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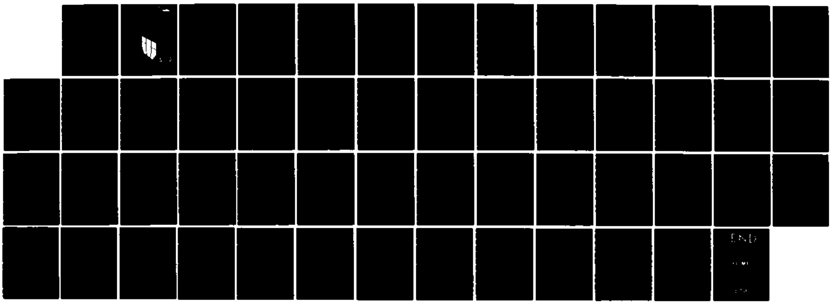

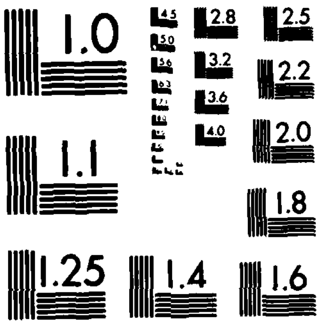

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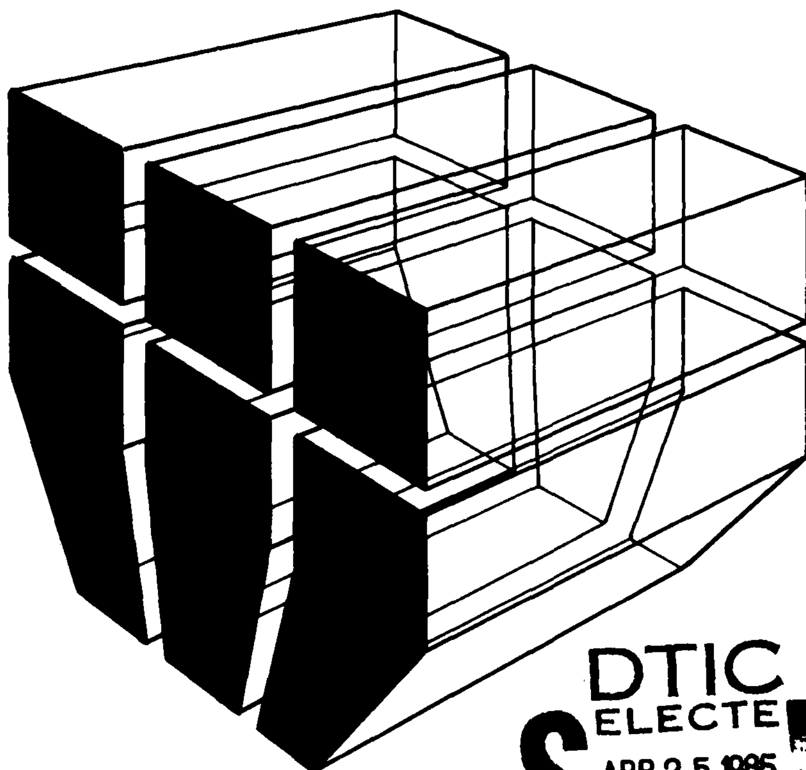
US Army Corps of Engineers
Construction Engineering Research Laboratory

TECHNICAL REPORT N-85/02
December 1984
Guild Based Training Area Maintenance

ECOLOGICAL BASELINE—PIÑON CANYON MANEUVER SITE, COLORADO

by
Victor E. Diersing
William D. Severinghaus



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A baseline ecological assessment was conducted on Piñon Canyon Army training maneuver site in south-central Colorado during May 1983. Ecological variation was quantified within and between two major habitats: pinyon-juniper woodland and shortgrass prairie. Extensive data were collected on soils (bulk density, texture, and soil strength), vegetation (diversity, abundance, density, and biomass), and birds and mammals (diversity, absolute and

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relative density, biomass, and guild structure). This report documents procedures used to obtain these data and summarizes the information obtained. This data base will serve as a source of information for evaluating impacts on these lands by tracked vehicle training which is scheduled to begin in 1985.

FOREWORD

This investigation was performed for the Office of the Assistant Chief of Engineers (ACE) by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (USA-CERL). The work was performed under Project 4A162720A896, "Environmental Quality Technology"; Task A, "Installation Environmental Management Strategy"; Work Unit 030, "Guild Based Training Area Maintenance." The ACE Technical Monitor was Mr. Donald Bandel, DAEN-ZCF-B.

The assistance of the following people is gratefully acknowledged: Joe Bourke, Tony Krzysik, and Larry Schmitt (USA-CERL) for field assistance; Edward Novak (USA-CERL) for technical guidance; Steven I. Apfelbaum, Karin A. Heiman, and John A. Prokes (Applied Ecological Services, Juda, WI) for collection and analysis of vegetation data; and Peter Smith (Camp, Dresser, and McKee, Inc., Denver, CO) for providing soils information. Edward W. Novak was the Environmental Resources Team Leader.

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

CONTENTS

TABLES

FIGURES

FIGURES (Cont'd)

ECOLOGICAL BASELINE--PIÑON CANYON MANEUVER SITE, COLORADO

1 INTRODUCTION

Background

Meeting defense needs is a primary national concern. To this end, one of the most important and necessary ingredients for the proper training of a standing army is the availability of enough land to conduct training exercises. Since land is a limited resource which is impacted by Army training, land managers and administrators must have scientifically sound information on the quality of Army lands. These data will serve as the basis for evaluating the various impacts. In addition, the law requires that "...consideration of environmental factors must be integrated into existing Army procedures..."[1] This report is one of several which document research conducted at various Army installations to establish cause and effect relationships between Army activities and the impacts they have on ecosystems.[2] Studies are being conducted which document the effects of tracked vehicle activity on the lands and biota of installations which represent four types of ecoregions: arid, semi-arid, temperate, and humid. The information will be useful to land use decision-makers who must assess these impacts and find ways of mitigating them.

Objective

The objective of this report is to quantify the physical and biological pre-training conditions of Piñon Canyon maneuver site in order to establish a data base for evaluating impacts caused by training activities scheduled to begin in 1985.

[1] R. K. Jain, L. V. Urban, and G. S. Stacey, Handbook for Environmental Impact Analysis, Technical Report E-59/ADA006241 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1974), p 13.

[2] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA073782 (USA-CERL, 1979), pp 1-64; W. D. Severinghaus and W. D. Goran, Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX, Technical Report N-113/ADA109646 (USA-CERL, 1981), pp 1-22; W. D. Severinghaus and W. D. Goran, Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Lewis, Washington, Technical Report N-116/ADA111201 (USA-CERL, 1981), pp 1-45; V. E. Diersing and W. D. Severinghaus, The Effects of Tactical Vehicle Training on the Lands of Fort Carson, Colorado--an Ecological Assessment, Technical Report N-85/03 (USA-CERL).

Approach

Extensive field surveys were conducted on four sites to determine the baseline physical and biological conditions. The survey results were analyzed and the information categorized according to site in order to define the magnitude and direction of changes that occur after training takes place.

Mode of Technology Transfer

It is recommended that the information obtained in this study be used to develop predictive algorithms and an information base and then incorporated into a computerized system for planning and maintenance of Army lands. Information on using this system will be transmitted to the field by a Technical Manual.

2 GENERAL SITE DESCRIPTION

Piñon Canyon Maneuver Site, which encompasses about 104,000 ha (Figure 1), is located entirely within Las Animas County in southeastern Colorado in the Raton Section of the High Plains Province.[3] Topographically, the parcel slopes gently to the southeast, culminating in the Purgatoire River (Arkansas River drainage), which serves as the parcel's eastern boundary. This slope is interrupted by mesas and deep canyons. Mean annual precipitation is about 33.5 cm, and the elevation varies from about 1311 to 1800 m. Historically, the parcel has been used for cattle grazing, but military training is expected to begin there in 1985.[4] Piñon Canyon contains two basic vegetation types: shortgrass prairie interspersed with varying densities of cholla and yucca and pinyon-juniper woodland.

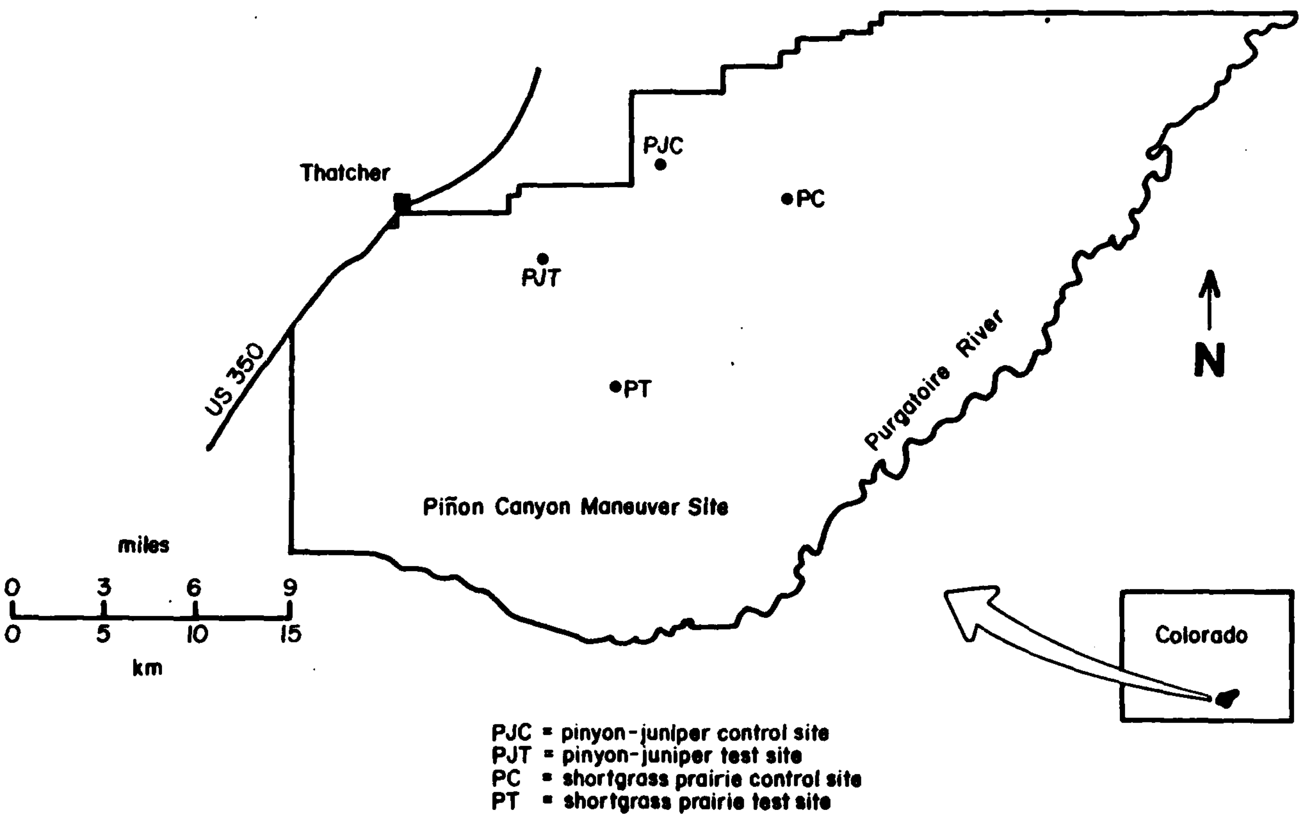

Figure 1. Piñon Canyon Maneuver Site, CO.

