum	C	11	14	10.0			21	1	5.83	7.04		
(Pine Vole)	S	1	1	0.0	0.002*	0.001*	2	---	0.72	---	-87.7	-100.0
	L	0	0	---			0	---	---	---		
Mus musculus	C	0	0	---			0	---	---	---		
(House Mouse)	S	1	4	1.0	0.042*	1.00	4	---	1.45	---	+	-
	L	0	1	---			0	---	---	---		

C = Control, S = Short Term, L = Long Term, * Statistically Significant at 0.05 level

The white-footed mouse 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 (see 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 this 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, these animals would immediately enter the gullies 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 is due to the increased wandering of reproductive males.

Data on the prairie vole are minimal; only three were taken on the grids: one from the control area and two from the long-term area, with a total of only six observations made. This species' habitat preference should have excluded them from all three grids, since they prefer open, grassy fields. The individuals captured on the control grid were taken along an overgrown road having 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 to protect a small area adjacent to the grid from vehicular activity and erosion. This species could not be expected in the short-term area, since no ground cover was left after the area had been cleared.

A fairly large population of pine voles was found at the control site. This was expected, since they prefer a forest floor which has 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 this difference is the lack of vegetation and the presence of erosion in the long-term area, and the scraping of the soil in the short-term area during clearing operations.

The house mouse 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 this species in the long-term area is probably 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 three 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 inhabiting the sink hole areas indicated that these 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 these areas by small mammals.

With one exception, all mammals captured 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 in the gullies or within 2 m except for the prairie voles, which were taken in the downed tree area.

The last measures used to examine small mammal populations in the three study areas were biomass (the weight of all organisms of a given designation in a given region) and guilds (groups of organisms that use the same environmental resources in a similar manner).

The impact on small mammal populations was generally negative (Figure 3), 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 approaching 65 percent. This information does not consider the desirability of the various species, but can approximate the area's abilities to sustain small mammal population and will have additional significance when considering the area's trophic structure.

The impact of tracked vehicle training on mammal guilds (Appendix A) has the most significance. Shrews, voles, and ground squirrels all lost large amounts of biomass (Table 3). Shrews and voles are exclusively surface dwellers, inhabiting nests or dens either on the surface or below ground close to the surface. Ground squirrels are somewhat similar, preferring to stay on the ground, although they will climb occasionally. All three guilds 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 vole and ground squirrel guilds.

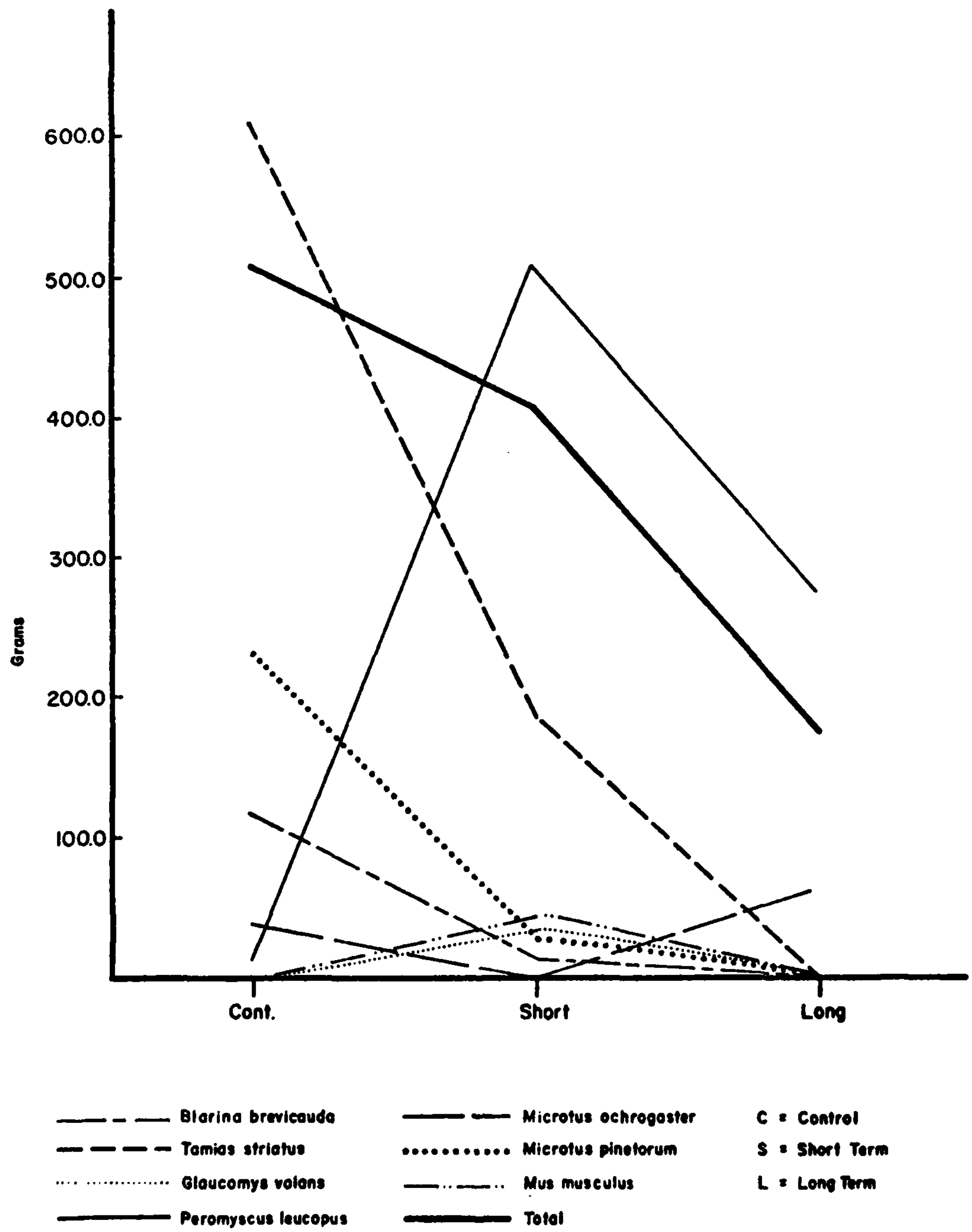

Figure 3. Biomass for small mammals.

Table 2

Biomass of Small Mammals
at Fort Knox, KY

Species	Control	Short-Term	Long-Term	Short-Term Change	Long-Term Change
Blarina brevicauda	58.2-116.4*	5.4-10.8	0	90.7%	100.0%
Tamias striatus	349.38-608.88	107.3-187.05	0	69.3%	100.0%
Glaucomys volans	0	25.2-35.28	0	-------	-------
Peromyscus leucopus	9.35-16.5	288.83-509.7	154.53-272.7	30.9X	16.5X
Microtus ochrogaster	30.71-39.84	0	43.88-59.52	100.0%	1.4X-1.5X
Microtus pinetorum	128.26-227.37	15.84-28.08	0	87.7%	100.0%
Mus musculus	0	26.1-43.5	0	-------	-------
Totals	575.8-1008.99	468.67-814.41	198.41-332.22	18.6-19.3%	65.5-67.1%

* Based on Index Value and weight range (grams) from R. W. Barbour and W. H. Davis, *Mammals of Kentucky*, Kentucky Nature Studies 5 (The University of Kentucky Press, 1974).
% Indicates percent loss, X indicates increase (3x = three-fold increase).

Table 3

Guild Biomass

24 Shrews	58.2-116.4	5.4-10.8 (90.7)	0 (100)
15 Voles	158.97-267.21	15.84-28.08 (89.5)	43.88-59.52 (77.7)
12 Ground Squirrels	349.28-608.88	107.3-187.05 (69.3)	0 (100)
10 Mice	9.35-16.5	314.93-553.2 (33.5X)	154.53-272.7 (16.5X)

Birds

Fifty-four species of birds were seen at the study sites during the 15-day survey. The birds were divided into three groups: "resident," "transient," and "occasional." [9] Tables 4, 5, and 6 show the data gathered for these groups. The adjusted figures in the second column under each grid heading take into account the area surveyed and the number of observation hours accumulated for each area.

Nineteen species were considered "residents" during the time of the survey (Table 4). Eight of these 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. This was also true when comparing the control and long-term areas.

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

Twenty-six of the species observed were considered "occasionals" (Table 6). 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; seven were observed more frequently in the short-term area (one 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 significant differences or were not observed more frequently at the control site. The Eastern Kingbird 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 prefers open country, ponds, marshes, and meadows, characteristics which more closely depict the short-term area. The Indigo Bunting 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 prefers brushy fields and open woodlands.

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[9] Richard J. Vogl, "Effects of Fire on the Plants and Animals of a Florida Wetland," Amer. Mid. Natur., Vol 89, No. 2 (1973), pp 334-347.

Table 4

"Resident" Birds

Species	Control Observed	Control Adjusted*	Short-Term Observed	Short-Term Adjusted	Long-Term Observed	Long-Term Adjusted
Mourning Dove	6	6.2	4	1.4	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**
Catbird	6	58	6	20	0	0
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	2194	118	399	12	112

* Data are adjusted for area surveyed.
** Indicates populations that are significantly different (P<0.05) than control.

