

**NATURAL RESOURCE SURVEY AND ANALYSIS
OF SUNSET CRATER AND WUPATKI NATIONAL MONUMENTS**

**FINAL REPORT
(PHASE IV)**

JANUARY, 1981

**PREPARED FOR THE
OFFICE OF NATURAL RESOURCES MANAGEMENT
SOUTHWEST REGION, NATIONAL PARK SERVICE**

**PREPARED BY MEMBERS OF THE
DEPARTMENT OF BIOLOGICAL SCIENCES
NORTHERN ARIZONA UNIVERSITY
FLAGSTAFF, ARIZONA 86011**

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FLAGSTAFF AREA NATIONAL MONUMENTS
6400 N HWY 89
FLAGSTAFF, AZ 86004

Final Report
(Phase IV)
January, 1981

Prepared for the
Office of Natural Resources Management
Southwest Region, National Park Service

Prepared by members of the
Department of Biological Sciences
Northern Arizona University
Flagstaff, Arizona 86011

Project Director:
Gary C. Bateman
Associate Professor of Biology
Phone: (602) 523-2381

GENERAL INTRODUCTION

For roughly the past five years several graduate students and faculty members of the Department of Biological Sciences at Northern Arizona University have been conducting various biological investigations at Sunset Crater and Wupatki National Monuments.

This series of studies was generously supported by the Office of Natural Resource Management, Southwest Region, National Park Service and has resulted in the production of three earlier annual reports. The work reported here was conducted under terms of contract No. CX702990005.

Research assistants involved in collecting field data, analyzing results, and preparing this report were: David M. Nelson (range conditions and interactions among locoweeds and their seed predators), Jon Peters (arthropod communities), and Bruce Palmer (herbivore diets and competition). Curtis Overcast helped by trapping small mammals.

Dr. C. D. Johnson, Professor of Biology at N.A.U., was helpful in planning certain aspects of the research reported here and reviewed the sections on beetle-locoweed interactions and arthropod communities. His help is gratefully acknowledged. Dr. Gary C. Bateman, Associate Professor of Biology, was the project director and principal editor of this report. In addition, he designed the study of roads and their influence on small mammals, interpreted the results and prepared that section of the report.

The investigators gratefully acknowledge the fine cooperation provided by various members of the National Park Service over the past several years. We feel that we have made a significant contribution to the

understanding of the biological interactions occurring at Sunset Crater and Wupatki National Monuments. We realize also that much remains to be discovered and hope that the series of reports we have prepared may serve as a stimulus to other investigators contemplating studies at these biologically interesting areas.

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I

A SURVEY OF RANGE CONDITION
TRENDS ON WUPATKI NATIONAL MONUMENT

David M. Nelson

INTRODUCTION

The primary purpose of this section of this year's report is to determine what impact, if any, cattle grazing has on the vegetation of Wupatki National Monument. For the past three field seasons four grazing exclosures have been analyzed with respect to trends in vegetation composition and compared with similar areas in which grazing is allowed to occur. When data from these areas are compared, certain trends in vegetation composition become apparent for which possible explanations are offered. These data are supplemented by a second method of determining range condition trends, cluster transects, for which data are also discussed.

Also included in this report is a section which is concerned with the formulation of wise management decisions for the preservation of the natural environment of this National Monument. In this section discussion ranges from trends observed in the data to the philosophy and purpose of the National Park Service.

METHODS AND MATERIALS

Grazing Enclosures

Several modifications in sampling procedure were necessary to complete this phase of the botanical survey of Wupatki National Monument. When data collected in 1979, using methods of previous years, were compared to the data collected in previous years, only those data obtained using the line-intercept method seemed to compare reasonably. The only difference in technique between 1977 and 1978 and 1979, was that the data were collected by different researchers. The line-intercept method proved to be the only method objective enough to allow the field work to be carried out by two different researchers. With the other methods employed in previous years, the researcher must decide what he considers one single grass plant, and that decision is a subjective one especially on a permanent transect where the plant cannot be dug up to determine the extent of its root system. For this reason, all methodology used in previous investigations was discarded except for the line-intercept technique.