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[3] N. M. Fenneman, Physiography of Western United States (McGraw-Hill, 1931), pp 1-534.

[4] Draft Environmental Impact Statement for Acquisition of Training Land for Fort Carson, Colorado in Huerfano, Las Animas and Pueblo Counties, Colorado (Department of the Army, Fort Carson, 1980), pp 1-220.

Four sites were selected for quantitative analyses--two within each vegetation type. Within each vegetation type, one site (the test site) was located in an area having a high likelihood of being impacted because of its proximity to roads and the suitability of its terrain for training, and the other (the control site) was more removed, with little chance of being disturbed. Within each vegetation type the two sites were selected for vegetation and topographic similarity.

The prairie control site (PC) was located in Township 29S, Range 59W, Section 2 (Figure 1). The prairie test site (PT) was located in Township 30S, Range 59W, Section 1. Both sites are typical blue grama (*Bouteloua gracilis*) grassland and are gently sloping. Other than moderate cattle grazing, there were no obvious disturbances.

The pinyon-juniper woodland sites were each located on rocky, moderately sloping sites. The vegetation was a typical mixture of pinyon (*Pinus edulis*), juniper (*Juniperus monosperma*), and sideoats grama (*Bouteloua curtipendula*). The pinyon-juniper control site (PJC) was located in Township 28S, Range 59W, Section 36, and the pinyon-juniper test site (PJT) was located in Township 29S, Range 59W, Sections 20/21. A slight amount of grazing was evident within the pinyon-juniper sites. Two or three junipers had been cut for firewood in the control site many years ago.

3 METHODS FOR OBTAINING DATA

Pretraining physical and biological conditions at the Piñon Canyon Maneuver Site were quantified. Physical properties monitored included soil strength as it relates to trafficability. Biological parameters investigated included floral and faunal ecological assessments as they relate to ecosystem stability.

Soils

The baseline characterization of three soil parameters (soil strength, bulk density, and particle size distribution) at the four study sites involved the use of three different field methods: (1) soil penetration measurements at different soil moisture conditions, (2) bulk density sampling, and (3) sampling of surface horizons for particle size distribution analysis. All sampling was done from May 11 through 13, 1983.

Particle Size Investigations

Sampling investigations were done to provide data for comparing particle size distribution within and between prairie and pinyon-juniper areas, and to characterize the baseline conditions. Samples were collected from the surface horizon, labeled, and placed in plastic bags. The hydrometer method was used to determine the percent by weight of sand, silt, and clay.[5] Four samples were collected from each pinyon-juniper site, nine from the prairie test site, and 10 from the prairie control site.

Penetrometer Investigations

Forty evenly spaced penetrometer measurements were made at each prairie study site. More than 25 measurements were attempted at the PJC and PJT sites; however, due to the high content of coarse fragments in the soils, and particularly in the surface horizons, all readings were voided, and further measurements in these areas were not attempted. Penetrometer measurements were taken only in small, bare areas (20 to 200 mm in diameter) between the clumps of vegetation.

Soil moisture data were obtained by bulk density samples taken within 24 hours of the penetrometer measurements. After the penetration reading was obtained, it was multiplied by 0.0703 and divided by the area (in square inches) of the penetrometer tip to provide the penetration resistance in kilograms per square centimeter. The mean and the standard deviation of the penetration resistance were calculated to characterize the soil's strength.

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[5] E. J. Felt, "Physical and Mineralogical Properties, Including Statistics of Measurement and Sampling," Methods of Soil Analysis, Monograph 9 (American Society of Agronomy, 1965), pp 400-412.

Bulk Density Investigations

Eighteen bulk density samples (PT6, PC6, PJT2, PJC4) were obtained from eight soil pits (two per site) located in penetrometer measurement points. Using hand augering, the soil profiles were examined to a 1000-mm depth or to bedrock, whichever was encountered first. Generic soil horizons greater than 101.6 mm thick were sampled to depths of 600 mm where possible, using a ring sampler and the core method[6]. Because of the rock fragment content in some of the soil profiles, sampling did not proceed any deeper than the A horizon. Samples were labeled and stored in airtight plastic containers. Laboratory personnel determined the wet weight and oven-dry weight for each sample. From these data, the bulk density and percent moisture for each sample were calculated using the following formulas:

$$\text{Bulk Density} = \frac{\text{Oven-Dry Weight (g)}}{\text{Volume (cm}^3\text{)}}$$

where the volume of the ring sampler equals 288.98 cm^3.

$$\text{Soil Moisture (\%)} = \frac{\text{Wet Weight - Oven-Dry Weight}}{\text{Dry Weight}} \times 100$$

The mean and the standard deviation of the bulk densities in the prairie and pinyon-juniper areas were calculated for comparison.

Vegetation

Vegetation transects originated from the bird survey transects (see pp 13,14). Two parallel bird transects were established at each site; the prairie sites were separated by 250 m, and the pinyon-juniper sites were separated by 150 m. The two bird transects on each pinyon-juniper site were 400 m long and those on each prairie site were 1000 m long. Each vegetation study transect was 50 m long and originated from a designated point along the bird transects. On each prairie site, the vegetation transects originated at the points delineating 0, 200, 400, 600, 800 (or 1000) m on one bird transect, and from the odd-numbered points on the other bird transect (100, 300, 500, 700, and 900 m). Thus, 10 vegetation transects were established at each site. In the pinyon-juniper study sites, transects were staggered similarly, but were spaced closer together. On all four sites, each vegetation transect, was measured from the bird transects along randomly generated compass bearings.

In each of the four study areas, intercepts of woody vegetation greater than 20 mm in diameter or 1 m high were tallied, by species, along ten 2- x 50-m transects.[7] Species importance and tree and shrub density and frequency were then determined from this information. Herbaceous vegetation and all plants less than 1 m high were studied for plant cover in 1-m^2 quadrats placed

[6]E. J. Felt, pp 400-412.

[7]D. Mueller-Dombois, Aims and Methods of Vegetation Ecology (John Wiley and Sons, 1974), pp 1-547.

systematically along the 50-m study transects at 5-m intervals. Ten quadrats were studied along each 50-m transect, and 100 quadrats were sampled in each study site. Random number generation was used to determine which of the 10 quadrats in each transect would be evaluated for biomass. One quadrat was clipped to ground level. In the pinyon-juniper study sites, live and dead biomass were separated; in the prairie study sites, only graminoid and non-graminoid plants were separated from the sample quadrat. All biomass was clipped to a height of 2 m above the quadrats in order to estimate browse availability. Some nonbrowse plants (e.g., Pinus edulis) also occurred in the study quadrats and were clipped for a more complete estimate of the above-ground biomass. Biomass samples were air-dried for 1 week and weighed to the nearest gram on a spring scale.

Plant identifications follow Harrington.[8] Plant species lists were prepared for the early summer study period, and thus include spring plants and perennial species that might bloom later in the year, especially woody perennials that bloom in fall. Voucher specimens were collected and maintained in the USA-CERL Biological Inventory Collection.

The percent cover of study quadrats by bare ground, woody litter, and rock was measured to facilitate remote sensing programs for monitoring vegetation cover dynamics and the types and success of revegetation and reclamation.

Birds

Birds were surveyed using the combined transect methods of Emlen, Severinghaus, and Balph, Stoddart, and Balph.[9] Two parallel transects were established at each study site. On the prairie sites, these transects were each 1000 m long and separated from each other by 250 m. On the pinyon-juniper sites, the transects were each 400 m long and were separated by 150 m. Transects were established by compass bearing and identified by placing .9-m-high flags at 50-m intervals on the prairie sites and at 10-m intervals on the pinyon-juniper woodlands sites. Transects were walked slowly, starting at sunrise for 10 days. As each transect was walked, the location of each bird detected along each side of the transect was recorded. The absolute density (birds per unit area) of each species was estimated by calculating the distance from the transect to the area where detection of a species declines significantly. On each prairie site, the observable distance along each side of a transect was 50 m. This is a daily observable area of 2000 m by 100 m, or 20 ha. On each pinyon-juniper site, the observable distance along each side of a transect was 25 m. Therefore, 800 m by 50 m, or 4 ha of observable area was used.

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[8] H. D. Harrington, Manual of the Plants of Colorado (The Swallow Press, 1964), pp 1-666.

[9] J. T. Emlen, "Population Densities of Birds Derived from Transect Counts," Auk, Vol 88 (1971), pp 323-342; J. T. Emlen, "Estimating Breeding Bird Densities from Transect Counts," Auk, Vol 94 (1977), pp 455-468; W. D. Severinghaus, Guidelines for Terrestrial Ecosystem Survey, Technical Report N-89/ADA086526 (USA-CERL, 1980); M. H. Balph, L. C. Stoddart, and D. F. Balph, "A Simple Technique for Analyzing Bird Transect Counts," Auk, Vol 94 (1977), pp 606-607.