Table 5

"Transient" Birds

Species	Control Observed	Control Adjusted*	Short-Term Observed	Short-Term Adjusted	Long-Term Observed	Long-Term 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

*Data is adjusted for area surveyed.
**Indicates populations that are significantly different (P<0.05) than control.

Table 6

"Occasional" Birds

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	33	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
Baltimore 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

* Data are adjusted for area surveyed.

The Red-tailed Hawk and the Turkey Vulture were observed in the study areas, but none of these areas incorporated enough acreage to include five or more individual territories; therefore, these data are not considered in this analysis. Pigeons were seen flying over the short-term area. Their presence could be attributed to the existence of an abandoned cluster of buildings located on Snow Mountain approximately 1000 m from this area. Several Bobwhites 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 7). Species weights were then determined.[10-13]

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

Vegetation

Herbs and Woody Vegetation Less Than 2 m in Height

Data for each site were summarized and tabulated. Table 8 shows data for herbs and woody plants less than 2 m in height; these data are for both the plants encountered in the 1/32 m^2 quadrats, and those found on the site but not sampled. These plants are generally rare to widely scattered on the site and are indicated in the table by P (present).

The most important species in the long-term area was Korean lespedeza (Lespedeza stipulacea), a naturalized forage plant probably introduced for erosion control. This perennial legume was well established over most of the open, disturbed ground. Camphor (Ambrosia bidentata), an annual weed of infertile and highly disturbed soils, was nearly as important as the Korean lespedeza. Although not very conspicuous, several species of grasses were widely established over the

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[10] Earl L. Poole, "Weights and Wing Areas in North American Birds," Auk., Vol 55 (1938), pp 513-518.

[11] S. P. Baldwin and S. C. Kendeigh, "Variations in the Weight of Birds," Auk., Vol 55 (1938), pp 416-467.

[12] R. A. Norris and D. W. Johnston, "Weights and Weight Variations in Summer Birds from Georgia and South Carolina," Wilson Bull., Vol 70, No. 2 (1958), pp 114-129.

[13] R. R. Graber and J. W. Graber, "Weight Characteristics of Birds Killed in Nocturnal Migration," Wilson Bull., Vol 74, No. 1 (1962), pp 74-88.

Table 7

Bird Biomass

Species	Control	Short-Term	Long-Term
Red-tailed Hawk	---	---	19462.11
Turkey Vulture	---	69360.00	47430.00
Bobwhite	12206.208	---	---
American Woodcock	3811.2	---	---
Rock Dove	---	17423.232	---
Mourning Dove	8545.68	2533.0272	---
Common Nighthawk	1742.016	---	---
Belted Kingfisher	3841.92	---	---
Common Flicker	5151.744	3101.7792	---
Pileated Woodpecker	---	2272.696	---
Yellow-bellied Sapsucker	4896.0	---	---
Hairy Woodpecker	---	1513.6664	---
Downy Woodpecker	775.296	373.4342	---
Eastern Kingbird	1070.496	515.6222	2938.2885
Great Crested Flycatcher	722.88	---	---
Eastern Wood Pewee	132.672	---	---
Rough-winged Swallow	151.2	72.828	---
Purple Martin	---	198.832	---
Blue Jay	51240.96	13111.8144	7911.324
Common Crow	37747.2	20454.264	---
Carolina Chickadee	1036.8	124.848	---
Tufted Titmouse	1691.136	101.8205	---
White-breasted Nuthatch	---	97.0578	000
Red-breasted Nuthatch	307.008	147.8755	---
Catbird	2058.048	991.2931	---
Brown Thrasher	1334.016	321.2755	---
Robin	10477.824	---	---
Wood Thrush	8486.4	240.448	---
Veery	314.4	---	---
Ruby-crowned Kinglet	2325.888	186.7171	106.4013
Red-eyed Vireo	7422.144	974.5347	---
Black and White Warbler	710.304	---	---
Prothonotary Warbler	1013.76	---	---
Yellow-rumped Warbler	84.768	163.3197	---
Myrtle Warbler	1117.44	67.2792	---
Black-throated Green Warbler	364.8	---	---
Prairie Warbler	1113.6	---	---
Palm Warbler	158.4	76.296	---
Kentucky Warbler	273.216	65.7995	---
Canada Warbler	---	40.46	---
Red-winged Blackbird	672.0	2589.44	1106.7
Baltimore Oriole	1344.0	---	---
Common Grackle	1174.08	---	---
Brown-headed Cowbird	806.4	194.208	---
Scarlet Tanager	1854.72	297.7856	---
Summer Tanager	806.4	---	---
Cardinal	2028.0	1367.548	---
Rose-breasted Grosbeak	2294.4	---	---
Indigo Bunting	---	360.672	---
American Goldfinch	514.944	---	---
Rufous-sided Towhee	1588.608	2869.4232	---
Dark-eyed Junco	---	96.7803	---
White-throated Sparrow	10839.744	13116.5309	---
Song Sparrow	199.104	---	---
Total	196447.824	155362.6082	78954.8238
Percent		20.914	59.8055

*All weights are in grams.

Table 8

Vegetation Less Than 2 m in Height*

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Abutilon theopharast								P				
Acalpha virginica				P	0.3	1.4	0.4	2.1	0.4	0.4	0.1	0.9
Acer rubrum									1.0	1.6	1.2	3.8
Acer sacecharum									0.2	0.4	0.7	1.3
Achillea millefolium				P								P
Agrimonia rostellata					0.1	0.4	0.5	1.0	0.9	0.4	0.6	1.9
Allium sp.	0.1	0.6	0.1	0.8				P				
Ambrosio artemesia-folia	0.1	0.6	0.1	0.8	0.6	2.2	2.6	5.4	0.2	0.4	0.1	0.7
A. bidentata	7.6	19.2	14.3	41.6	0.3	1.0	4.4	5.7				
A. trifida				P				P				
Amphicarpa bracteata									0.7	1.2	0.6	2.5
Anagallis arrensis								P				P
Andropogeon scopaurius					0.3	0.7	1.1	2.1	0.9	0.8	0.4	2.1
A. virginicus				P				P				
Anemone canadensis								P				P
A. cylindrica								P				
Anthemis cotula					0.7	1.4	1.6	3.7				
Apocynum cannabinum								P				P

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Aralia spinosa					0.6	0.7	0.3	1.6	0.2	0.4	0.1	0.7
Arisaema dracontium												P
A. triphyllum									1.0	0.8	0.3	2.1
Asclepias sullivantii								P				
A. tuberosa								P				
Asplenium platyneuron								P	0.2	0.4	0.1	0.7
Aster solidagineus					0.9	1.0	0.4	2.3	0.9	1.2	0.6	2.7
Barbarea vulgaris												P
Bidens vulgata	0.3	1.7	3.0	5.0				P				P
Botrychium dissectum								P	0.3	0.8	0.3	1.4
Bromus racemosus								P				
Cacalia atriplicifolia								P				
Carex sp.								P				P
Carya globra									0	0	0.4	0.4
Cassia nictitans var. nictitans	0.2	1.1	10.2	11.5								
Centaurea maculosa	1.7	5.0	13.5	20.2	0.3	0.7	0.8	1.8				P
Cerastium vulgatum												P
Cercis canadensis	0.1	0.6	0.1	0.8								P
Chimaphila maculata								P				P

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Chrysanthemum leucant-hemum	0.1	0.6	0.3	1.0				P	0	0	0.1	0.1
Chenopodium album								P				-
Circaea quadrisulcata					0.2	0.4	0.3	0.9				P
Cirsium discolor								P				P
Clitoria mariana					0.2	0.7	0.4	1.3				P
Commelina communis								P				
Convolvulus sepium				P								
Cornus florida								P	3.4	5.9	6.4	15.7
Crotalaria purshii								P				
Cryptotaenia canadensis								P	0.4	0.4	0.2	1.0
Cuscuta sp.								P				P
Cynoglossum virginianum									0.2	0.4	1.0	1.6
Danthonia spicata				P	0.8	0.4	0.3	1.5	3.3	1.2	0.5	5.0
Datura stramonium								P				
Daucus carota	0.2	1.1	1.8	3.1	0.1	0.4	0.2	0.7				
Desmodium dillenii								P	1.2	2.4	3.1	6.7
D. paniculatar	0	0	0.3	0.3								
D. rigidum					0.2	0.4	0.1	1.7				
Dianthus armenia								P				

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Digitaria sp.					1.6	3.6	1.9	7.1				
Diodia teres	1.0	5.0	4.0	10.6	1.7	3.3	1.8	6.8	0.2	0.4	0.1	0.7
Diospyros virginiana					0.1	0.4	0.5	1.0				
Echinochloa micro-stachya					0.2	0.4	0.3	0.9				
E. occidentalis								P				
Elymus glaucus								P				P
E. virginicus								P				
Erechtites hieraci-folia					0.9	0.7	0.2	1.9				P
Erigeron anuus	0	0	0.5	0.5	0.3	1.0	0.9	2.2	0.3	0.4	0.1	0.3
E. acris								P				
Eupatorium rugosum	0	0	0.3	0.3	16.6	14.4	9.9	40.9	4.3	4.7	3.3	12.3
Euphorbia corollata	0.1	0.6	1.9	2.6	0.1	0.4	2.0	2.4				
Filago germanica								P	0.2	0.8	0.1	1.1
Fragaria virginiana									0.4	0.4	0.1	0.9
Gallium aparine								P				P
G. circaezans								P	0.7	1.2	0.5	2.4
G. triflorum									0.9	0.4	0.1	1.4
Geranium columbinum								P				
Geum caunadensis								p	4.5	3.2	0.9	3.6