Four 60 X 60m fenced grazing enclosures were established on Wupatki National Monument in 1977. Three of these enclosures were erected in the Juniper/Grassland community and one in the Cold Desert Shrub community. In all four cases, one 50m baseline was established inside the enclosure and one outside. For Grazing Enclosures I and II an additional 50m baseline was established on Coconino National Forest as a control. Five 50m transects were placed at right angles to the baseline at 10m intervals, transect 1 beginning at the 5m marker and transect 5 beginning at the 45m marker. Each of these transects has been permanently marked for future evaluation.

Cover values of all plants were determined by measuring their intercepts along each 50m transect (Canfield, 1941). Intercepts measured for all grass

species included only the root crown area which intercepted the tape while intercepts for all other plant species included any plant part which was located directly over the tape when view from directly above. These data were combined to give a total transect length of 250m at each sampling site. Relative and absolute cover values were calculated for each species according to the following formulae (Mueller-Dombois and Ellenberg, 1974):

$$\text{Relative cover} = \frac{\text{intercept of a species}}{\text{total intercept of all species}} \times 100$$

$$\text{Absolute cover} = \frac{\text{total intercept of a species}}{250\text{m}} \times 100$$

It is regrettable that importance values and coefficients of similarity cannot be derived from the above measurements however, it is our opinion that these are the only values that can be directly compared from year to year and remain immune to researcher subjectivity.

Cluster Transects

Three cluster transects were established within the Juniper/Grassland community for the purpose of analyzing long term range condition trends. These transects, which were permanently staked during the 1978 field season, each consisted of three 100 foot transects arranged in a straight line 100 feet apart. Stakes were set at the 0.0 foot mark, the 50.5 footmark and at the 101 footmark.

A transect within a cluster was established by stretching a 100 foot tape as tightly as close to the ground as possible. Measurement of vegetation along the transect was achieved by placing a 0.75 inch loop horizontally at each foot marker along the right-hand side of the tape. This allowed 100 sample points per transect. All data gathered from cluster transects, including hits on vegetation, dot tallies, and rock, litter and bare soil hits were recorded and

summarized on U.S.D.A. Forest Service form R-3 2200-23. When there was no hit on perennial vegetation, a dot tally was recorded for the nearest perennial plant in a 180° arc to the right hand side of the tape. No plant was recorded more than once. Hits and dot tally composition were separated into three categories, increaser, decreaser and invader, in accordance with the Species Classification List in Forest Service Handbook 2209.21 R3. Increaser composition was multiplied by 0.25, decreaser composition by 2.0 and invader composition by minus 1. The values obtained by this procedure were then totaled and a composition scorecard on page 34.11 of Forest Service Handbook 2209.21 R3. Actual plant hits within the 0.75 inch ring were the basis by which vegetation cover was determined. From this information a forage cover index was established using Forage Cover Index Scoring Guide b. Grass vigor was calculated by measurement of the longest leaf of ten dominant grasses selected at random. The forage cover index value, the composition value and the vigor value were then totaled to determine a condition class for the range land based on a 100 point scale:

<u>Numerical Score</u>	<u>Condition</u>
81-100	excellent
61-80	good
41-60	fair
21-40	poor
0-20	very poor

The soil stability was rated by totaling the erosion hazard value and the current erosion value. Methods for obtaining these values are described in Forest Service Handbook 2209.21 R3 and their total was then compared to a 100 point scale, exactly like the one above, to give a soil condition class.

RESULTS

Grazing Exclosure I

Grazing Exclosure I was located in Halls Canyon, a four-wing saltbush and galleta dominated wash within the Juniper/Grassland community. Within this exclosure the five 50m transects were sampled on 11 August 1977, 15 May 1978, and 3 November 1979. The set of transects established in this area were located approximately 350m south of the Coconino National Forest boundary line near Arrowhead Tank. This group of transects was read on 17 June 1977, 21 May 1978, and 3 November 1979.

Results from all three field seasons are presented in Table 1. A general trend is observed for all three transects (inside, outside, Forest Service) showing that galleta (Hilaria jamesii (Torr.) Benth.) increased in absolute cover from 1977 to 1978, then decreased from 1978 to 1979. A reverse of that trend was indicated for dead galleta, except in the outside transect where there was a general increase in dead galleta over the three year period. Four-wing saltbush (Atriplex canescens (Pursh)Nutt.) showed an increase in cover for both the inside and outside transects but a decrease in cover on Forest Service property. Both showed an increase in dead four-wing saltbush while it decreased inside the exclosure in 1979.