The bird fauna occupying the four study sites were compared, using measures of species diversity, density, biomass, and guild structure. Significant differences were identified by using Student's t-test of the means. The weights of both birds and mammals were calculated using information given by Amadon, Armstrong, Baldwin and Kendeigh, Behle, Esten, Graber and Graber, Norris and Johnson, and Poole.[10]

Mammals

Small mammals were surveyed using 100 snap traps per night (92 Museum Specials and eight rat traps) at each site over a 10-day period (1000 trap-nights per site). These surveys were conducted during the same 10-day period as the bird surveys. At each site, the 100 traps were set parallel or along the full length of the bird transects. On the prairie sites, the traps were placed at 10-pace (≈ 10-m) intervals and on the pinyon-juniper sites, they were placed at 4-pace (≈ 4-m) intervals. Each trap line was moved every 2 days in the following sequence: days 1 and 2, about 50 m outside one of the bird transects; days 3 and 4, about 50 m outside the other bird transect; days 5 and 6, midway between the two bird transects; days 7 and 8, along one bird transect; and days 9 and 10, along the other transect.

Traps were set and baited with a mixture of rolled oats and peanut butter each evening, and captures were removed each morning immediately after the morning bird counts. All mammals collected were placed in a plastic bag labeled with the date and place collected, frozen, prepared as scientific study specimens, and identified according to species.

Data collected included species diversity, total number collected per site, and actual capture numbers for each species by site. Chi-square tests were used to identify significant differences in the number of individuals of each species collected among the sites. The total biomass (in grams) of each guild was also compared among sites.

[10] D. Amadon, "Bird Weights and Egg Weights," Auk, Vol 60 (1943), pp 221-234; D. M. Armstrong, Distribution of Mammals in Colorado, Monograph No. 3 (Museum of Natural History, University of Kansas, 1972), pp 1-415; S. R. Baldwin and S. C. Kendeigh, "Variation in the Weight of Birds," Auk, Vol 55 (1938), pp 416-467; W. N. Behle, "Weights of Some Western Species of Horned Larks," Auk, Vol 60 (1943), pp 216-221; S. R. Esten, "Bird Weights of 52 Species of Birds (Taken from Notes of William Van Goider)," Auk, Vol 48 (1931), pp 572-574; R. R. Graber and J. W. Graber, "Weight Characteristics of Birds Killed in Nocturnal Migration," Wilson Bulletin, Vol 74, No. 1 (1962), pp 74-88; R. A. Norris and D. W. Johnson, "Weights and Weight Variations in Summer Birds from Georgia and South Carolina," Wilson Bulletin, Vol 70, No. 2 (1958), pp 114-129; E. L. Poole, "Weights and Wing Areas in North American Birds," Auk, Vol 55 (1938), pp 513-518.

4 RESULTS

Soils

Particle Size Distribution

On the pinyon-juniper study sites, the A horizon was sampled in eight different profiles: four times in the PJT site and four times in the PJC site. Both sites showed relatively undisturbed soil and vegetation. Generally, the textures were loam, except in two areas where they were clay. In most areas, there were sizable amounts of very fine sand (20 to 40 percent by weight) and relatively little fine and coarser sand (less than 15 percent). These soils generally had more than 34 percent silt and less than 25 percent clay. These surface textures are common in Penrose soils. Table 1 and Figure 2 present the particle size distribution data of all pinyon-juniper sampling locations.

Table 1

Particle Size Distribution in Surface Horizons of Pinyon-Juniper Study Sites

	Sand	Silt	Clay	Texture*	Depth (cm)
		Pinyon-Juniper Control Site			
	36	39	25	L	0-15
	37	43	20	L	0-13
	17	34	49	C	0-13
	23	37	40	C	0-10
Mean	28.2	38.2	33.5		
		Pinyon-Juniper Test Site			
	37	48	15	L	0-10
	48	33	19	L	0-10
	42	43	15	L	0-8
	46	41	13	L	0-8
Mean	43.2	41.2	15.5		

*L - loam, C - clay.

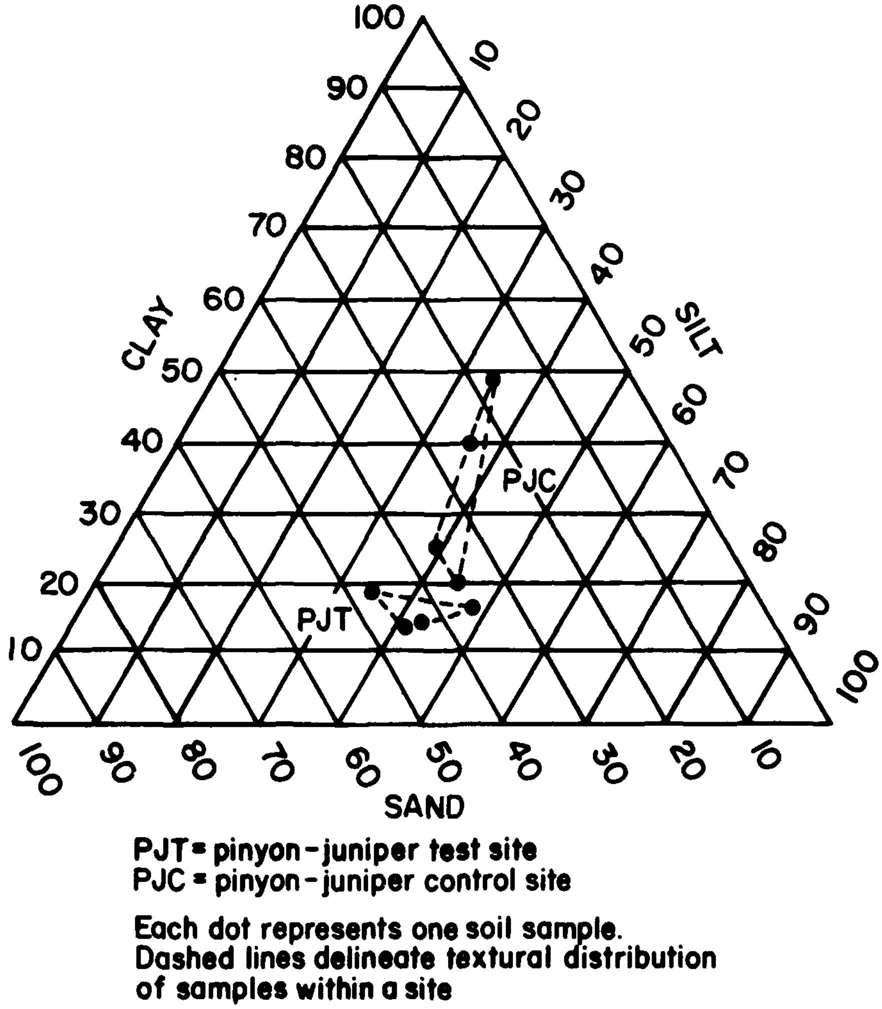


Figure 2. Soil particle size distribution of pinyon-juniper sites.

On the prairie study sites, the A horizon was sampled in 20 different locations: 10 at the PT site and 10 at the PC site. The soil was relatively undisturbed in these areas. The average texture at the PC site was a silty clay loam, and at the PT site the average texture was a loam. Table 2 and Figure 3 provide the particle size distribution data of all prairie sampling locations.

The surface horizon of the Fort Collins soils[11] at the PT site was either a sandy loam or a loam consisting of 16 to 26 percent clay, less than 14 percent fine and coarser sand, and 20 to 50 percent very fine sand. The Manzanola soils[12] at the PC site were generally heavy textured and consisted of silty clay, silty clay loam, clay loam, and silt loam. The clay percentage generally ranged from 25 to 40 percent. There was typically very little fine and coarser sand (less than 10 percent) and little very fine sand (less than 13 percent).

[11] Soil Conservation Service, Soil Survey of Las Animas County, Colorado (Soil Conservation Service, 1983).

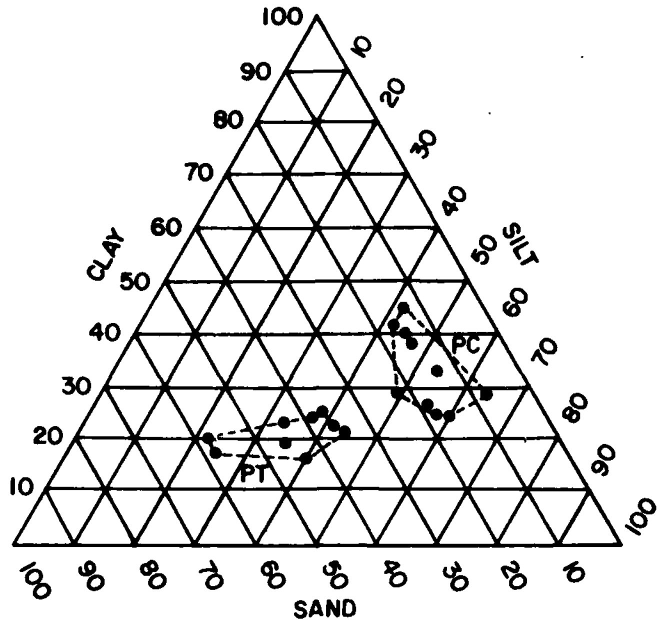
[12] Soil Survey of Las Animas County, Colorado.

Table 2

Particle Size Distribution in Surface Horizons of Prairie Study Sites

	Sand	Silt	Clay	Texture*	Depth (cm)
			Prairie Control Site		
	16	42	42	SIC	0-13
	8	63	29	SICL	0-10
	13	53	34	SICL	0-10
	16	45	39	SICL	0-10
	15	47	38	SICL	0-8
	19	57	24	SIL	0-10
	22	49	29	CL	0-10
	13	42	45	SIC	0-10
	18	59	23	SIL	0-10
	17	60	23	SIL	0-10
Mean	14.7	51.7	30.6		
			Prairie Test Site		
	37	38	25	L	0-20
	44	40	16	L	0-13
	59	23	18	SL	0-13
	59	22	19	SL	0-13
	43	34	23	L	0-13
	44	36	20	L	0-13
	34	45	21	L	0-13
	36	38	26	L	0-13
	34	45	21	L	0-13
Mean	42.1	36.9	21.0		

*SIC - silty clay; SICL - silty clay loam; SIL - silt loam; CL - clay loam; L - loam; SL - sandy loam.