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Gillenia stipulata								P				
Goodyera pubescens												P
Habenaria lacera								P				
Hedeoma pulegvoides									0.9	0.8	0.1	1.8
Hemerocallis fulva								P				
Houstonia caeruela					0.2	0.7	0.1	1.0				P
H. purpurea								P	0.2	0.4	0.1	0.7
Hypericum punctatium					0.3	1.4	0.1	1.8				P
Impatiens biflora								P	0.4	0.8	0.3	1.5
Ipomoea pandurata				P				P				
Juncus sp.								P				
Juniperus virginiana				P				P	0.4	0.4	0.1	0.9
Krigia biflora								P				
Lactuca canadensis								P				P
L. serriola								P				
Lespedeza hirta								P	2.2	1.6	1.5	5.3
L. stipulacea	21.6	17.4	15.2	54.2	2.7	3.6	4.4	10.7				P
Lespedezea sp.												P
Liatris punctata									0	0	0.1	0.1
Lindera benzoin												P
Lindernia anagallidae								P				

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Linum sulcatum												P
L. virginianum				P	0.5	1.4	0.1	2.0				P
Liparis lilifolia								P				P
Liriodendron tupipifera					9.0	6.5	1.3	16.8	0.5	1.2	1.4	3.1
Lobelia spicata var leptostachys								P	0.4	0.8	0.1	1.3
Lonicera japonica				P'	0.9	3.3	9.4	14.1	10.8	14.2	23.5	48.5
Lotus corniculatus								P	0.2	0.4	0.1	0.7
Lycopodium complanatum									0.2	0.4	0.2	0.8
Lysimacbia lanceolata								P				
Melilotus alba		2.8	4.6	3.4	0.2	0.7	0.5	1.4				P
M. officinalis				P				P				P
Mollugo verticillata					0.1	0.4	0.1	0.6				
Monarda fistulosa								P				
Muhlenbergii sp.				P	0.9	1.8	3.5	5.4	21.2	8.7	5.7	35.6
Oenothera biennis		0.6	0.1	0.8								
Oxalis stricta					1.2	2.9	1.1	5.2	0.7	0.8	0.1	1.6
Panicum clandestinum								P				
P. lanuginosum		1.7	2.2	4.3				P				
P. nitidum					2.5	6.5	3.4	12.4				
P. polyanthes								P				

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
P. sphaerocarpon					0.5	1.4	1.2	3.4				
Panicum sp.					4.4	3.6	1.8	14.8	2.4	2.0	0.6	5.0
Parthenocissus quinquefolia					0.1	0.4	0.1	0.6	2.2	3.1	4.5	9.8
Petunia hybrida								P				
Phryma leptostachya								P				P
Phytolacca americana					0.6	1.4	0.4	2.4				P
Pilea pymila									1.2	2.0	1.6	4.8
Plantago aristata				P				P				
P. lanceolata	0.5	0.6	0.1	1.2	0.3	0.7	0.1	1.1				
P. major				P	0.1	0.4	0.1	0.6				P
P. virginica					0.2	0.7	0.6	1.5				
Poao pratensis	2.3	0.6	4.5	7.4	16.9	1.4	3.2	21.5	2.6	2.0	0.4	5.0
Podophyllum peltatum												P
Polygala ambigua					0.1	0.4	0.1	0.6				
P. nuttallii								P				
P. sanguinea								P				
Polygonum persicaria								P				
P. virginianum												P
Polystichium acrostichoides								P	0.2	0.8	7.3	8.3

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Potentilla canadensis	0	0	2.9	2.9	0.3	1.0	3.7	5.0	1.7	2.0	1.0	4.7
Prunella vulgaris								P				
Prunus serotina									0.2	0.4	0.6	1.2
Psoralea psoralioides								P				
Pterdium aquilinum								P				
Pycnanthemum flexosum								P				
Quercus imbricaria					0.2	0.7	0.4	1.3	0.4	0.8	0.3	1.5
Quercus sp.												
Rhus copallinum	0.1	0.6	5.0	5.7	0.2	1.0	2.3	3.5				P
R. glabra												P
R. radicans				P					5.5	5.1	4.3	14.9
Rosa sp.	0	0	0.2	2.2								
Rubus procumbens								P				P
Rubus sp.	0.1	0.6	0.8	1.5	0.4	1.0	1.8	3.2				
Rudbeckia serotina	0.2	0.6	0.6	1.4				P	0.2	0.4	0.6	1.2
Rumex acetosella								P				
R. crispus				P	0.1	0.4	0.1	0.6				
Salvia pratensis												P
Sanguinaria canadensis												P
Sanicula canadensis									0.7	0.8	0.3	1.8

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Sassafras albidum					0.6	2.2	3.3	6.1				
Scutellaria leonardi												P
Setaria glauca	9.5	12.9	3.9	26.3	3.3	2.9	4.6	10.8				
Smilax glauca	0	0	2.7	2.7	0.8	2.2	4.4	7.4	0.9	0.8	0.6	2.3
S. herbacea var. herbacea									0.4	0.4	0.6	1.4
Smilicina racemosa												P
Solanum carolinense					0.1	0.4	2.4	2.9				P
S. nigrum								P				
Solidago nemoralis	0.4	1.1	0.5	2.0								P
Solidago sp.				P	2.1	1.4	0.3	3.8	1.2	1.2	0.4	2.8
Sonchus arvensis								P				
Specularia perfoliata								P				P
Stellaria sp.												P
Sympharicarpes albus								P	0.2	0.4	1.6	2.2
Taraxacum officinale								P	0.2	0.4	0.1	0.7
Tephrosia virginiana								P				
Thelypteris hexagonoptera									0.4	0.4	0.4	1.2
Tovara virginiana								P				
Trifolium agrarium								P				
T. hybridum								P				
T. incarnatum								P				

Table 8 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
T. pratense								P				
T. repens					0	0	0.1	0.1				
Unknown graminoids	52.4	23.7	7.7	83.8	21.3	11.3	7.2	39.3				
Unknown seedlings									8.1	7.5	1.9	17.5
Vaccinium stamineum									0.2	0.4	0.1	0.7
Verbascum thapsus								P				
Verbena simplex				P				P				P
V. stricta												P
V. urticifolia												P
Verbesina occidentalis								P				P
Veronica arvensis					0.2	0.4	0.1	0.7				
Viola sp.					0.2	0.8	2.9	3.9	7.2	6.3	4.8	18.3
Vitis sp.	0.2	0.6	0.5	1.3	1.1	1.0	0.5	2.6	0.2	0.4	1.3	1.9
Xanthium spinosum				P				P				
Totals	100.3	100.5	102.4	303.2	104.7	101.5	97.1	303.3	101.3	98.7	88.1	288.6
Richness (sampled)		29				56				61		
Total (including "P")		48				144				112		

*D = Relative Density, F = Relative Frequency, C = Relative Cover, W = Importance Value (D+F+C = IV)
P = present but not in 1/32 m^2 quadrats

disturbed soils of the long-term site. These unknown graminoids were rarely more than 10 cm tall and appeared to be a mixture of native grasses, including poverty grass (Andropogon virginicus), little bluestem (A. scoparious), and danthonia (Danthonia spicata). Collectively, these grasses were more important than the lespedeza or the camphor. Other important plants were foxtail grass (Setaria glauca) -- an annual grass -- and bachelor's button (Centaurea maculosa) and white sweet-clover (Melilotus alba) -- both biennials or short-lived perennials. Sweet-clover may also have been seeded on the site, although it was generally distributed in old disturbed communities. Forty-eight species were observed in the herb layer of the long-term site.

The short-term site had more species (144) in the herb layer than either of the other sites. Importance was evenly distributed among many species, so none could be represented as the most important. White snake-root (Eupatorium rugosum) had the greatest importance value of any one species, but this was mainly because numerous small seedlings of this species were present throughout the site; however, most of these seedlings cannot be expected to survive. Seedlings and sprouts of tulip poplar (Liriodendron tulipifera) were important in the herb layer, and if this area were left relatively undisturbed, tulip poplar would become a more important species in the tree layer as a direct result of the disturbance. Korean lespedeza was well represented, although it was not nearly as dominant as in the long-term area. The introduced perennial vine--Japanese honeysuckle (Lonicera japonica)--is more common in woodland areas, but remained an important species in this cleared site. Several grasses were well established, including panic grass (Panicum spp.), Kentucky bluegrass (Poa pratense), and foxtail. Many grasses were too immature to identify, but their importance should be considered.