Total absolute cover value for the inside transect rose between 1977 and 1978 from 14.04 to 28.11 percent then declined in 1979 to 14.59 percent. In the transects outside the exclosure, absolute cover increased from 11.85 to 19.84 to 23.59 percent from 1977 to 1978 to 1979 respectively. On Forest Service property the absolute cover values remained fairly stable and very high going from 24.55 to 33.04 then back to 29.55 percent.

Grazing Exclosure II

Grazing Exclosure II was located about 300m east of the cattleguard on Forest Service Road 545 and is also within the Juniper/Grassland community. Three 50m baseline transects were established here, one inside the exclosure, one outside of and adjacent to the exclosure, and one on the Coconino National Forest. The inside transect was established 12 August 1977 then re-sampled on 22 May 1978 and 28 September 1979. The transect outside of the exclosure was established on 29-30 June 1977 and re-read on 23 May 1978 and 28 September 1979. The transect on Coconino National Forest was established on 11-12 August 1977 and was re-read on 23-24 May 1978 and 29 September 1979. The results for Grazing Exclosure II are presented in Table 2.

For the transect inside Grazing Exclosure II, galleta was highest in terms of absolute cover for all three field seasons, rising from 13.49 in 1977 to 21.41 percent in 1978, then declining to a new low of 6.69 percent in 1979. As was generally true for Grazing Exclosure I, dead galleta showed an opposing trend. The outside transect showed much the same trends except that the line galleta was not nearly as widely fluctuating, rising from 6.68 to 9.38 percent then declining to 7.02 percent. Dead galleta showed a gradual increase over the three year period. The Forest Service transect gave data much like the inside transect for both live and dead galleta. Live galleta rose from 11.28 percent in 1977 to 15.38 percent in 1978, then fell to its lowest level of 7.36 percent in 1979. Again dead galleta showed the reverse of this showing its lowest cover values when live galleta showed its highest, and vice-versa. Black grama (Bouteloua eriopoda (Torr.) Torr.) was also an important plant on the Forest Service transect and showed a decrease from 2.49 percent in 1978 to 1.02 percent in 1979. Fendler three-awn (Aristida fendleriana Steud.) showed an increase from .97 to 1.77 percent absolute cover over the

same period.

Each of the transects showed the same trend for total absolute cover over the three year period rising from a low level in 1977 to the highest level in 1978 then lowering again in 1979. This trend was true for both galleta and total absolute cover.

Grazing Exclosure III

Grazing Exclosure III is located in Cedar Canyon near the Magnetic Mesa well site, about 5m west of the road. An inside transect and an outside transect were established here. The transect inside of the exclosure was established on 9 August 1977 then re-sampled on 10 May 1978 and 29 September 1979. The outside transect was established on 13 June 1977 and re-read on 6-7 May 1978 and 29 September 1979.

Results for Grazing Exclosure III are recorded in Table 3. Galleta showed trends which were nearly the same as for Grazing Exclosures I and II both inside the exclosure and outside. Cover values inside the exclosure are higher than those outside, both showing an increase in percent cover from 1977 to 1979. For the inside transect a dramatic increase of Russian thistle (Salsola kali Tausch.) was observed, rising from 0.0percent in 1977 and 1978, to 10.25 percent in 1979. This trend was not observed outside the exclosure however.

Grazing Exclosure IV

Grazing Exclosure IV was located about 1.5 kilometers from Forest Service Road 545 approximately 100m south of the Wukoki Road. This exclosure was the only one located in the Cold Desert Shrub community. Two 50m baseline transects were established here, one inside the exclosure and the other outside and immediately adjacent to the exclosure. These transects were sampled on 3 December 1977, were not re-sampled in 1978 but were on 5 October 1979.

Table 4 presents the results for Grazing Exclosure IV. This exclosure has remained very stable over the three year period with Artemisia frigida Willd. being the dominant cover plant in 1977 and 1979 both inside and outside of the exclosure. Percent cover inside the exclosure for A. frigida in 1977 totaled 7.40 percent and remained close to that value at 7.3 percent in 1979. Four-wing saltbush was second inside the exclosure increasing from 2.67 percent in 1977 to 3.36 percent in 1979. Outside the exclosure A. frigida increased from 7.86 percent in 1977 to 9.46 percent in 1979. Ephedra torreyana Wats. was second in cover decreasing from 1.98 to 1.69 percent over the two year period.