PT = prairie test site
PC = prairie control site

Each dot represents one soil sample.
Dashed lines delineate the textural distribution of samples within a site

Figure 3. Soil particle size distribution of shortgrass prairie sites.

Penetrometer Readings

All readings of soils at the PJC and PJT sites were voided due to their high content of coarse rock fragments. However, on the prairie sites, 80 measurements were obtained: 40 in the PT site and 40 in the PC site (Table 3). The mean penetration resistance of the PC soils was 33.3 kg/cm^2, with a standard deviation of 8.92. The mean penetration resistance on the PT sites was 31.7 kg/cm^2, with a standard deviation of 11.2. These means are not significantly different at the 0.05 level. At the PT site, soil moisture percentages ranged from 13.0 to 17.4, and averaged 15.5, while at the PC site, soil moisture ranged from 13.5 to 22, and averaged 18.2.

The soils in the prairie study sites have been surveyed by the Soil Conservation Service. One soil association--Manzanola silty clay loam, with 1 to 4 percent slope--has been mapped in and adjacent to the PC site. Manzanola soils are deep, well drained, and formed in loess, alluvium, or residuum derived primarily from calcareous shale. The subsoil is typically a heavy, silty clay loam, heavy clay loam, or clay.

At the PT site, the soil is a Fort Collins sandy loam with 0 to 7 percent slope. Fort Collins sandy loam is a deep, well-drained soil, formed in eolian material and/or alluvium derived from mixed sedimentary bedrock. It typically has a light clay loam or loam subsoil, and a sandy loam or fine sandy loam surface layer.

Table 3

Penetrometer Data From Prairie Study Sites

Prairie Test (PT)			Prairie Control (PC)		
Area (sq in.)	Reading	Penetration Resistance (kg/cm^2)	Area (sq in.)	Reading	Penetration Resistance (kg/cm^2)
0.1	53	37.3	0.1	42	29.5
0.1	63	44.3	0.1	32	22.5
0.1	55	38.7	0.1	40	28.1
0.1	32	22.5	0.1	38	26.7
0.1	69	48.5	0.1	37	26.0
0.1	29	20.4	0.1	33	23.2
0.1	45	31.6	0.1	39	27.4
0.1	52	36.6	0.1	38	26.7
0.1	27	19.0	0.1	48	33.7
0.1	22	15.5	0.1	53	37.3
0.1	45	31.6	0.1	83	58.3
0.1	52	36.6	0.1	54	38.0
0.1	39	27.4	0.1	44	30.9
0.1	51	35.8	0.1	49	34.4
0.1	39	27.4	0.1	41	28.8
0.1	48	33.7	0.1	64	45.0
0.1	59	41.5	0.1	46	32.3
0.1	64	45.0	0.1	52	36.6
0.1	34	23.9	0.1	75	52.7
0.1	83	58.3	0.1	62	43.6
0.1	49	34.4	0.1	62	43.6
0.1	48	33.7	0.1	50	35.2
0.1	46	32.3	0.1	61	42.9
0.1	30	21.1	0.1	37	26.0
0.1	45	31.6	0.1	45	31.6
0.1	15	10.5	0.1	27	19.0
0.1	28	19.7	0.1	43	30.2
0.1	28	19.7	0.1	55	38.7
0.1	23	16.2	0.1	52	36.6
0.1	72	50.6	0.1	44	30.9
0.1	30	21.1	0.1	20	14.1
0.1	26	18.3	0.1	54	38.0
0.1	58	40.8	0.1	35	24.6
0.1	45	31.6	0.1	32	22.5
0.1	79	55.5	0.1	61	42.9
0.1	45	31.6	0.1	63	44.3
0.1	41	28.8	0.1	47	33.0
0.1	51	35.8	0.1	51	35.8
0.1	53	37.3	0.1	41	28.8
0.1	29	20.4	0.1	44	30.9
Number of Samples:		40			40
Mean:		33.3			31.7
Standard Deviation:		8.82			11.20

Bulk Density

Four soil profiles were sampled for bulk density analysis on the pinyon-juniper study sites: two in the PJC site and two in the PJT site. Since coarse fragments predominated in the PJT profiles, only the A horizon of each profile was sampled (Table 4). The soil profiles observed in the PCT site are borderline between the Penrose and Sunup series. The coarse fragment content was estimated as ranging between 30 to 40 percent by volume. Since 35 percent by volume is the separation point between Penrose and Sunup soils, it is likely that both soils are intermixed at the PJT site. These soil series were also observed in the PJC site.

The mean bulk density of the two samples collected at the PJT site was 1.50 g/cm^3. The mean bulk density of the four samples collected for the two PJC profiles was 1.18 g/cm^3. The overall bulk density mean of the six samples collected at the pinyon-juniper sites was 1.28 g/cm^3. In the PJT samples, a large number of coarse fragments was observed when the soil material was removed from the ring sampler and deposited in the airtight plastic container.

Table 4

Bulk Density and Soil Profiles of Pinyon-Juniper Study Sites

Site*	Soil Horizon	Depth (cm)	Bulk Density (g/cm^3)	Bulk Soil Series
PJT	A	0-10	1.34**	Penrose or Sunup
PJT	A	0-8	1.65**	Penrose or Sunup
PJC	A	0-15	1.02	Penrose
	C	15-51	1.23	Penrose
PJC	A	0-13	1.23	Penrose or Sunup
	C	13-36	1.22	Penrose or Sunup
	Number of Samples		6	
	Mean		1.28	

*PJT = Pinyon-Juniper Test
PJC = Pinyon-Juniper Control
**Samples contained more than 15 percent by volume of coarse fragments, which tends to bias the sample.

In the prairie sites, four soil profiles consisting of three horizons each were sampled to 600 mm for bulk density analysis: two at the PC site and two at the PT site. Six samples were collected in the PC site, and the soil profile observed was Manzanola; the mean of the measurements was 1.38 g/cm^3. The average bulk density for the two A horizons sampled was 1.38 g/cm^3, and the average bulk density for the B horizons was 1.45 g/cm^3. Six samples were collected in the PT study site; the overall mean bulk density of all samples was 1.46 g/cm^3. The average bulk density was 1.35 g/cm^3 for the A horizons and 1.42 g/cm^3 for the B horizons. The mean bulk density for the B_k horizons was 1.59 g/cm^3. The soil profile observed in these two pits was the Fort Collins type. Table 5 provides bulk density data and soil series observed in the PC and PT profiles.

Vegetation

Woody Vegetation

Both the prairie control and test sites had no measurable woody vegetation. Based on density (Table 6), Pinus edulis dominated the pinyon-juniper control site, with 770 individuals recorded per hectare compared to 420 individuals in the PJT site. Densities at both sites (pinyon and juniper) were fewer than 1500 trees per hectare and varied between about 1000 to 1400. Dividing the number of trees and shrubs per 1000 m^2 by 10 provided the average number of trees in each study transect and showed that 10 to 14 trees of all species were intercepted in any one transect. Density measurements also accounted for the presence of Rhus trilobata on the test site.

Plant Production

Plant production studies (Table 7) suggested that the prairie control and test sites had mean dry-weight biomasses of 92 to 130 g/m^2 compared to samples from pinyon-juniper study sites (Table 8), which had values ranging from 29 to 39 g/m^2. Quadrat values ranged from 0 to 95 g/m^2 in the pinyon-juniper study sites and up to 330 g/m^2 in the prairie study sites. On the average, the prairie communities were at least twice as productive as the pinyon-juniper sites during this early summer sample period. Production was highly variable in all study sites, but especially so in the pinyon-juniper study areas. At the pinyon-juniper sites, quadrats with no biomass (rock pavements, washes) were contrasted with those in which Pinus edulis biomass was as high as 1375 g/m^2. Based on mean total plant production values, pinyon-juniper study areas were comparable. The prairie control site had a higher mean total biomass than the prairie test site.

Quadrat Sampling

Ground cover and substrate cover types (Table 9) were analyzed for organic litter (needles and grasses), wood litter, bare soil, rock, and live vegetative ground cover. On the prairie sites, ground cover consisted largely of bare soil (56 percent--PT, 74 percent--PC) and live vegetation (44 percent--PT, 26 percent--PC). On the pinyon-juniper sites, percent bare ground was low (26 percent--PJC, 27 percent--PJT), with rock, wood litter, and organic litter combined making up about 60 percent of the ground cover on each site. Live vegetation ground cover was low--15 percent at PJC and 13 percent at PJT.

Table 5

Bulk Density and Soil Profiles of Prairie Study Sites

Prairie Control (PC)

Soil Horizon	Depth (cm)	Bulk Density (g/cm^3)	Bulk Soil Series
A	0-13	1.42	Manzanola
B_1	13-30	1.22	
Bt	30-60	1.43	
A	0-10	1.33	Manzanola
Bt_1	10-41	1.40	
Bt_2	41-60	1.51	
Number of Samples		6	
Mean		1.38	

Prairie Test (PT)

Soil Horizon	Depth (cm)	Bulk Density (g/cm^3)	Bulk Soil Series
A	0-20	1.36	Fort Collins
Bt	20-48	1.45	
Bk	48-60	1.54	
A	0-13	1.34	Fort Collins
Bt	13-41	1.39	
Bk	41-60	1.65	
Number of Samples		6	
Mean		1.46	

Table 6

Density for Woody Species in Pinyon-Juniper Study Sites
(Each column represents the number of each species intercepted along a 2- x 50-m random transect--a total of 10 per site.)