The control site's herb layer was similar to that of the short-term site in many respects, but had fewer total species (112) and a less even distribution of importance. Japanese honeysuckle was especially important, occurring in essentially every community, although it was not common in the old-growth forest. Poison ivy (Rhus radicans), a native woody vine, was also important, but less so than honeysuckle. Violets (Viola spp.) and seedlings of flowering dogwood (Cornus florida) were noteworthy. White snake-root, one of the most important herbs in the short-term area, was also important in the control area, but to a much lesser extent. Generally, woody seedlings were more prominent in the herb layer of this site, whereas sprouts predominated in the short-term site.

Woody Vegetation Greater Than 2 m in Height

Table 9 summarizes data for woody vegetation greater than 2 m in height. Species are summarized by relative density, frequency, and cover; the importance value of each species is indicated for each site.

Table 9

Woody Vegetation

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Acer rubrum									0	0	1.4	1.4
A. saccharum				P	1.8	3.4	1.6	6.8	16.4	9.5	14.2	40.1
Aralia spinosa								P	0.3	1.6	0.1	2.0
Carpinus caroliniana									1.3	2.6	0.8	4.7
Carya cordiformis					1.8	3.4	*	5.2	1.3	3.7	1.9	6.9
C. glabra				P	4.6	6.6	2.6	13.8	1.6	5.2	4.2	11.0
Catalpa speciosa				P								
Celtis occidentalis									0	0	0.1	0.1
Cercis canadensis									0.3	1.1	0.5	1.9
Cornus florida								P	42.8	9.5	33.4	35.7
Carylus americana									0.6	0.1	0.2	0.9
Crategus sp.									0.2	0.1	0.1	0.4
Diospyros virginiana				P				P	1.6	5.3	0.1	7.0
Fagus grandifolia									0.1	0.1	0.1	0.3
Fraxinus americana												P
F. pennsylvanica									0.6	2.1	0.2	2.9
Juglans nigra					1.8	3.4	1.6	6.8	0.6	2.1	1.4	4.1
Juniperus virginana				P				P	6.0	5.3	5.3	16.6
Liriodendron-tulipifera					13.8	10.0	14.9	33.7	7.2	8.9	1.5	17.6

Table 9 (cont'd)

Species	Lont-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Morus alba									0.2	1.6	0.2	2.0
Nyssa sylvatica					0	0	0.5	0.5	3.5	3.7	3.5	10.7
Ostrya virginiana									0.1	0.1	1.7	1.9
Pinus echinata					1.8	3.4	1.6	6.8				
Plantanus occidentalis								P	0.3	0.1	0.3	0.7
Prunu serotina				P	1.8	3.4	*	5.2	0.6	3.2	0.2	4.0
Quercus alba					36.7	23.3	33.8	93.8	1.9	3.2	0.7	5.2
Quercus coccinea									0	0	0.5	0.5
Quercus falcata					1.8	3.4	*	5.2				
Quercus imbricaria					4.6	6.6	6.7	17.9	1.6	5.3	6.4	13.3
Quercus muhlenbergii					1.8	3.4	*	5.2	0.9	3.2	1.9	6.0
Quercus nigra					4.6	3.4	2.6	10.6				
Quercus rubra					9.2	16.6	22.1	47.9	0.9	1.6	1.2	3.5
Quercus stellata					9.2	3.4	9.7	22.3	0.2	1.1	0.2	1.5
Quercus velutina					4.6	6.6	2.6	13.3	0.2	1.1	1.4	2.7
Rhamnus carolinianus									0.2	0.1	0.4	0.7
Rhus capallinum				P				P	0.6	1.6	0.3	2.5
Rhus glabra				P					1.3	1.6	0.7	3.6
Robinia pseudoacacia												P

Table 9 (cont'd)

Species	Long-Term				Short-Term				Control			
	D	F	C	W	D	F	C	W	D	F	C	W
Salix sp.				P					0.6	0.1	1.6	2.3
Sambucus canadensis				P								
Sassafras albidum				P				P	5.7	8.4	4.6	18.7
Ulmus rubra									0.3	3.2	1.1	4.6
Ulmus thomasii									0.2	0.1	0	0.3
Total	0	0	0	0	99.9	100.3	100.3	300.5	100.2	96.5	91.8	288.5
Richness (sampled)				0				16				36
Richness (including P)				11				23				38

Except in protected depressions, most trees and shrubs had been eliminated from the long-term site. In the white sweet-clover-shrub community, small sassafras (Sassafras albidum), persimmon (Diospyros virginiana), and red cedar (Juniperus virginiana) were present, but widely spaced. There were no trees in the camphor-lespedeza, the largest community. All other tree species were present only in or around the depressions where tracked vehicles rarely moved. Eleven species of woody plants greater than 2 m tall were found.

All understory had been removed from the short-term area by bulldozing, and nearly all the woody vegetation consisted of larger trees. The exceptions were many species of trees present in the herb layer as seedlings and sprouts, and a few small trees such as sassafras, red cedar, winged sumac (Rhus copallinum), and persimmon that the bulldozer had missed. These were widespread or on the edges of depressions that had not been disturbed. The most important large tree was white oak (Quercus alba), followed by red oak (Q. rubra) and tulip poplar. The latter species were less than half as important as white oak. Several other species, primarily oaks and hickories, shared the site with these dominants. Altogether, 23 species taller than 2 m were found.

Although 11 community types were recognized in the control area, no attempt was made to sample each one statistically; therefore, the data are combined. Flowering dogwood, which occurred in every community, was more than twice as important as any other woody plant, although it is primarily an understory species. Sugar maple (Acer saccharum), a prominent member of mesic, old-growth forests, was second to dogwood, primarily because young trees were becoming established beneath the closed canopy of such trees as red cedar and shingle oak (Quercus imbricaria) that had become established in old fields. Tulip poplar, like dogwood, not only becomes established in open fields, but also persists into the older, more mesic communities as succession continues. Tulip poplar was important, along with early invaders such as red cedar and sassafras. The overall importance of such trees as dogwood, sassafras, red cedar, and shingle oak is clearly shown by comparing their importance to that of other species. Altogether 38 species were found at the control site, and all but two were sampled.

Table 10 provides data on the basal area of woody plants found at both the short-term and control sites, and Table 11 shows the distribution of species by size class. Of the 16 individuals sampled in the short-term area, dogwood was the only species having individuals in a diameter class of less than 25 cm (see Table 11). White oak had nearly three times more basal area as tulip poplar, the next most important species (see Table 10). Tulip poplar and red oak were also relatively important, followed closely by post oak and black oak. Tulip poplar accounted for nearly 22 percent of the basal area of the control site, followed by shingle oak, sugar maple, and dogwood. The combined species basal area in the control area is nearly six times greater than that of the short-term area, although the number of individuals present in the

Table 10

Absolute and Relative Basal Areas for Woody Species

Species	Site	N	Basal Area (M^2/ha) Absolute	Relative
Acer saccharum	S	1	.13	2.1
	C	10	3.42	9.9
Carpinus caroliniana	S	-	-	-
	C	1	.26	.75
Carya cordiformis	S	1	.13	2.1
	C	2	.53	1.5
Carya glabra	S	2	.26	4.3
	C	9	2.4	6.9
Cercis canadensis	S	-	-	-
	C	1	.26	.75
Cornus florida	S	-	-	-
	C	10	3.2	9.2
Diospyros virginiana	S	-	-	-
	C	2	.53	1.5
Juglans nigra	S	1	.13	2.1
	C	-	-	-
Juniperus virginiana	S	-	-	-
	C	9	2.6	7.5
Liriodendron tulipifera	S	6	.79	12.9
	C	22	7.9	22.8
Nyssa sylvatica	S	-	-	-
	C	8	2.1	6.1
Plantanus occidentalis	S	-	-	-
	C	3	.8	2.3
Prunus serotina	S	1	.13	2.1
	C	-	-	-
Quercus alba	S	14	2.1	34.5
	C	4	1.1	3.2
Quercus coccinea	S	-	-	-
	C	5	.26	.75
Quercus falcata	S	1	.13	2.1
	C	-	-	-
Quercus imbricaria	S	2	.26	4.3
	C	10	3.7	10.7
Quercus muhlenbergii	S	1	.13	2.1
	C	-	-	-
Quercus nigra	S	2	.26	4.3
	C	-	-	-
Quercus rubra	S	5	.66	10.8
	C	5	1.8	5.2
Quercus stellata	S	4	.53	8.7
	C	1	.26	.75

Table 10 (cont'd)

Species	Site	N	Basal Area (M^2/ha) Absolute	Relative
Quercus velutina	S	3	.39	6.4
	C	4	1.3	3.8
Sassafras albidum	S	-	-	-
	C	4	1.1	3.2
Ulmus rubra	S	-	-	-
	C	3	1.1	3.2
Total	S	44	6.03	98.8
	C	113	34.62	100.0