Cluster Transects

Three cluster transects were established on Wupatki National Monument on 1-2 November 1978 and were re-sampled for comparison in 1979. One cluster was placed in the Juniper/Grassland community, one in Halls Canyon and one in the Grassland community. More exact locations of these transects are presented in the Phase III Final Report (Bateman, 1980). Results for all three transects for 1979 are presented Table 5.

Cluster Transect 1, located in the Grassland community, averaged 17 hits on forage plants and scored 57 for an erosion hazard index. Vegetation condition class scored a 26 which results in a ranking of poor. Cluster Transect 1 scored 23 for the soil stability condition, rating it as poor also. Leaf blades were selected at random and measured for galleta and New Mexico feathergrass (Stipa neomexicana (Thurb.) Scribn.) averaging 9.69 and 13.8cm in length respectively. These measurements result in a very poor vigor rating.

Located in the Juniper/Grassland community, Cluster Transect 2 averaged seven hits on all forage plants and scored a 73 erosion hazard index. A score of 19, for vegetation condition class places Cluster Transect 2 in very poor condition.

Soil stability condition rated poor, scoring only 21. Galleta leaf blade measurements averaged 10.92cm indicating poor vigor.

Cluster Transect 3 is located in upper Hulls Canyon. Four hits on forage plants was the average for this transect and the erosion hazard index was 92. Vegetation condition rating was scored 36 placing it in the very high end of the poor condition class. The soil stability condition totaled 13 for a very poor condition rating. Galleta leaf lengths averaged only 5.6cm which indicates low vigor.

DISCUSSION

Grazing Exclosures

The data presented in Tables 1-3, for Grazing Exclosure I, II, and III, indicate at least two general trends occurred with respect to vegetation cover values. These trends included: 1) an increase in galleta from 1977 to 1978 and then a marked decrease in 1979, cover values remained stable or increased under the influence of grazing pressure. It must be noted that Grazing Exclosure I was broken into and cattle entered it during the winter between 1978 and 1979. The effect of this is not apparent in the data however.

The increase in galleta from 1977 to 1978 then its decrease in 1979 is observed in eight of eight sets of baseline transects in Grazing Exclosures I, II, and III. This trend can be explained by referring to the rainfall data presented in Table 8. Galleta displays a tendency toward two separate growing seasons. In Arizona, there is an early spring growth period in March and April, then semi-dormancy in May and June followed by a second growth period in July and August (West, 1972). Year to year variability in galleta production is closely related to precipitation (Hutchings and Stewart, 1947). Grazing Exclosures I, II and III were all sampled in May, June or very early August of 1977 including only the spring season growth in the data. The winter and early spring rainfall in 1977 was very low and consequently galleta showed a low cover value. Later that season in July and August, during galleta's late season growth period, considerable rainfall was recorded. This rainfall may have stimulated very good late season growth for galleta in 1977. This late season growth in 1977 was coupled with good early spring rainfall in 1978 to boost galleta cover values considerably when exclosures were sampled again in early summer, 1978. A poor July-August monsoon season in 1978 along with a poor 1979 spring season pushed galleta cover values back down to levels similar to those

observed for galleta in 1977. Hence, it could be that galleta cover values are very dependent on early and late growth season precipitation variations at Wupatki National Monument.

Another trend which appeared in the data for Grazing Exclosures I, II and III was a general increase in total cover values outside of the exclosures where grazing pressure is present. When data collected inside the exclosures were compared with those from outside the exclosures, it was evident that there was a higher fluctuation of total cover values, and especially of cover by galleta, inside of the exclosures. Galleta appears to respond to precipitation much more opportunistically inside of the exclosures rising to very high cover values in good years. It then collapses drastically in bad years, perhaps due to the increased intraspecific competition resulting from the high densities which are remnant of the previous good year. Outside of the exclosures, grazing may act to control galleta's increase in density in good years, the result being lower density the next year and reduced intraspecific competition in poor years. Thus, grazing pressure may act to stabilize total cover values as well as, or as a result of, having a stabilizing effect on galleta.