Pinyon-Juniper Test Site

											Totals No./1000 m^2	Totals No./10,000 m^2
Pinus edulis	10	5	5	1	1	4	5	4		7	42	420
Juniperus monosperma	4	4	11	4	5	10	11	3	5	3	60	600
Rhus trilobata	1	-	-	-	-	-	-	1			2	20
Totals											104	1040

Pinyon-Juniper Control Site

											Totals No./1000 m^2	Totals No./10,000 m^2
Pinus edulis	9	8	5	9	13	13	14	1		5	77	770
Juniperus monosperma	7	8	6	8	8	7	9	6	2	4	67	670
Totals											144	1440

Table 7

Plant Production (g/m^2) From Prairie Study Sites

Prairie Control Site			Prairie Test Site		
Herb	Grass	Total	Herb	Grass	Total
20.0	90.0	110.0	45.0	75.0	120.0
85.0	130.0	215.0	40.0	107.0	147.0
15.0	40.0	55.0	93.0	75.0	168.0
0.	75.0	75.0	0.	0.	0.
40.0	58.0	98.0	65.0	70.0	135.0
40.0	40.0	80.0	0.	85.0	85.0
0.	70.0	70.0	20.0	60.0	80.0
210.0	120.0	330.0	0.	70.0	70.0
0.	40.0	40.0	0.	55.0	55.0
40.0	190.0	230.0	0.	60.0	60.0
45 ± 63.7*	85 ± 48.8	130 ± 95	26.3 ± 33.3	65.7 ± 27.5	92 ± 50.5

*Mean plus or minus one standard deviation

Table 8

Plant Production (g/m^2) From Pinyon-Juniper Study Sites

Pinyon-Juniper Control Site			Pinyon-Juniper Test Site		
Herb	Grass	Total	Herb	Grass	Total
0.	35.0	35.0	(1345.0)* 15.0	15.0	(1375.0)* 30.0
0.	0.	0.	20.0	70.0	90.0
0.	50.0	50.0	0.	0.	0.
0.	60.0	60.0	30.0	55.0	85.0
(35.0)*	0.	(35.0)*	15.0	50.0	65.0
0.	30.0	30.0	0.	25.0	25.0
50.0	35.0	85.0	0.	0.	0.
60.0	35.0	95.0	0.	0.	0.
0.	40.0	40.0	0.	0.	0.
0.	0.	0.	0.	0.	0.
11.0 ± 27.3	28.5 ± 21.5	39.5 ± 34.1	8.0 ± 11.1	21.5 ± 27.2	29.5 ± 37.1

*This value is for trees or cacti also sampled in biomass clips; data have not been included in calculations.

Table 9

Summary of Ground Cover and Substrate Cover Types on All Study Sites (Data presented [mean ± 1 standard deviation] are based on one hundred 1-m^2 quadrat samples in each study site.)

	PJC	PJT	PC	PT
Organic litter (needles and grasses)	23.2 ± 11.2	23.2 ± 11.4	--	0.1 ± 0.2
Wood litter	7.5 ± 5.7	9.4 ± 7.2	--	0.4 ± 0.6
Bare soil	26.1 ± 20.8	26.6 ± 8.9	73.5 ± 11.3	55.6 ± 20.1
Rock	29.1 ± 23.9	27.9 ± 21.8	--	--
Live vegetative ground cover	≃ 15%	≃ 13%	≃ 26%	≃ 44%

Table 10 gives plant cover and frequency determinations for plants less than 1 m tall. Historic soil disturbances, particularly on the prairie sites, are suggested by the proliferation of plants that use disturbed habitat. These include plants such as Russian thistle (Salsola kali), sunflower, (Helianthus annuus), and cactus (Opuntia--several species). Some species showed limited distributions, such as in the pinyon-juniper habitat (e.g., sideoats grama grass, Bouteloua curtipendula). Based on cover and frequency, blue grama grass (Bouteloua gracilis) was the dominant plant in all study areas. The Piñon Canyon pinyon-juniper sites were dominated by pinyon and juniper with an understory of sideoats grama grass, and were located on rocky, exposed, low-relief ridges. Scattered wild flowers, such as beard tongue (Penstemon sp.), borage (Cryptantha sp.) and snakeweed, (Gutierrezia sp.) were found throughout the study areas.

Birds

Prairie Sites

The bird faunas of the two prairie sites were remarkably similar (Table 11). All species observed (N = 7)* were found on both sites, except the mourning dove, which was seen only on the PT site. However, the horned lark was significantly more common ($p < .001$)** on the PC site than on the PT

*N = number.
**p = probability.

Table 10

Summary of All Plants Less than 1 m in Height on All Study Sites (Relative (%) cover and frequency for all plants less than 1 m tall sampled in one hundred 1-m^2 circular quadrats are given.)

Species	PJC		PJT		PC		PT	
	%C	%F	%C	%F	%C	%F	%C	%F
Abronia fragrans			.15	.70				
Agropyron sp.	.40	1.11	.20	.40	13.55	9.80	1.60	1.20
Andropogon scoparius	.70	.60	.50	.55				
Aristida longiseta	3.90	5.60	4.94	6.97			.10	.20
Artemisia tridentata			.12	.20				
Asclepias subverticillata					.10	.40		
Aster arenosus							.10	.50
Astragalus sp.	.20	.20	.75	2.50	.05	.40	.10	.60
Astragalus missouriensis	.10	.50						
Atriplex spp.					.05	.50		
Bouteloua curtipendula	22.70	15.50	19.50	9.90				
Bouteloua gracilis	12.80	5.30	23.69	11.50	31.60	14.40	28.00	12.30
Castelleja sessiflora	.05	.10						
Chenopodium album	.70	4.60	1.03	6.31	.30	1.40	.05	.10
Cirsium undulatum	.05	.10						
Cryrtantha anesii			.20	.80				
Cymopterus acaulis					.05	.20		

Table 10 (cont'd)

Species	PJC		PJT		PC		PT	
	%C	%F	%C	%F	%C	%F	%C	%F
Cymopterus montanus	.25	1.30			.90	4.10	.20	1.0
Descurianna pinnata	.95	5.30	1.20	6.00	1.40	4.70	.38	1.00
Draba sp.	.35	2.00						
Echinocerus viridiflorus	.05	.10					.05	.20
Erigeron canadensis	.40	2.50						
Erysimium asperum					.40	.70		
Eurotia lanata					.30	.90	.20	.30
Eriogonum sp.							.30	.80
Festuca sp.					.05	.20		
Gaura coccinea	.10	.40	.14	.60	.30	.70		
Gayophyton sp.					.20	.30	.30	.70
Gilia aggregata	.05	.10					.05	.10
Gutierrezia sarothrae	1.55	5.00	6.68	12.89	.65	1.40		
Happlopappus spinulosa			.05	.20			1.35	1.90
Helianthus annuus	.35	2.80	.57	4.0	.70	4.90	.60	2.30
Helitropium sp.	P		P		P		.25	.90
Hilaria jamesii	P		P		.85	3.70	.15	.70
Juniperus monosperma	14.95	4.60	15.15	3.27				
Lappula redowski	.30	2.20	.31	1.90	2.30	20.30	1.25	4.20
Lathyrus sp.	P		.20	.54	2.50	3.10	P	

Table 10 (Cont'd)

Species	PJC		PJT		PC		PT	
	%C	%F	%C	%F	%C	%F	%C	%F
Lesquerella fendleri	.25	.90	.15	.60				
Leucocrinum montanum	.10	.20	P	.05	.20	P		
Linum lewisii					2.80	4.20	.05	.20
Lithospermum incisum	.15	.90					.05	.10
Lupinus kingii							.45	.50
Lyncium pallidum	P		P		.05	.10	P	
Marrubium vulgare L.			.10	.20	P		P	
Mentzelis spp.	P		P		P		.05	.10
Muhlenbergia montana	P		1.20	.80	P		P	
Muhlenbergia torreyi	.10	.60	P		5.35	3.10	1.15	1.50
Nostoc	.10	.30			P		.10	1.0
Oenothera albicaulis					.05	.10	.10	.20
Opuntia polycantha	.35	1.0	.10	.60	3.30	7.20	1.20	.60
Oryzopsis hymenoides	1.00	3.0	2.26	5.74	P		.10	.20
Penstemon angustifolius			.10	.20			.10	.20
Petalostemum sp.	.25	1.30	.10	.40				
Phlox spp.	.15	.50	.06	.27	.15	.50	P	
Physalis lobata					.10	.20	P	
Pinus edulis	7.00	2.10	6.25	1.91				

Table 10 (Cont'd)

Species	PJC		PJT		PC		PT	
	%C	%F	%C	%F	%C	%F	%C	%F
Plantago purshii			.05	.20	.10	.40	.25	.40
Polygonum sp.	P				P		.05	.20
Rhus trilobata	.30	.20	.60	.27				
Salsola kali	P		.25	1.00	P		.40	2.10
Schedonnardus paniculatus					.05	.10	P	
Senecio mutablis					.05	.10	P	
Silene acaulis	.45	2.00						
Sitanion hystrix			.14	.70	1.95	5.00	.65	1.80
Solanum spp.	P		P		.15	1.00	P	
Sonchus sp.	.05	.20			P		P	
Sphaeraclea coccinea	.15	.60	.14	.40	3.70	6.90	1.10	2.20
Taraxacum officinale	P		.05	.30	P		P	
Tridens pilosus	.40	1.90	.65	1.80	P		P	
Unknown canascent alt. lf. shrub			.15	.40			.20	.40
Unknown compositae	.10	.70	.42	1.20	P		.10	.20
Unknown cruciferae			.20	.40				
Unknown grass	.10	.60	.10	.40	.05	.20	.10	.30

Table 10 (Cont'd)

Species	PJC		PJT		PC		PT	
	%C	%F	%C	%F	%C	%F	%C	%F
Unknown palmate if. herb	.35	1.60	.60	2.01	.25	.40	.60	2.10
Unknown seedlings	.55	2.50	.46	2.94	.65	1.80	.20	.70
Verbena ambrosifolia					2.65	4.00	.15	.40
Viola nuttallii					P		.20	.50
Yucca spp.					P		.40	.20

Table 11

Avian Species--Densities and Biomass on Prairie Sites

Species List	Test		Control		Guild**
	No./100 ha	g/100 ha	No./100 ha	g/100 ha	
Test and Control					
Western kingbird	1	36	1	36	12
Horned lark*	56	1512	116	3132	1a
Western meadowlark	9	990	6	660	28
Lark bunting	4	104	4	104	1b
Lark sparrow	3	84	1	28	1b
Brewer's sparrow*	1	13	8	104	1b
Sparrow (unknown kind)	1	13	1	13	1b
Test Only					
Mourning dove	1	132		___	8
		2884 g		4077 g	

*Statistically significant at the p = 0.05 level or above.
**For an explanation of guilding numbers, see p 32 of text.

site. Brewer's sparrow was also significantly more common ($p < .005$) on the PC site than on the PT site. However, this difference was due to a small stand (estimated at about 100 m^2) of greasewood (Sarcobatus vermiculatus) in the PC site where several of these sparrows were seen each day.