S - short term impact study site
C - control
M^2/ha - square meters per hectare

Table 11

Size Class Frequency of Woody Species

Species		N	Size Class* 0-4.8	5.0-9.9	10.1-14.9	15.2-20.0	20.3-25.1	25.4-30.2	30.5-35.3	35.0-40.4	40.6+
Acer rubrum	S	0									
	C	18	33.9	11.1	33.3	16.7					
A. saccharum	S	1									
	C	157	81.5	12.7	2.5	1.3	0.6		0.6		0.6
Aralia spinulosa	S	0									
	C	6	66.6	33.3							
Carpinus caroliniana	S	0									
	C	8	62.5	25.0		12.5					
Carya cordiformis	S	0									
	C	4	25.0		25.0		25.0				25.0
Carya glabra	S	0									
	C	10	10.0		10.0			20.0	30.0	20.0	10.0
Cercis canadensis	S	0									
	C	4	75.0		25.0						
Cornus florida	S	2		100.0							
	C	449	83.3	11.1	3.7	2.0					
Corylus americana	S	0									
	C	6	100.0								
Crategus sp.	S	0									
	C	2	100.0								
Diospyros virginiana	S	0									
	C	13	72.2	11.1	5.5	5.5	5.5				
Fagus grandifolia	S	0									
	C	1	100.0								
Juglans nigra	S	0									
	C	6	16.6				83.3				
Juniperus virginiana	S	0									
	C	63	46.0	27.0	9.5	4.8	7.9	4.8			
Lindera benzoin	S	0									
	C	7	100.0								
Liriodendron	S	3						33.3			66.6
tulipifera	C	76	44.7	30.3	7.9	7.9	2.6	2.6	1.3	1.3	1.3
Morus alba	S	0									
	C	3	100.0								

Table 11 (cont'd)

Species		N	Size Class* 0-4.8	5.0-9.9	10.1-14.9	15.2-20.0	20.3-25.1	25.4-30.2	30.5-35.3	35.0-40.4	40.6+
Nyssa sylvatica	S	0									
	C	41	65.9	7.3	14.6	7.3	4.8				
Ostrya virginiana	S	0									
	C	3	33.3	66.6							
Plantanus occidentalis	S	0									
	C	3	33.3			66.6					
Prunus serotina	S	0									
	C	7	57.1	28.6	14.3						
Quercus alba	S	1						100.0			
	C	24	66.6	16.6	4.2	4.2		4.2			4.2
Quercus muhlenbergii	S	0									
	C	10	70.0	20.0					10.0		
Quercus falcuta	S	0									
	C	2					50.0	50.0			
Quercus imbricaria	S	2						100.0			
	C	16	31.3		25.0	12.5	6.3	12.5			
Quercus nigra	S	1							100.0		
	C	0									
Quercus rubra	S	2							100.0		
	C	11	45.5	18.2	9.1				9.1	9.1	9.1
Quercus stellata	S	2								100.0	
	C	3	66.6					33.3			
Quercus velutina	S	1							100.0		
	C	7	42.9	14.3			14.3	14.3	14.3		
Rhus copallinum	S	0									
	C	9	100.0								
Rhus glabra	S	0									
	C	12	83.3	16.7							
Salix sp.	S	0									
	C	6	100.0								
Sassafras albidum	S	0									
	C	36	47.2	27.8	11.1	5.6					
Ulmus rubra	S	0									
	C	11	45.5	36.4	9.1	9.1					

Table 11 (cont'd)

Species		N	Size Class*								
			0- 4.8	5.0- 9.9	10.1- 14.9	15.2- 20.0	20.3- 25.1	25.4- 30.2	30.5- 35.3	35.0- 40.4	40.6+
Ulmus thomasii	S	0									
	C	2	100.0								
Totals S	N	15		2.0				4.0	4.0	2.0	3.0
	%	99.8		13.3				26.6	26.6	13.3	20.0
Totals C	N	1041	748.5	151.9	42.7	39.6	26.0	11.5	10.4	5.2	7.3
	%	100.1	71.9	14.5	4.1	3.8	2.5	1.1	1.0	0.5	0.7

* Data in percent for those woody species greater than 2 m in height, N = number, samples taken with d.b.h calipers and tape, S = short-term site, C = control site.

control area approaches 70.0 times that of the short-term area. The majority of the species on the control site have continuous Type 3 survivorship curves;[14] with a few species, such as shingle oak and the hickories, having either disjuncted size classes or populations exhibiting other than Type 3 survivorship curves.

Soil compaction tests, although highly variable (Table 12), indicate some conclusions regarding the impact of tracked vehicles. In the long-term area, the camphor-lespedeza community had the least variable, most compacted soil. The white sweet-clover/shrub community and gullies had a relatively low compaction and were spatially more variable. In the short-term area, the open weedy community and recent tracked vehicle paths had approximately the same high compaction and variability. The remaining communities had soils that were less compacted. The control site, being a mosaic of different communities, had quite variable soils. The recently cut-over oak-hickory forest community had the most compacted soils of the communities examined, followed by the riparian, oak-hickory forest, and finally the least compacted soils -- the depression forest. Generally, three soil compaction classes were recognized: high, medium, and low. High-compaction areas included the camphor-lespedeza community of the long-term site, the open weedy community, and cut-over oak-hickory forest of the short-term site, and recent tracks in all communities. The low-compaction areas were the gullies of the long-term site, and the riparian and depression forests of the control area. The remaining communities were considered to be medium-compaction areas.

[14] Robert H. Whittaker, Communities and Ecosystems, 2nd ed. (MacMillan Publishing Co., 1975).

Table 12

Soil Compaction Test Results for Site A (Heavy Use), Site B (Medium Use), and Site C, the Control. (Sampling was accomplished using a hand-held soil penetrometer to the 2.5-cm depth.)

Study Site Community Designation	Mean Compaction (No. of Samples)	Standard Deviation
A		
Gullies	56.6 (16)	24.8
Camphor Weed-Lespedeza	195.9 (22)	36.3
White Sweetclover-Shrub	76.4 (32)	34.7
B		
Open Weedy	140.0 (18)	52.2
Sandhill Prairie	71.0 (20)	47.1
Nearly Continuous Canopy	89.8 (20)	68.9
Widely Scattered Canopy	96.8 (20)	63.8
Tank Tracks	153.3 (20)	69.2
C		
Riparian	65.0 (20)	23.2
Depression Forest	35.0 (20)	17.4
Oak-Hickory	52.0 (20)	14.9
Cut-over Oak-Hickory	86.0 (20)	36.5

5 DISCUSSION

Mammals

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 period of time. There was also ample indication that mammals which 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, vegetative disturbance, and resulting erosion caused by training. The primary niche parameter affected is the removal of or damage to the nesting and cover necessary for survival after the loss of food resources (initially vegetative growth and secondarily, seed production).

Some important conclusions can be drawn on the overall impact of tracked vehicle training on all mammal guilds. Table 13 is a composite of all guilds showing the probable impact of tracked vehicle training as determined by habitat preference, feeding preference, and trophic status, and to what extent the loss of habitat and food contributed to the probable impact. Generally, 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.

Birds

Study results showed that the methods and results of preparation for tracked vehicle training cause a moderate (20 percent) 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 this reduction. Data show that populations of woodland species are severely reduced (Wood Thrush, Tufted Titmouse, Red-eyed Vireo, and Carolina Chickadee), while populations of species that prefer an open woodland or forest edge habitats are moderately reduced (Cardinal, Common Flicker, Common Crow, Catbird, and Mourning Dove). 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 vegetative stratification, and disturbance of soil surface.

Table 13

Impact on Mammal Guilds

Guilds*	Probable Impact** Clearing	Training	Niche Parameter Disturbed Den-Nest-Cover	Food
1	--	---	---	---
2	--	---	---	-
3	-	-	-	-
4	-	-	-	-
5	N/A	N/A	N/A	N/A
6	N/A	N/A	N/A	N/A
7	--	---	---	--
8	---	---	---	--
9	---	---	---	-
10	+	-	++	-
11	---	---	---	-
12	+	+	++	-
13	--	--	-	--
14	-	-	-	-
15	-	--	-	--
16	--	--	--	--
17	--	---	-	---
18	--	--	-	--
19	-	-	-	-
20	--	---	---	-
21	--	---	---	-
22	--	---	--	---
23	---	---	-	---
24	N/A	N/A	N/A	N/A
25	--	---	-	--
26	--	---	-	---
27	N/A	N/A	N/A	N/A
28	--	--	-	-
29	N/A	N/A	N/A	N/A
30	++	-	-	++

* For discussion of guilds, see Appendix A
**--- negative and extensive
-- negative and moderate
- negative but minimal
+++ positive and extensive
++ positive and moderate
+ positive but minimal

The virtual 100 percent reduction in most "resident" species in the long-term area is indicative of the severely eroded and vegetatively 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.