The only instance in which the previously described trend was not apparent was in data presented for inside of Grazing Exclosure III. This transect, although inside an exclosure, showed an increase in total cover from 1977 to 1979. The increase in cover from 1978 to 1979, however, was a result of a dramatic increase from 0.0 to 10.25 percent cover for Salsola kali Tausch. This increase in Russian thistle was probably due to the fencing around the exclosure catching the tumbling plants, effectively acting as a seed trap (Bateman, pers. comm.).

Data for grazing Exclosure IV are presented in Table 4. Vegetation cover values in this area of the Cold Desert Shrub community seem to have

remained very stable from 1977 to 1979. This exclosure was not sampled in 1978, however, and any increases which may have occurred during that exceptionally good growing season are not detectable.

Cluster Transects

Cluster Transect 1, located in the Grassland Community, was rated in a poor vegetation condition class in 1979. In 1978, this area was rated in a very poor vegetation condition class and a poor soil condition class and a poor soil condition class. Data from Cluster Transects 2 and 3 indicate that vegetation condition has remained stable from 1978 to 1979 in the Juniper/Grassland and Atriplex Hilaria communities. Vegetation condition remained very poor for Cluster Transect 3. Soil condition improved one class from very poor to poor for Cluster Transect 2 and remained very poor for Cluster transect 3. These data suggest that range conditions for these three communities have remained fairly stable over the period from 1978 to 1979.

MANAGEMENT RECOMMENDATIONS

It was suggested in previous reports that perhaps the reason that cover values rose more rapidly inside of grazing exclosures than outside of them was because of the reduced grazing pressures on the inside from 1977 to 1978. We feel that this is a valid conclusion for that period. However, the data for almost every set of baseline transects show a marked decrease in cover for the period from 1978 to 1979, and this decrease in cover is also most apparent where grazing is restricted. When considered along with rainfall data for this period, these data suggest that grazing reduction allows plant cover to increase more rapidly than when grazing is allowed to occur during favorable growing seasons, but when seasons are not favorable, the increased cover inside of the exclosures leads to increased plant competition and a greater die-off inside the exclosures.

Although the data presented do show wide fluctuations in plant cover for the period from 1977 to 1978 and then again from 1978 to 1979, not enough time has elapsed to allow long term range condition trends to be seen. Such changes might include not only plant cover but also shifts in plant species composition and relative abundances. It is possible that further study would reveal the creation of a non-natural plant community, that is, one that fosters the predomination of "increaser" species under grazing pressure at the expense of other less resistant forms. Other points which must be considered are; the effect of grazing on threatened and endangered plants and, the effect of grazing competition on native wildlife which otherwise might be more abundant on this "semi-natural" area.

Lands administered by the National Park Service are held in trust for future generations of Americans. If grazing by domestic stock appears to be

detrimental to the natural vegetation of such lands it should be terminated. Unlike some other federal agencies, such as the U.S. Forest Service and Bureau of Land Management, the National Park Service owes no allegiance to livestock interests.

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Table 1. Results of the inside, outside and Forest Service transects of Grazing Exclosure I.

<u>Grazing exclosure I, inside</u>	<u>Absolute cover values %</u>			<u>Relative cover values %</u>		
	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
<u>Hilaria jamesii</u>	5.51	16.51	2.59	38.16	58.75	17.75
Dead <u>Hilaria jamesii</u>	1.23	.56	1.02	8.53	1.99	6.99
<u>Atriplex canescens</u>	4.39	7.7.0	8.70	30.41	27.38	59.63
Dead <u>Atriplex canescens</u>	2.88	2.96	1.57	19.91	10.52	10.76
Cowpie	.43	.33	.17	2.99	1.18	1.17
<u>Sphaeralcea subhastata</u>	.00	.00	.48	.00	.00	3.29
<u>Bouteloua eriopoda</u>	.00	.00	.02	.00	.00	.14
<u>Bouteloua gracilis</u>	.00	.05	.00	.00	.18	.00
Total cover	14.04	28.11	14.59	100.00	100.00	100.00
<u>Grazing exclosure I, outside</u>						
<u>Hilaria jamesii</u>	2.98	8.60	3.41	25.15	43.34	14.46
Dead <u>Hilaria jamesii</u>	.44	.72	.88	3.68	1.45	3.73
<u>Atriplex canescens</u>	4.55	5.24	12.52	38.40	26.38	53.07
Dead <u>Atriplex canescens</u>	3.28	4.26	6.32	27.69	21.44	26.79
Cowpie	.60	.92	.31	5.07	4.65	1.31

Table 1. Continued.