The horned lark was by far the most common species on each site, representing 74 percent of the total individuals seen on the PT site and 85 percent on the PC site. The meadowlark was the second most common (excluding Brewer's sparrow on the PC site), representing 12 percent of the total numbers on the PT site and 4 percent on the PC site. Together, the horned lark and meadowlark comprised 86 percent (PT) and 89 percent (PC) of the total bird fauna. The lark bunting, western kingbird, lark sparrow, Brewer's sparrow, and mourning dove made up the remainder of the bird fauna on the two sites. The presence of the lark bunting seemed to depend on the availability of cholla cactus (Opuntia arborescens) for nest sites. The western kingbird was not a resident of the prairie, but was only transient. The lark sparrow and the Brewer's sparrow probably nest in the area using cholla, greasewood, and other "shrubby" species as nest sites.

Total bird biomass was much lower on the PT site (2884 g per 100 ha) than on the PC site (4077 g per 100 ha). Almost all of this difference was due to the greater biomass (actual and relative) of horned larks on the PC site (3132 g) than on the PT site (1512 g). Biomass of the other species was closely comparable. However, the relative biomass of meadowlarks on the PT site was markedly higher (34 percent of the total) than on the PC site (16 percent).

The bird data collected at Piñon Canyon were applied to guild theory, which assumes that species belonging to the same guild use resources similarly.[13] Table 12 illustrates that five guilds were found on the PT site and four on the PC site. All guilds, except guild 8, which contains the mourning doves, were common to both sites. Guild 1a, containing the horned lark (a seed-eating, bare ground species), was the dominant guild on both sites. Guild 28, which contains the omnivorous, open field meadowlark, was the second most dominant guild. These two guilds made up 86 percent of the total biomass of birds on the PT site and 93 percent on the PC site. The two remaining guilds--1b and 12--comprised the majority of the species present, but only 88 percent (PT) and 7 percent (PC) of the total biomass. Besides the western kingbird (guild 12), species present were lark bunting, lark sparrow, and Brewer's sparrow (guild 16). These latter three species are seed-eaters and prefer open prairies with scattered half-shrubs and small shrubs.

Pinyon-Juniper Sites

A maximum of 25 species of birds were seen on the two sites (Table 13); of these, 11 species were common to both sites, 11 were unique to the PJT site, and three were unique to the PJC site. On a percentage basis, 87 percent of the total individuals seen were common to both sites. Of the 11 species common to both sites, only the number of ash-throated flycatchers was significantly different between the two sites, being more common ($p < .02$) on

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[13] W. D. Severinghaus, "Guild Theory Development as a Mechanism for Assessing Environmental Impact," Journal of Environmental Management, Vol 5, No. 3 (1981), pp 187-190.

Table 12

Bird Guilds of the Prairie Sites

	Primary Guild Characteristics	Biomass Test	Biomass Control	Frequency (%)* Test	Frequency (%)* Control	Frequency** Difference
1a	Seedeating, bare ground	1512	3132	52	77	25+
1b	Seedeating, open field	214	249	7	6	1
8	Mast/grain, small, brush/field	132	0	5	0	5
12	Insectivorous, sallying, open	36	36	1	1	0
28	Omnivorous, open field	990	660	34	16	18+

*Frequency: The biomass of each guild is expressed as a percent of the total biomass for each site.
**Frequency difference: Within a guild, the difference in frequency between sites.
+Major differences within a guild between sites.

the PJT site. The most common or characteristic species on both sites were the ash-throated flycatcher, pinyon jay, Bewick's wren, and lark sparrow. Together, these four species made up 72 percent and 73 percent, respectively, of the total number of individuals seen on the PJT and PJC sites. Uncommon species (again referring to those species observed on both sites) included the mourning dove, mountain bluebird, and brown-headed cowbird. Relatively rare species included broad-tailed hummingbird, western kingbird, rufous-sided towhee, and chipping sparrow.

Of those species limited to the PJT site, none was abundant; only one was uncommon (plain titmouse), and the remainder were relatively rare. Within this latter group, the majority were noted in only one sighting and included the northern flicker, green-tailed towhee, yellow-rumped warbler, loggerhead shrike, and an unidentified small woodpecker and hummingbird. The three species seen only on the PJC site (scrub jay, Swainson's thrush, and Brewer's blackbird) were all relatively rare.

Total bird biomass was much higher on the PJC site (7038 g) than on the PJT site (5887 g); however, most of this increase was due to the greater number of pinyon jays seen on the PJC site. Pinyon jays made up 20 percent of the total biomass on the PJT site and 53 percent on the PJC site. Excluding the pinyon jay, the ash-throated flycatcher, mourning dove, and lark sparrow contributed 41 percent of the total bird biomass on the PJT site and 30 percent on the PJC site.

Fifteen guilds were present on the pinyon-juniper sites (Table 14). Nine of these guilds were present on both sites, five were limited to the PJT site, and one was unique to the PJC site. Of the six guilds recorded from only one site, four were incidental, being represented by a single individual (Brewer's blackbird, PJC, guild 28; unidentified small woodpecker, PJT, guild 26; loggerhead shrike, PJT, guild 32; northern flicker, PJT, guild 29). The other two guilds unique to the PJT site were the plain titmouse (guild 5) and northern mockingbird (guild 31). These two species were represented on the PJT site by what appeared to be single breeding pairs.

Table 13

Avian Species--Densities and Biomass on Pinyon-Juniper Sites

Species List	Test No./100 ha	Test g/100 ha	Control No./100 ha	Control g/100 ha	Guild
Test and Control					
Mourning dove	5	660	10	1320	8
Broad-tailed hummingbird	1	5	1	5	6
Western kingbird	6	216	1	36	12
Ash-throated flycatcher*	31	899	14	406	13
Pinyon jay	14	1190	44	3740	30
Bewick's wren	29	232	18	144	15
Mountain bluebird	8	288	6	216	12
Brown-headed cowbird	9	396	6	264	30
Rufous-sided towhee	1	39	4	156	3
Lark sparrow	30	840	14	392	1b
Chipping sparrow	10	130	1	13	1b
Test Only					
Hummingbird (unknown kind)	1	5			6
Northern flicker	1	132			29
Woodpecker (small, unknown kind)	1	75			26
Empidonax sp.	4	40			13
Western wood-pewee	5	60			13
Plain titmouse	9	189			5
Northern mockingbird	6	294			31
Hermit thrush	3	102			27
Loggerhead shrike	1	48			32
Yellow-rumped warbler	1	9			13
Green-tailed towhee	1	38			3
Control Only					
Scrub jay			3	255	30
Swainson's thrush			1	33	27
Brewer's blackbird			1	58	28
		5887 g		7038 g	

*Statistically significant at the p = 0.05 level or above.

Table 14

Bird Guilds of Pinyon-Juniper Sites

	Primary Guild Characteristics	Biomass Test	Biomass Control	Frequency (%)* Test	Frequency (%)* Control	Frequency** Difference
1b	Seedeating, open field	970	405	16	6	10+
3	Seedeating, edge	77	156	1	2	1
5	Fruit/seed, woods edge	189	-	3	0	3
6	Nectar	10	5	-	-	0
8	Mast/grain, small, brush/field	660	1320	11	19	8+
12	Insectivorous, sallying, open	504	252	9	4	5
13	Insectivorous, sallying, woodland	1008	406	17	6	11+
15	Insectivorous, gleaner, small	232	144	4	2	2
26	Invertebrate, woodworker	75	-	1	-	1
27	Omnivorous, woods/brush	102	33	2	-	2
28	Omnivorous, open field	-	58	-	1	1
29	Omnivorous, mixed, ground	132	-	2	-	2
30	Omnivorous, mixed, non-ground	1586	4259	27	61	34+
31	Omnivorous, disturbed sites	294	-	5	-	5
32	Carnivorous, open areas	48	-	1	-	1

*Frequency: The biomass of each guild expressed as a percent of the total biomass for each site.
**Frequency difference: Within a guild, the difference in frequency between sites.
+Major differences within a guild between sites.

Of those (N = 9) guilds common to both sites, guild 30 was dominant (based on total biomass). This guild contains the omnivorous, large seed-eating jays (scrub and pinyon) and the brown-headed cowbird. Guild 30 made up 34 percent of the total bird fauna. The second most dominant guild was guild 13, which contains the insectivorous ash-throated flycatcher, the wood-pewee, the yellow-rumped warbler, and the Empidonax flycatcher. The third most dominant guild (guild 16), which contains the seed-eating, open-field lark and the chipping sparrows, made up 10 percent of the total bird fauna. Guild 8, containing the seed-eating mourning dove, made up 8 percent of the total bird fauna.

Mammals

Prairie Sites

Seven species were collected on the PT site, and six were taken on the PC site (Table 15). On both sites combined, a total of eight species were found. Five were common to both sides: the kangaroo rat, Dipodomys ordii; the pocket mouse, Perognathus flavus; the plains harvest mouse, Reithrodontomys megalotis; the grasshopper mouse, Onychomys leucogaster; and

Table 15

Mammal Capture Data

Species (scientific name)	Pinyon-Juniper Captures Test	Pinyon-Juniper Captures Control		Prairie Captures Test		Prairie Captures Control
Dipodomys ordii (65)*	1	2	<.01*	28	<.005**	1
Perognathus flavus (7)	4	4		9		14
Reithrodontomys megalotis (12)	3	2		4		-
Reithrodontomys montanus (11)	-	-		8		1
Onychomys leucogaster (35)	1	-		10		1
Peromyscus leucopus (29)	3	2		3		-
Peromyscus maniculatus (19)	29	19	<.001*	7		5
Peromyscus truei (26)	21	16	<.001*	-		2
Neotoma albigula (219)	6	5		-		-
Total individuals/site	68	50		69		23

*Average weight in grams of each species.
**Statistically significant differences (0.05 level and above).

the deer mouse, Peromyscus maniculatus. The white-footed mouse (Peromyscus leucopus) and the western harvest mouse (Reithrodontomys megalotis) were collected on the PT site, and the pinyon mouse (Peromyscus truei) was collected only on the PC site. The pinyon mouse is typically a resident of pinyon-juniper woodlands; apparently, the two individuals collected in the open prairie (PC site) were dispersals from a nearby (about 500 m) stand of pinyon-juniper. Significantly, more kangaroo rats ($p < .005$) were taken on the PT site (N = 28) than on the PC site (N = 1). In addition, the total number of individuals for all species combined was much higher on the PT site (N = 69) than on the PC site (N = 23). The kangaroo rat was the most common species on the PT site, comprising 41 percent of the total individuals collected. The pocket mouse was the most common species (N = 14) on the PT site, representing 61 percent of the total catch.