Vegetation

One result of clearing and continued heavy use of tracked vehicles in the long-term area is extensive sheet erosion and local, intensive gully erosion. This site was open with widely scattered weedy herbs and grasses. Sprouts of persimmon and sassafras up to 2 to 3 m high were present throughout, usually in small areas where tracked vehicle use was infrequent. Most of the original soil profile was absent or disturbed, and chert fragments were abundant. In depressions and draws, especially those with less disturbed vegetation, soil deposition was pronounced. Trees, especially oaks, hickory, sassafras, cottonwood, and willow were present in many of these depressions. Predominant herb cover was camphor weed and white sweet-clover in the disturbed areas, and woody vines, especially poison ivy, Virginia creeper, trailing blackberry, and cinquefoil in the slightly older areas. Korean lespedeza was abundant throughout the disturbed area, apparently having been seeded for soil protection. The less disturbed depressions, many supporting a pond or wet habitat, may serve as important refuge for birds, deer, and other area wildlife. Three communities were recognized in the long-term area. Depressions supported a diverse oak-sassafras-hickory community. Many older trees of species characteristic of relatively undisturbed woodlands were present, along with disturbed-site species such as sassafras, sumac, cottonwood, and willow. A white sweet-clover/shrub community occupied the upland areas that have been relatively undisturbed for 3 or more years (based on ages of shrubs). Shrubs were primarily sassafras and persimmon. White sweet-clover and lespedeza were common, and ground cover was nearly complete. The camphor-lespedeza community (the least community) occurred in all remaining areas. Few woody plants occurred here, and the soil was heavily disturbed and compacted.

Prior to recent clearing, the short-term area was a diverse forest of mixed oak and tulip poplar with old field openings dominated by eastern red cedar, sassafras, and persimmon. Several of the ridges had apparently been cleared for agriculture and abandoned approximately 30 to 50 years ago. The forested area had been intensively cut over and opened 35 to 40 years ago, with canopy closure occurring approximately 15 to 20 years ago. Most trees remaining after the most recent clearing were 40 to 75 years old. The absence of older trees, except for a few in clearings, supported the assumption that the present forest originated early in this century, probably on ground previously used for agriculture.

Five communities were recognized in the short-term area:

1. Open, early weed communities on disturbed soil

2. Sand-hill prairie

3. Parkland, recently cleared, with only widely scattered trees remaining

4. Open forest with nearly continuous canopy, recently cleared

5. Relatively undisturbed forest

    a. Old field, abandoned 30 to 50 years ago, dominated by red cedar, primarily on ridges.

    b. Older forests, with trees 40 to 75 years old, closed canopy, primarily on slopes

    c. Depression forest, probably never cleared.

Most of the control area had been cleared for agricultural use in the past and permitted to revert to forest. However, one small area supported old-growth forest without evidence of disturbance. In addition, eight other communities were recognized, each representing a unique set of biotic and abiotic conditions. These sites all appeared to be the result of reforestation of cleared land that had been used either for cultivation or pasture, or both. Eastern red cedar persisted in all but two communities and dominated in three communities. Oaks, especially shingle oak, white oak, black oak, and hickories, were important in all communities. Oaks and hickories dominated on upland sites, and maple and tulip poplar were among the more important on mesic sites. Tree reproduction was sparse or absent in both the old-growth forest community and the oak-hickory-dominated community. In all other communities, reproduction was good, especially of sugar maple. Flowering dogwood was the predominant understory tree in most of these communities, followed by sugar maple.

The communities recognized were:

1. Old-growth forest, with codominance of shingle oak, sugar maple, tulip poplar, white oak, black oak, and red oak, and having a poorly developed understory

2. Oak-hickory forest, with codominance of shingle oak and pignut hickory, and having poorly developed understory

3. Riparian community, with codominance of tulip poplar and sugar maple, and having sparse understory of redbud, spicebush, and young sugar maple

4. Old-field cedar, dominated by shingle oak and red cedar, and having sugar maple understory

5. Cut-over oak-hickory community, dominated by shingle oak, white oak, and scarlet oak, and having extensive sugar maple understory; some red cedar also was present

6. Depression community, dominated by tulip poplar, sugar maple, butternut hickory, and having heavy sugar maple understory

7. Black gum community, dominated by black gum, tulip poplar, sugar maple, and butternut hickory

8. Sugar maple-ironwood community, dominated by young sugar maple and ironwood

9. Young field cedar, dominated by mixed herbs, red cedar, sumac, sassafras, and persimmon

10. Old field deciduous community, dominated by tulip poplar, black locust, shingle oak, red oak, and butternut hickory, and having scattered old red cedars.

The old-growth forest represented the only example of undisturbed forest in the control area. It persisted on a northwestern edge of the stream. The community was characterized by a rich assortment of large old-growth trees and a sparse, poorly developed understory. There was no evidence that this community had ever been seriously disturbed. Japanese honeysuckle was the only alien invader and occurred extensively only on the margins. In the future, a combination of disease and windthrow should be expected to create small openings in which these species may reproduce and perpetuate this community.

The oak-hickory community occurred along the northern edge of the control site. It was characterized by medium-sized oaks and hickories, especially shingle oak and pignut hickory. Other important trees included black oak, white oak, red cedar, sassafras, persimmon dogwood, and scattered tulip poplar. Reproduction was poor to absent. This community had apparently become established as a result of abandonment of agricultural land. Soils were moderately compacted and topsoil was thin to absent over a moderately deep subsoil. Red cedar, sassafras, and persimmon are expected to give way during the next 20 to 30 years as a result of gradual increase in the size of oaks, hickories and tulip poplar. Dogwood will persist in the understory and may increase in abundance. Sugar maple can eventually be expected to become established in this community, and ultimately lead to a decline in the importance of oaks and hickories.

The riparian community occupies the frequently flooded bottomland along the stream draining through the area. Soils there were the deepest and most fertile and had the least compaction. Herbaceous ground cover was extensive. In addition to the dominant tulip poplar and sugar maple, sycamore and black walnut were also present. This community is subject to periodic disturbance by flooding and is expected to maintain its integrity in the absence of outside disturbance. Characteristic indicators of this community include dragon's head (Arisaema draconian) in the herbaceous layer and spice (Lindera benzoin) in the shrub layer. Sparse reproduction by all species was evident.

The old field cedar forest developed from abandoned agricultural land approximately 70 years ago. Both red cedar and shingle oak have persisted since the initial settlement. Sassafras and persimmon have given way to these two codominants. Sugar maple has invaded the understory and is expected to replace the red cedar and much of the shingle oak eventually. Other species of oak, tulip poplar, and hickory can be expected to slowly become established, leading ultimately to a mixed oak-deciduous forest. Ground cover is relatively sparse and is presently dominated by perennial forbs. Soil is moderately compact and showed evidence of past erosion.

The cut-over oak-hickory forest was last harvested approximately 15 years ago and evidence remains of either intensive high grading or total disregard for the quality of timber left to reproduce. Trees remaining tend to be primarily poor-quality black and scarlet oaks. However, sugar maple, which was probably established before the harvest occurred, has rapidly developed into a heavy understory and may be expected to eliminate many of these less tolerant species eventually. This site shows further evidence of timber harvest or other disturbance approximately 50 years ago. The site may have been pastured, but was probably never totally cleared of tree cover. The soils are relatively shallow and moderately compacted.

The depression community is localized in a large sink immediately against the north side of the control, adjacent to the oak-hickory community. It apparently has a similar history, but because of deeper soils and more mesic conditions, it supports a community dominated by older sugar maple, tulip poplar, and butternut hickory. Sugar maple reproduction is well advanced.

The small black gum community extends along the southern side of the old-growth forest and is characterized by an unusual number of relatively small black gum, most less than 75 years old. Many of the same species present in the old-growth forest are also represented in this community, but none were nearly as large or as old. This community apparently originated as a result of heavy cutting, approximately 60 to 70 years ago. The site probably never was totally cleared of trees and probably was never pastured. Slopes range from 15 to 25 percent, and soils are moderately shallow but relatively noncompacted. Reproduction by all species is adequate and in the absence of disturbance, the community will eventually develop into a mesophytic community very much like the old-growth forest.

The sugar maple-ironwood community is characterized by extensive sugar maple reproduction and the absence of larger, older trees. Evidence of timber harvest within the past 20 years indicates that this was apparently an old-growth forest, probably dominated by nearly the same assortment of trees found in the old-growth forest. In the absence of future disturbance, this forest will develop into a community dominated by sugar maples, with flowering dogwood and ironwood in the understory. Soils are relatively deep and uncompacted. Honeysuckle is well established.

Old-growth cedar was the most extensive community in the control area. It occupies all areas in and around the other communities. Cores from the dominant trees indicated that the community originated approximately 70 to 80 years ago, following the abandonment of cleared agricultural land. This community has been subjected to moderate disturbance. Soils are relatively deep over slopes, which rarely exceed 15 percent with thin to absent topsoil. Other old field pioneers such as sassafras, dogwood, persimmon, and sumac are occasional, but in most areas have given way to the dominants. In a few areas, open glades have developed over shallow soils, and widely scattered red cedar occurs. Reproduction is poor for all these species, with only scattered sugar and tulip poplar showing evidence of becoming established. As the shingle oaks eventually overtop and eliminate the red cedar, sugar maple and tulip poplar become abundant and will eventually replace much of the shingle oak.

The young-field cedar represents the earlier stage of succession from agricultural fields abandoned within the past 20 to 40 years. As with the older community, the red cedar and shingle oaks can be expected to replace much of the sumac, persimmon, sassafras, grass and forbs eventually. Soils are moderately compact and severely eroded.