	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
<u>Muhlenbergia porteri</u>	.00	.00	.5	.00	.00	.21
<u>Sphaeralcea subhastata</u>	.00	.00	.92	.00	.00	3.89
<u>Bouteloua eriopoda</u>	.00	.04	.00	.00	.22	.00
<u>Astragalus lentiginosus</u>	.00	.06	.00	.00	.32	.00
Total cover	11.85	19.84	25.59	100.00	100.00	100.00
<u>Grazing exclosure I, Forest Service</u>						
<u>Hilaria jamesii</u>	3.56	7.86	4.61	12.03	23.80	15.60
Dead <u>Hilaria jamesii</u>	.67	.50	.72	2.26	1.82	2.44
<u>Atriplex canescens</u>	10.50	8.06	6.67	35.53	24.39	22.57
Dead <u>Atriplex canescens</u>	14.80	16.28	18.31	50.09	49.26	61.96
<u>Sphaeralcea subhastata</u>	.00	.00	.62	.00	.00	2.09
<u>Muhlenbergia porteri</u>	.02	.24	.00	.08	.73	.00
Total cover	29.55	33.04	29.55	100.00	100.00	100.00

Table 2. Results of the inside, outside and Forest Service transects of Grazing Exclosure II.

	<u>Absolute cover values %</u>			<u>Relative cover values %</u>		
	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
<u>Grazing exclosure II, inside</u>						
<u>Hilaria jamesii</u>	13.49	21.41	6.69	69.38	79.69	54.03
Dead <u>Hilaria jamesii</u>	2.56	1.51	2.72	13.28	5.61	21.97
<u>Aster arenosus</u>	.02	.17	.14	.58	.63	1.13
<u>Gutierrezia sarothrae</u>	.12	.12	.03	1.25	.45	.24
<u>Juniperus monosperma</u>	1.64	1.92	2.08	8.52	7.15	16.80
<u>Sporobolus flexuosus</u>	.48	1.20	.29	2.52	.43	2.34
<u>Sphaeralcea subhastata</u>	.06	.12	.06	.31	4.48	.48
Cowpie	.32	.11	.04	1.66	.42	.32
<u>Stipa neomexicana</u>	.02	.02	.00	.08	.07	.00
<u>Bouteloua eripoda</u>	.04	.06	.00	.19	.22	.00
Dead <u>Sporobolus flexuosus</u>	.18	.21	.33	.94	.79	2.66
<u>Stephanomeria pauciflora</u>	.00	.02	.00	.00	.06	.00
Total cover	18.93	26.87	12.38	100.00	100.00	100.00

Table 2. Continued.

	<u>Absolute cover values %</u>			<u>Relative cover values %</u>		
	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
<u>Grazing exclosure II, outside</u>						
<u>Hilaria jamesii</u>	6.68	9.38	7.02	49.15	56.36	46.31
Dead <u>Hilaria jamesii</u>	1.50	1.77	2.08	10.98	10.62	13.72
<u>Juniperus monosperma</u>	4.17	4.41	4.57	30.67	26.51	30.14
<u>Bouteloua eriopoda</u>	.53	.41	.72	3.88	2.45	4.75
Dead <u>Bouteloua eriopoda</u>	.19	.30	.02	1.38	1.80	.13
<u>Aster arenosus</u>	.02	.07	.12	.15	.43	.13
Cowpie	.32	.29	.33	2.32	1.73	2.17
<u>Sphaeralcea subhastata</u>	.00	.02	.00	.00	.10	.00
<u>Gutierrezia sarothrae</u>	.10	.00	.30	.77	.00	1.98
<u>Stipa neomexicana</u>	.05	.00	.00	.38	.00	.00
Total cover	13.56	16.65	15.16	100.00	100.00	100.00
<u>Grazing exclosure II, Forest Service</u>						
<u>Hilaria jamesii</u>	11.28	15.38	7.36	53.49	63.42	41.35
Dead <u>Hilaria jamesii</u>	2.88	2.43	4.10	13.68	9.90	23.03

Table 2. Continued.