Pinyon-Juniper Sites

Eight species were collected on the PJT site, and seven were taken on the PJC site (Table 15). On both sites combined, eight species were found; all were common to both sites except the grasshopper mouse, which was limited to the PJT site (one individual). There were no significant differences in the number of each species collected on the two sites. The total number of individuals collected on each site was also similar, with 68 taken on the PJT site and 50 on the PJC site. The two most common species on both sites were the deer mouse (N = 29 on the PJT site and N = 19 on the PJC site) and the pinyon mouse (N = 21 on the PJT site and N = 16 on the PJC site). These two species made up 74 percent of the total catch on the PJT site and 70 percent on the PJC site.

A few diurnal and fossorial mammals were also collected on or near the four study sites; several of these are important additions to our knowledge on the distribution of small mammals.[14] The chestnut-faced pocket gopher (Pappogeomys castanops) was common throughout much of the installation (prairies and pinyon-juniper woodlands). Dirt mounds from gopher digging were noted on all but the PC site. The gray woodrat (Neotoma micropus) was not collected on the prairie site, but this species was abundant in nearby areas where there were dense stands of cholla (Opuntia arborescens). Two thirteen-lined ground squirrels (Spermophilus tridecemlineatus) were collected on the PT site, but none were seen elsewhere. The spotted ground squirrel (Spermophilus spilosoma) was common in many other areas, especially along roadsides.

Prairie and Pinyon-Juniper Sites Compared

The mammal faunas of the prairie and pinyon-juniper habitats were remarkably similar. Of the nine species reported from both habitats (referring only to small nocturnal mammals), seven occurred in both habitats. The white-throated woodrat (Neotoma albigula) was restricted to the pinyon-juniper sites and the plains harvest mouse was limited to the prairie (Table 15). Two pinyon mice were taken in the prairie, only because there was an adjacent stand of pinyon-juniper. Although the kangaroo rat and deer mouse were present in both habitats, the former was particularly abundant on the prairie, and the latter was abundant in the pinyon-juniper woodland. Total abundance was higher in the pinyon-juniper woodland (N = 118) than in the prairie (N = 92), although the difference was not significant.

Four guilds of mammals were present on the pinyon-juniper sites (Table 16), and all except guild 10 (the woodrat guild) were present on the prairie sites. In terms of biomass, the dominant guild on the prairie sites was guild 11 (seed-eating, nonnest-building pocket mice and kangaroo rats); on the pinyon-juniper sites, guilds 10 and 12 were dominant (seed- and foliage-eating, nest-building woodrats, and white-footed and harvest mice). The total biomass for each site was similar on the PJT, PJC, and PT sites (range of 2331 to 2589 g). However, the PC site had a remarkably low biomass (356 g).

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[14]V. E. Diersing, W. D. Severinghaus, and E. W. Novak, "Distribution Records of Some Small Mammals From South-Central Colorado," The Southwestern Naturalist, in review (1984).

Table 16

Mammal Guilds on All Four Sites

Guild Number	Species or Grcup	PJT	PJC	PT	PC
2	Onychomys leucogaster (grasshopper mouse)	35 g(1)*	0 g(0)	350 g(14)	35 g(10)
10	Neotoma albigula (woodrat)	1095(45)	1314(56)	0(0)	0(0)
11	Perognathus-Dipodomys (pocket mouse, kangaroo rat)	93(4)	158(7)	1883(73)	163(46)
12	Peromyscus-Reithrodontomys (white-footed and harvest mice)	1220(50)	859(37)	356(14)	158(44)
	Total biomass/site	2443 g	2331 g	2589 g	356 g

*Frequency: The biomass of each guild expressed as a percent of the total for each site.

5 DATA ANALYSIS

Soils

Loam soils are relatively unacceptable for tactical vehicle use;[15] silty clay loam soils are moderately acceptable for tracked vehicle use, and clay soils are acceptable because they are less susceptible to erosion. The texture of soils on the pinyon-juniper sites was either loam or clay. Soils are shallow in these areas and plants have only an effective rooting depth of 254 to 508 mm. Because most pinyon-juniper land is modestly sloped, water erosion is likely. Soils in these areas frequently contain a high percentage of rock fragments which may have a shearing action on plant roots when tracked vehicles use the land. The texture of the soils in the prairie areas was largely silty clay loam at the control site and loam at the test site.

Penetrometer readings (a measure of soil strength) were voided on the pinyon-juniper sites because of the large number of rock fragments. Readings on the prairie sites were similar. No significant differences in the bulk densities were found between the prairie site (Manzanola versus Fort Collins soils). Bulk densities differed between the pinyon-juniper sites, but the small sample sizes and probable bias by rock fragments made detailed comparisons virtually impossible.

Vegetation

Pinyon-Juniper Woodland

Pinyon and juniper trees grow very slowly. Core samples taken from the trunks (1/2 m above ground) of two average-sized junipers (estimated at 4.5 m tall) revealed an approximate age of 226 to 259 years. An average-sized pinyon (estimated at 4 m high) was about 92 years old. Thus, regeneration of replacement trees is very slow. Few young trees of either species were seen on the sites. Most of the understory herbaceous vegetation was blue grama and sideoats grama grass. The latter species is restricted to the pinyon-juniper sites and probably requires partial shade cast from the trees to survive.

Shortgrass Prairie

Vegetation on the two prairie sites was largely similar, with blue grama grass being dominant. Less common grasses on both sites were ring muhly (Muhlenbergia torreyi), galleta (Hilaria jamesii), and bottlebrush squirreltail (Sitanion hystrix). Plant production on the PC site (130 g/m^2) was higher than on the PT site (92 g/m^2). This difference may result from different grazing pressures. The PC site had not been grazed in the 1983 growing season, but the PT site had been heavily grazed.

[15] R. M. Lacey and W. D. Severinghaus, Natural Resource Considerations for Tactical Vehicle Training Areas, Technical Report N-106/ADA103276 (USA-CERL, 1981), p 18.

Birds

Pinyon-Juniper Woodland

The pinyon-juniper woodland reaches its northern limits in south-central and central Colorado and its avifauna there are poorly known. The pinyon-juniper habitat has two major trees (Pinus sp. and Juniperus sp.) with a typically sparse understory. This habitat is characterized by hot summers, cold winters, and low precipitation (low productivity). Large quantities of juniper berries and pinyon seeds are produced periodically.

Various numbers of breeding species have been reported in the pinyon-juniper woodland. Twelve species were reported in Arizona, and 15 and 22 from two samplings in Utah.[16] There is good evidence that at least 16 species were breeding in the Piñon Canyon pinyon-juniper study sites. Of these, the scrub jay and the plain titmouse are largely obligatory breeders in this vegetation type; i.e., they breed only in pinyon-juniper woodlands. The ash-throated flycatcher, piñon jay, Bewick's wren, rufous-sided towhee, and lark sparrow are chiefly semi-obligatory breeders, nesting in one habitat other than the pinyon-juniper. It is not certain what portion of the breeding bird species are permanent residents and what portion are summer residents only. Near Mesa Verde, CO, in a pinyon-juniper woodland, 53 percent of the breeding species were permanent residents.[17] Of the 16 species considered to breed in the woodlands at Piñon Canyon, at least four, or 25 percent, use tree cavities for nesting (ash-throated flycatcher, Bewick's wren, mountain bluebird, and northern flicker). In eastern Utah, 21 percent of the bird fauna in a pinyon-juniper woodland required tree cavities for nesting.[18]

Density of breeding birds in Arizona was considered to average 95 pairs per 40 ha in this habitat type.[19] However, other studies have reported 30 and 33 pairs per 40 ha.[20] The latter figures are in close agreement with the results of this study, which has estimated that 32 pairs per 40 ha were present on the pinyon-juniper test site, and 24 pairs per 40 ha were on the control site.

It is not known why the ash-throated flycatcher was much more common on the PJT site. However, it is likely that this species prefers more open (less dense) stands of pinyon-juniper (104 trees per hectare on the PJT site versus 144 per hectare on the PJC site). The overall effect of fewer trees on the

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[16] I. D. Rasmussen, "Biotic Communities of Kaibab Plateau, Arizona," Ecol. Monog., Vol 3 (1941), pp 229-275; R. Hardy, "Breeding Birds of the Pygmy Conifers in the Book Cliff Region of Eastern Utah," Auk, Vol 62 (1945), pp 523-542; L. Hering, "Breeding Bird Census Piñon-Juniper Forest," Aud. Field Notes, Vol 11 (1957), pp 448-449.

[17] Hering, pp 448-449.

[18] Hardy, pp 523-542.

[19] R. P. Balda and N. Masters, "Avian Communities in the Pinyon-Juniper Woodland: A Descriptive Analysis," Management of Western Forests and Grasslands for Nongame Birds, General Technical Report INT-86 (U.S. Department of Agriculture [USDA], Forest Service, September 1980), pp 146-167.

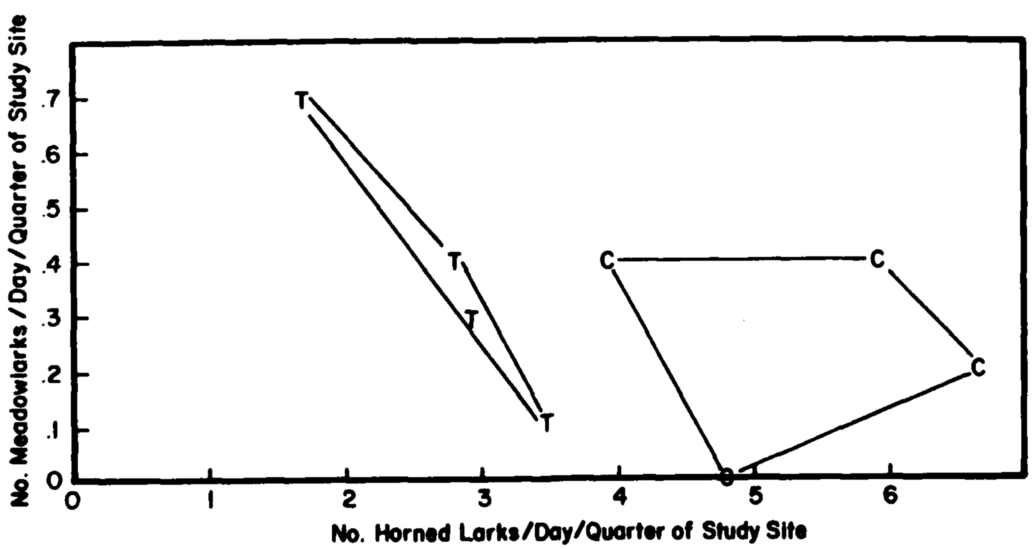
[20] Hering, pp 448-449; R. G. Beidleman, "Breeding Bird Census. Piñon Pine-Rocky Mountain Juniper Forest," Aud. Field Notes, Vol 14 (1960), pp 495-496.