The old-field deciduous forest has developed on relatively deep soils along the stream in the eastern part of the control area. The presence of black locust and red cedar indicates a history of disturbance. This area probably was cleared at one time and then abandoned, leading to establishment of red cedar and initiating successional processes that gave rise to the present forest. Black locust may have been introduced near the time of abandonment.

Historically, the study sites are similar, all having been previously disturbed through logging, agricultural use, and possible use by the Army. The long-term site has been continually disturbed for at least 13 years (as revealed by shrub ages). The perennial plant species that require a longer time than others for establishment and reproduction have been virtually eliminated over much of the long-term area, and along the more frequently traveled track vehicle roads meandering through the short-term and control areas. Annual opportunist species are favored in these high-risk areas. These plants reproduce, set, and disseminate seed in 2 or 3 months; the seeds, which are often long-lived in the soil, are relatively invulnerable.

Gullies in the long-term area were virtually devoid of vegetation, probably becoming unstable and continually changing substrates.

Depression communities in this area were actively filling with outwash from the more heavily used areas of the site. If this continues, associated aquatic and riparian vegetation may be eliminated, resulting in a reduced plant species richness, and inevitably, a parallel trend of elimination in associated organisms.

The short-term area had the richest herb flora of the three study areas. This diversity undoubtedly resulted from both the establishment of weedy species because of disturbances and the persistence of many species present before the disturbance.

Tank training site preparation involved the clearing of all woody vegetation less than 8 cm dbh. This had many side effects. The remaining trees were frequently damaged during the clearing process. Nearly 80 percent of the remaining trees had limb, trunk, and root wounds from the clearing machinery or from falling against one another during the clearing process. Most wounds were quite severe, and some of the damaged trees showed upper branch die-back only 6 months after the land was cleared. When this occurs disease organisms will be able to enter and infect the tree, and may ultimately cause tree death. Tree death may also result from failing root systems because of damage incurred during the initial clearing and from subsequent track vehicle training. The short-term area may become very much like the long-term area, with the rate of regression dependent on how frequently and extensively the site is used for training.

Loss of remaining trees and use by tracked vehicles may result in the removal of persisting woodland herb species dependent on the ameliorating effects of a tree canopy, deciduous leaf litter, shade, rich soils, and other tree-related attributes. Much of this reduction in the richness of herbs would occur simply because of site preparation and would be accelerated by tracked vehicle training.

As evidenced from the control area, if the short-term site is left fallow in its present condition, the forest canopy may take 100 years or more to close again, and the site may take even longer to stabilize. During this time, some of the more common native plant species will become established again, although such Eurasian plant species as the Japanese honeysuckle may become established to such an extent that native species are excluded. This trend was evident in the old-field deciduous and in sections of the old-field cedar and riparian communities in the control area.

Soils of the areas studied are naturally compact and have suffered considerable erosion as a result of past agricultural practices. Where vegetation is removed, especially on slopes greater than 6 percent, continued erosion soon eliminates the small amount of topsoil that has accumulated since the soils were fallowed from agricultural use. Removal of vegetation and use of heavy, tracked vehicles compounds this problem, because soils become increasingly compacted; as a result, infiltration is reduced, loss of organic material and litter decreases the population of animals that otherwise would increase soil porosity, and disturbance prevents establishment of protective vegetative cover.

The initial impact of tracked vehicle travel on soil compaction is evident in the short-term site where soil penetrometer measurements were taken in all community types in recent vehicle tracks. The mean compaction value from these measurements is substantially greater than the mean values from all other community types except the open weedy community.

Vehicles scrape the upper few inches of soil into a loose duff and, at the same time, compress the lower horizons. Less water infiltrates, but instead more easily removes the loosened soil at the surface. Compaction, especially when the soil is wet, leads to a loss of soil structure, and erosion leads to a loss of soil fertility. Ultimately, the damage to the soil would lead to a totally barren landscape, similar to what the long-term site now resembles, on which few species would survive even if disturbances were halted. Such soil damage would heal naturally only during successional processes spanning perhaps a thousand or more years. During this time of soil development, vegetation would resemble the sparse, weedy communities now present in nearby areas that have suffered similar disruption.

6 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, vegetative disturbance, and resulting 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 affecting birds appear to be reduction of understory, disruption of vegetative stratification, and disturbance of soil surface.

Tank training site preparation involved the clearing of all woody vegetation less than 8 cm dbh. The remaining trees were frequently damaged during the clearing process, and were endangered by infection from disease organisms and failing root systems. Loss of remaining trees and use by tracked vehicles may result in the removal of persisting woodland herb species dependent on the ameliorating effects of a tree canopy, deciduous leaf litter, shade, rich soils, and other tree-related attributes. Much of this reduction in the richness of herbs would occur simply because of site preparation and would be accelerated by tracked vehicle training. Compaction, especially when the soil is wet, leads to a loss of soil structure, and erosion leads to a loss of soil fertility. Ultimately, such soil damage would lead to a totally barren landscape on which few species would survive even if disturbances were halted.

It appears as though several alterations of the methods discussed in this report can accomplish the same results more efficiently. Mammals should be dealt with on a transect, trap night basis, birds on a transect, manhour of observation basis, and plants on a more direct quantitative basis.

The guild concept as described in Appendix A worked well with mammals. Bird and plant guilds are now being developed.

APPENDIX: THE GUILD CONCEPT

The guild concept as it applies to ecology was defined by Root[15] as a "group of species that exploit the same class of environmental resources in a similar way." This concept has been used as it pertains to some avian members of the foliage-gleaning guild,[16] three guilds of arthropods that feed on collards,[17] and a guild containing six species of parasitic hymenoptera that use sawfly cocoons.[18] Root[19] discussed the resource use of the Blue-Gray Gnatcatcher and later compared the community structure of collards and their susceptibility to herbivorous arthropods.[20] Price[21] discussed the resource partitioning of six members of a parasitic insect guild.

Hypothetically, the nonmarine mammals inhabiting the continental United States can be divided into 25 guilds (see Figure A1). The first separation in the dendritic representation is based on size. An adult weight of 15 kg was selected as separating large mammals from small mammals.[22] The beaver (Castor canadensis) caused the most significant problem, since it borders the 15 kg dividing point. Foxes have been arbitrarily grouped with the other canids as large mammals to maintain simplicity in the system, and form another exception to the weight classification. Any other division point is thought to lead to similar or greater problems.

Other terms such as herbivorous, carnivorous, seed eating, grass eating, and insectivorous refer to the major or dominant feeding strategies of mammals. Omnivorous and opportunistic refer to mammals that characteristically use two or more of these strategies. The remainder of the terminology should be self-explanatory. It should be pointed out that this system of guilds is not meant to be definitive, as would be required for detailed ecological studies, but should be sufficient for environmental impact analyses. A second point is that the structure of

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15 R. B. Root, "The Niche Exploitation Pattern of the Blue-Gray Gnatcatcher," Ecol. Monogr., Vol 37 (1967), pp 317-350.

16 Root, 1967.

17 R. B. Root, "Organization of a Plant-Arthropod Association in Simple and Diverse Habitats: the Fauna of Collards (Brassica oleracea)," Ecol. Monogr., Vol 43 (1973), pp 95-124.

18 P. W. Price, "Niche Breadth and Dominance of Parasitic Insects Sharing the Same Host Species," Ecology, Vol 52 (1971), pp 587-596.

19 Root, 1967.

20 Root, 1973.

21 Price, 1971.

22 H. E. Balbach, "Detailed Attributes for Ecology," Environmental Impact Computer System Attribute Descriptor Package: Reference Document, Technical Report E-86/ADA024303 (U.S. Army Construction Engineering Research Laboratory, 1976), pp 1-37.