	<u>Absolute cover values %</u>			<u>Relative cover values %</u>		
	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
<u>Bouteloua eriopoda</u>	2.15	2.49	1.02	10.20	10.13	5.73
<u>Aristida fendleriana</u>	.50	.97	1.77	2.39	3.94	9.94
<u>Juniperus monosperma</u>	1.99	2.28	2.71	9.45	9.26	15.22
<u>Aster arenosus</u>	.04	.14	.06	.19	.57	.34
<u>Zinnia grandiflora</u>	.05	.04	.00	.23	.16	.00
<u>Stipa neomexicana</u>	.00	.10	.00	.00	.41	.00
Dead <u>Aristida fendleriana</u>	.33	.18	.00	1.56	.73	.00
<u>Bouteloua gracilis</u>	.02	.03	.00	.11	.11	.00
<u>Gutierrezia sarothrae</u>	.23	.00	.17	1.10	.00	.95
Dead <u>Bouteloua eriopoda</u>	.56	.34	.61	2.64	1.37	3.43
Total cover	20.03	24.38	17.80	100.00	100.00	100.00

Table 3. Results of the inside and outside transects of Grazing Exclosure III.

	<u>Absolute cover values %</u>			<u>Relative cover values %</u>		
	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
<u>Grazing exclosure III, inside</u>						
<u>Hilaria jamesii</u>	5.08	8.37	2.90	29.56	40.08	11.46
Dead <u>Hilaria jamesii</u>	.61	.45	.84	3.54	2.16	3.32
<u>Chrysothamnus nauseosus</u>	3.55	4.04	2.92	20.68	19.34	11.54
Dead <u>Chrysothamnus nauseosus</u>	2.66	1.81	1.42	15.49	8.66	5.61
<u>Juniperus monosperma</u>	3.55	3.49	3.49	19.52	16.71	13.79
<u>Sphaeralcea subhastata</u>	.13	.57	.60	.75	2.74	2.37
<u>Bouteloua eriopoda</u>	.15	.45	.14	1.08	2.14	.55
<u>Hoffmanseggia jamesii</u>	.02	.16	.07	.09	.77	.28
<u>Atriplex canescens</u>	.71	.69	.44	4.15	3.31	1.74
<u>Gutierrezia sarothrae</u>	.12	.11	.04	1.49	.52	.16
Cowpie	.44	.27	.20	2.54	1.30	.79
<u>Salsola kali</u>	.00	.00	10.25	.00	.00	40.51
<u>Sporobolus airoides</u>	.00	.00	1.83	.00	.00	7.23
<u>Aster arenosus</u>	.04	.14	.07	.26	.00	.28
<u>Psilostrophe sparsiflora</u>	.00	.00	.21	.00	.00	.83

Table 3. Continued.

	<u>Absolute cover values %</u>			<u>Relative cover values %</u>		
	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
<u>Aristida fendleriana</u>	.04	.11	.07	.00	.00	.28
<u>Muhlenbergia porteri</u>	.11	.16	.00	.63	.00	.00
Total cover	17.21	20.82	25.30	100.00	100.00	100.00
<u>Grazing exclosure III, outside</u>						
<u>Hilaria jamesii</u>	2.63	5.31	3.61	20.22	34.03	20.13
<u>Chrysothamnus nauseosus</u>	6.25	5.04	7.90	47.99	32.32	44.06
Dead <u>Hilaria jamesii</u>	.00	.00	1.16	.00	.00	6.47
<u>Bouteloua eriopoda</u>	.36	1.14	.77	2.80	7.33	4.29
<u>Juniperus monosperma</u>	2.72	2.82	3.06	20.86	18.06	17.07
Cowpie	.40	.30	.44	3.07	1.95	2.45
<u>Sphaeralcea subhastata</u>	.08	.14	.06	.68	.90	.33
<u>Psilostrophe sparsiflora</u>	.06	.08	.32	.52	.54	1.78
<u>Atriplex canescens</u>	.41	.35	.61	3.13	2.26	3.40
<u>Stipa neomexicana</u>	.01	.09	.00	.09	.56	.00
<u>Muhlenbergia porteri</u>	.00	.06	.00	.00	1.69	.00

Table 3. Continued.

	<u>Absolute cover values %</u>			<u>Relative cover values %</u>		
	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
<u>Gutierrezia sarothae</u>	.08	.00	.00	.71	.36	.00
<u>Hoffmanseggia jamesii</u>	.02	.00	.00	.12	.00	.00
Total cover	12.94	15.64	17.93	100.00	100.00	100.00

Table 4. Results of the inside and outside transects of Grazing Exclosure IV.