PJT site probably resulted in a lower total bird biomass (5887 g versus 7038 g on the control site). Also, the fewer trees on the PJT site appear to reflect the quality of the site, because total plant production (herbaceous) was lowest on the site. Guild 1b--the seed-eating, open-field guild, which includes larks and chipping sparrows--was much more common on the PJT site than on the PJC site.

Shortgrass Prairie

The shortgrass prairie is a relatively two-dimensional, "flat" habitat, having an extremely limited vertical dimension. Thus, different prairie sites often look similar, and one wonders if prairie birds actually prefer, or differentially select, one site over another. To test this hypothesis, USA-CERL divided both study sites into quarters of 5 ha each, and recorded the number of meadowlarks and horned larks seen in each quarter (Figure 4). Each PT site quarter consistently had fewer horned larks than each PC quarter. This illustration documents that (1) birds are differentially selecting sites and (2) an area smaller than 20 ha per site could be monitored and still produce a reasonable estimate of the true population of horned larks at each site.

It is not certain why more horned larks and fewer meadowlarks were recorded at the PC site. However, the evidence indicates that with increased bare ground, horned larks increase and meadowlarks decrease. Seventy-four percent of the ground on the PC site and 56 percent on the PT site was bare (see Table 9). The other species (lark bunting, lark sparrow, and Brewer's sparrow) seem to depend on the presence of the various half-shrubs and shrubs.



Each "T" and "C" represents a PT site quarter (5 ha) or PC site quarter (5 ha), respectively.

Figure 4. Bivariate analysis documenting differential habitat selection by birds on the shortgrass prairie.

The mean number of breeding birds on numerous shortgrass prairie sites was reported as 4.3.[21] Five species (meadowlark, horned lark, lark bunting, lark sparrow, and Brewer's sparrow) were breeding on each prairie site. Thus, it is clear that the shortgrass prairie contains few avian species--seven, as compared to 24 or 25 in the pinyon-juniper woodland; however, in terms of total bird biomass, the prairies averaged 53 percent of the biomass of the pinyon-juniper woodlands (3481 g versus 6463 g). Other studies have indicated that about 75 to 88 percent of the avian individuals on any rangeland site belong to the two most abundant species.[22] This study found that the horned lark and meadowlark together comprised 86 percent (PT) and 89 percent (PC) of the total bird fauna.

It should be noted that Agropyron sp. was one of the dominant grasses on the PC site. Some of these grasses (A. cristatum and A. desertorum) were shown by Reynolds and Trost to be detrimental to native avian communities.[23] They documented that these plantings reduced species diversity and relative density; however, this was not found to be true on the PC site.

Mammals

Small rodent diversity and abundance was apparently as high or higher on the Piñon Canyon prairies than in other shortgrass prairie sites sampled in Colorado. A study in Yuma County (northeastern Colorado) collected five species representing 17 individuals in an ungrazed prairie and six species representing 23 individuals in a grazed prairie (based on 1000 trapnights per site).[24] The Piñon Canyon study reported seven species and 69 individuals on the PT site and six species and 23 individuals on the PC site (based on 1000 trapnights per site).

There are two major differences between the mammal faunas on the two prairie sites: (1) mammals are much more abundant on the PT site (69 individuals versus 23 on the PC site) and (2) there is an inverse relationship between the numbers of kangaroo rats (Dipodomys ordii) and pocket mice (Perognathus flavus) on the two sites. Both of these differences can be readily explained on the basis of soil texture and competitive interactions between kangaroo rats and pocket mice. It is well known that rodents burrow in soils for shelter; therefore, the sandier the soil, and thus the easier to dig, the greater the number of individuals present if all else is equal. The

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[21] J. A. Wiens and M. I. Dyer, "Rangeland Avifaunas: Their Composition, Energetics, and Role in the Ecosystem," Proceedings of the Symposium on Management of Forest and Range Habitats for Nongame Birds, General Technical Report WO-1 (USDA, Forest Service, 1975), pp 146-182.

[22] Wiens and Dyer, pp 146-182.

[23] T. D. Reynolds and C. H. Trost, "The Effect of Crested Wheatgrass Plantings on Wildlife on the Idaho National Engineering Laboratory Site," The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, General Technical Report RM-65 (Rocky Mountain Forest and Range Exp. Station, 1979), pp 665-666.

[24] M. P. Moulton, J. R. Choate, S. J. Bissell, and R. A. Nicholson, "Association of Small Mammals on the Central High Plains of Eastern Colorado," The Southwestern Naturalist, Vol 26 (1981), pp 53-57.

average sand component was 42 percent on the PT site (69 individuals collected) and 15 percent on the PC site (23 individuals taken). Also, kangaroo rats are competitors of pocket mice.[25] Since kangaroo rats are large-bodied, it is hard for them to burrow in "tight" soils. In their absence, the smaller pocket mouse becomes relatively abundant, such as on the PC site (one kangaroo rat and 14 pocket mice collected). On sandy soils, such as the PT site, the kangaroo rat excludes many pocket mice (28 kangaroo rats and nine pocket mice collected).

Small mammals are therefore exceedingly substrate- (soil texture) oriented, and total seed/foliage production does not seem to be the primary factor regulating their diversity and numbers. On the other hand, birds appear to be regulated by vegetation structure.

The assessment of these physical and biological parameters has led to several conclusions regarding the relative susceptibility of vegetation types, landforms, and vertebrate groups to future tracked vehicle training.

The pinyon-juniper woodland habitat is the most susceptible to future tracked vehicle training. This is due to its increased slope (which increases the effects of water erosion); shallower soils (rooting depth is limited); presence of numerous rock fragments intermixed with the soils (fragments act as shearing devices on roots when pressure is applied to the soils); and lower productivity (there is less vegetative ground cover and growth rates are slower, especially for pinyons and junipers).

The shortgrass prairie's qualities make it the most resilient habitat to tracked vehicle training. These include gentle slopes, deep and relatively rock-free soils, and high productivity (increased vegetative ground cover and more rapid replacement rates).

Birds will be more susceptible to training-induced impacts for several reasons. Each habitat has a unique bird fauna (faunal similarity of 19 percent). Also, in the pinyon-juniper habitat, diversity is exceedingly high (15 guilds); this suggests a fine partitioning of the habitat (relative to variables such as tree size, percent canopy cover, and availability of tree cavities for nesting) such that minor changes in the vegetation structure/composition may significantly affect one or more species. In the prairie habitat, several species (lark bunting, Brewer's sparrow, and lark sparrow) require the sparse half-shrub and shrub layer which is made up chiefly of cholla, snakeweed, and greasewood; however, because of their brittle, woody nature, these shrubs may be susceptible to training activities.

Small mammals are largely cosmopolitan, with most species occurring in both habitats (faunal similarity of 75 percent). Diversity is low, and the typical species is a relative generalist.

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[25] C. Lemen and P. W. Freeman, "Quantification of Competition Among Coexisting Heteromyids in the Southwest," The Southwestern Naturalist, Vol 28 (1983), pp 41-46.

6 CONCLUSIONS

This report has quantified the physical and biological pre-training conditions of Piñon Canyon Maneuver Site.

The soil texture on the pinyon-juniper sites was either loam or clay, while that of the prairie areas was mostly silty clay loam. The increased slope, shallower soils, presence of rock fragments, and lower productivity of the pinyon-juniper woodland habitat makes it most susceptible to future tracked vehicle training.

Pinyon and juniper trees grow very slowly, so regeneration of replacement trees is slow. These trees also provide the shade required by other forms of vegetation to survive. Thus, from the standpoint of vegetation survival, the pinyon-juniper sites are inferior for conducting tracked vehicle training.

Birds will generally be susceptible to training impacts, because species are diverse and the habitat is finely partitioned. Thus, even minor changes in the habitat will adversely affect one or more species.

Small mammals are very substrate-oriented, and their diversity and numbers therefore are less dependent than birds on vegetation structure. Of the small mammals noted at Fort Carson, most occurred in both habitat types.

Table 17 summarizes the various biotic features that distinguish the shortgrass and pinyon-juniper woodland habitats.

Table 17

Characteristic Features of Biota of Pinyon-Juniper Woodland and Shortgrass Prairie

	Pinyon-Juniper Woodland		Shortgrass Prairie
Mammals			
Most abundant species	*Peromyscus maniculatus* *Peromyscus truei* (together 72% of all individuals collected)	(different)	*Dipodomys ordii* *Perognathus flavus* (together 57% of all individuals collected)
Diversity	8	(same)	8
Captive index (captures/1000 trapnights)	59	(similar)	46
Biomass index (captures/1000 trapnights)	2387 g	(different)	1473 g
Faunal similarity		75% (similar)	
Birds			
Most abundant species	Pinon jay Bewick's wren ash-throated flycatcher lark sparrow (together 73% of all individuals seen)		horned lark meadowlark (together 88% of all individuals seen)
Diversity	24	(different)	7
Density	151/100 ha	somewhat (similar)	107/100 ha
Biomass	6463 g/100 ha	(different)	3481 g/100 ha
Faunal similarity		19% (different)	
Vegetation			
Most abundant species (based on cover)	*Pinus edulis* *Juniperus monosperma* *Bouteloua curtipendula*	(different)	*Bouteloua gracilis* *Agropyron sp.* *Muhlenbergia torreyi*
Diversity	60	(similar)	61
Plant production	35 g/m^2	(different)	112 g/m^2
Percent basal cover (vegetation)	14%	(different)	35%
Floral similarity		57% (moderately similar)	

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