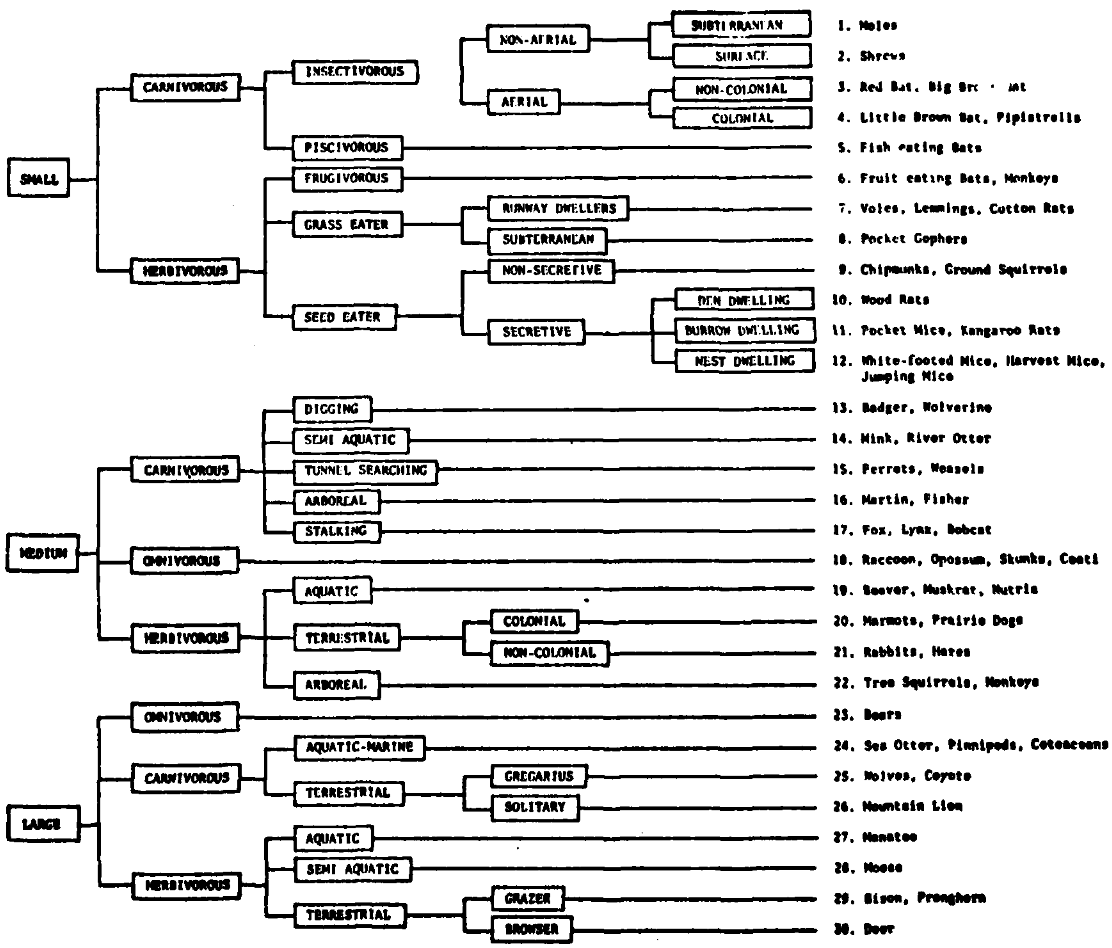

Figure A1. Guilds of nonmarine mammals.

this guild system is almost entirely subjective, and the descriptive terminology used to separate the guilds leaves an obvious amount of potential overlap.

The usefulness of guilds lies in the principle that if the members of a guild "exploit the same class of environmental resources in a similar way," then actions impacting one member of a guild should impact the other members of that guild similarly. For example, actions that impact most species of voles, lemmings, and cotton rats in the grasslands of the southwestern United States (members of what could be referred to as the small-herbivorous-grasseater-runway dweller guild [see Figure 3], should impact members of this guild in a similar manner in the grasslands of the central United States, even though the species composition of these two areas is very different). The ranges of the montane vole (Microtus montanus), meadow vole (M. pennsylvanicus), long-tailed vole (M. longicaudus), mexican vole (M. mexicanus), prairie vole (M. ochrogaster), hispid cotton rat (Sigmodon hispidus), and Arizona cotton rat (S. arizonae) include the grasslands of the southwestern United States.[23] The members of the same guild inhabiting the grasslands of the central United States are the meadow vole, prairie vole, pine vole (Microtus pinetorum), southern bog lemming (Synaptomys cooperi), and

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23 D. M. Armstrong, "Distribution of Mammals in Colorado," Monogr., No. 3 (Museum of Natural History, University of Kansas, Lawrence, 1972); R. H. Baker, "Nutritional Strategies of Myomorph Rodents in North America Grasslands," J. Mammal, Vol 52 (1971), pp 800-805; E. C. Birney, W. E. Grant, and D. D. Baird, "Importance of Vegetative Cover to Cycles of Microtus Populations," Ecology, Vol 57 (1976), pp 1043-1051; W. Conley, "Competition Between Microtus: A Behavioral Hypothesis," Ecology, Vol 57 (1976), pp 224-237; J. S. Findley, A. H. Harris, D. E. Wilson, and C. Jones, Mammals of New Mexico (University of New Mexico Press, Albuquerque, 1975); J. S. Findley and C. Jones, "Distribution and Variation of Voles of the Genus Microtus in New Mexico and Adjacent Areas," J. Mammal, Vol 43 (1962), pp 154-166; E. R. Hall and K. R. Kelson, The Mammals of North America (Ronald Press Company, 1959); J. Joule and G. N. Cameron, "Field Estimation of Demographic Parameters: Influences of Sigmodon hispidus Population Structure," J. Mammal, Vol 55 (1974), pp 309-318; R. A. Rowlett, "First Records of Eumops perotis and Microtus ochrogaster in New Mexico," J. Mammal, Vol 53 (1972), p 640; E. G. Zimmerman, "Karyology, Systematics, and Chromosomal Evolution in the Rodent Genus Sigmodon," Michigan State Univ., Publ. Mus., Biol. Ser., Vol 4 (1970), pp 389-454.

hispid cotton rat.[24] Similar examples could be given for other guilds of mammals, as well as for guilds within other groups of flora and fauna.

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24 R. H. Baker, "Nutritional Strategies of Myomorph Rodents in North America Grasslands," J. Mammal, Vol 52 (1971), pp 800-805; L. E. Beasley, and W. D. Severinghaus, "A Survey of the Cricetine Rodents of West Tennessee," J. Tenn. Acad. Sci., Vol 48 (1973), pp 106-111; E. C. Birney, W. E. Grant, and D. D. Baird, "Importance of Vegetative Cover to Cycles of Microtus Populations," Ecology, Vol 57 (1976), pp 1043-1051; J. B. Bowles, "Distribution and Biogeography of Mammals in Iowa," Vol 9, Spec. Publs (The Museum of Texas Tech Univ., Lubbock, 1975), pp 1-184; E. L. Cockrum, "Mammals of Kansas," Univ. Kansas Publs., Vol 71 (Museum of Natural History, 1952), pp 1-303; R. D. Crawford, "High Population Density of Microtus ochrogaster," J. Mammal, Vol 52 (1971), p 478; E. D. Fleharty, and J. R. Choate, "Bioenergetic Strategies of the Cotton Rat, Sigmodon hispidus," J. Mammal, Vol 54 (1973), pp 680-692; E. R. Hall, and K. R. Kelson, The Mammals of North America (Ronald Press Company, 1959); E. W. Jameson, Jr., "Natural History of the Prairie Vole (Mammalian Genus Microtus)," University of Kansas Publications, Vol 1 (Museum of Natural History, 1947), pp 125-151; J. K. Jones, Jr., "Distribution and Taxonomy of Mammals of Nebraska," University of Kansas Publications, Vol 16 (Museum of Natural History, 1964), pp 1-356; C. J. Krebs, "Competition Between Microtus pennsylvanicus and Microtus ochrogaster," Amer. Midl. Natur., Vol 97 (1977), pp 42-49; C. J. Krebs, B. L. Keller, and R. H. Tamarin, "Microtus Population Biology: Demographic Changes in Fluctuating Populations of M. ochrogaster and M. pennsylvanicus in Southern Indiana," Ecology, Vol 50 (1969), pp 587-607; E. P. Martin, "A Population Study of the Prairie Vole (Microtus ochrogaster) in Northeastern Kansas," University of Kansas Publications, Vol 8 (Museum of Natural History, 1956), pp 361-416; C. W. Schwartz, and E. R. Schwartz, The Wild Mammals of Missouri (Univ. Missouri Press, Columbia, and Missouri Conserv. Comm., 1959); W. D. Severinghaus, and L. E. Beasley, "A Survey of the Microtine and Zapodid Rodents of West Tennessee," J. Tenn. Acad. Sci., Vol 48 (1973), pp 129-133; J. O. Whitaker, Jr., "Habitat and Reproduction of Some of the Small Mammals of Vigo County, Indiana, with a List of Mammals Known to Occur There," Occas. Papers, C. C. Adams Cent. Ecol. Stud., Vol 16 (1967a), pp 1-24; J. O. Whitaker, Jr., "Habitat Relationship of Four Species of Mice in Vigo County, Indiana," Ecology, Vol 48 (1967b), pp 867-872; J. O. Whitaker, Jr., and E. G. Zimmerman "Microtus ochrogaster in Alabama and Tennessee," J. Mammal, Vol 49 (1968), p 328; K. Yang, C. J. Krebs, and B. L. Keller, "Sequential Live Trapping and Snap-Trapping Studies of Microtus Populations," J. Mammal, Vol 51 (1970), pp 517-526; E. G. Zimmerman, "A Comparison of Habitat and Food of Two Species of Microtus," J. Mammal, Vol 46 (1965), pp 605-612; E. G. Zimmerman, "Karyology, Systematics, and Chromosomal Evolution in the Rodent Genus Sigmodon," Michigan State Univ. Publ. Mus., Biol. Ser., Vol 4 (1970), pp 389-454.

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64 p. ; 27 cm. (Special report ; N-77)

1. Natural history -- KY. 2. Ft. Knox, KY. 3. Tanks (military science). 4. Man -- influence on nature. I. Riggins, Robert E. II. Goran, William D. III. Title. IV. Series: U.S. Army Construction Engineering Research Laboratory. *Special report ; N-77.*