	<u>Absolute cover values %</u>		<u>Relative cover values %</u>	
	<u>1977</u>	<u>1979</u>	<u>1977</u>	<u>1979</u>
<u>Grazing exclosure IV, inside</u>				
<u>Artemisia frigida</u>	7.40	7.32	53.15	50.59
<u>Tetradlea coulteri</u>	.36	.18	2.59	1.24
<u>Atriplex canescens</u>	2.67	3.36	19.20	23.22
<u>Astragalus lentiginosus</u>	.32	.07	2.27	.43
<u>Muhlenbergia porteri</u>	.32	.00	2.27	.00
<u>Chrysothamnus nauseosus</u>	.78	.50	5.44	3.45
<u>Ephedra torreyana</u>	.00	.93	3.51	6.43
<u>Eriogonum aureum</u>	.00	.29	.00	2.00
<u>Ephedra viridis</u>	.00	.22	.00	1.52
<u>Tridens pulchella</u>	.00	.02	.00	.14
Cowpie	.00	.10	.00	.69
Dead <u>Artemisia frigida</u>	1.90	1.48	5.46	10.22
Total cover	13.48	14.47	100.00	100.00

Table 4. Continued.

	<u>Absolute cover values %</u>		<u>Relative cover values %</u>	
	<u>1977</u>	<u>1979</u>	<u>1977</u>	<u>1979</u>
<u>Grazing exclosure IV, outside</u>				
<u>Artemisia frigida</u>	7.86	9.46	52.64	57.75
<u>Ephedra torreyana</u>	1.93	1.69	13.29	10.32
<u>Tetradlea coulteri</u>	.15	.06	1.02	.37
Dead <u>Artemisia frigida</u>	1.89	1.42	12.68	8.67
<u>Muhlenbergia porteri</u>	.43	.50	2.89	3.05
<u>Atriplex canescens</u>	.89	.84	5.95	5.13
Dead <u>Atriplex canescens</u>	.91	.72	6.11	4.39
<u>Atragalus lentiginosus</u>	.16	.10	1.07	.61
<u>Chrysothamnus nauseosus</u>	.25	.44	1.69	2.69
<u>Fallugia paradoxa</u>	.31	.24	2.06	1.46
<u>Salsola kali</u>	.00	.04	.00	.24
<u>Eriogonum aureum</u>	.00	.68	.00	4.15
Total cover	14.83	16.38	100.00	100.00

Table 5. Results of cluster transects established on Wupatki National Monument.

	<u>Cluster 1</u>					<u>Cluster 2</u>					<u>Cluster 3</u>				
Transect number	1	2	3	total	ave	1	2	3	total	ave	1	2	3	total	ave
Hits: all plants	18	15	20	53	18	3	3	15	22	7	6	6	1	13	4
Rock	5	5	3	13	4	1	3	1	5	2	0	0	0	0	0
Litter	13	23	26	62	21	12	13	30	55	18	4	3	4	11	4
Bare soil	64	57	51	172	57	84	81	53	218	73	90	91	95	276	92
Total	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100
Hits: all forage plants	17	14	20	51	17	3	3	15	21	7	6	6	1	13	4
Erosion hazard index	64	57	51	172	57	84	81	53	218	73	90	91	95	276	92
Forage cover index				12					5					3	
Composition				11					11					31	
Vigor				3					3					2	
Total				26					19					36	
Condition class	poor					very poor					poor				
Erosion hazard				8					6					3	
Current erosion				15					21					13	

Table 5. Continued.

	<u>Cluster 1</u>	<u>Cluster 2</u>	<u>Cluster 3</u>
Total	23	21	13
Condition class	poor	poor	very poor
	near mammal grid- grassland	by exclosure 2 in Juniper/grassland	Upper Halls Canyon Atriplex - Hilaria

Table 6. Precipitation, in inches, at the Wupatki National Monument Weather Station for 1977, 1978, and 1979.

	<u>1977</u>	<u>1978</u>	<u>1979</u>
January	.62	.52	1.32
February	.36	1.62	.28
March	.15	1.54	.32
April	.37	.10	.03
May	.01	.02	1.59
June	.41	.01	.35
July	2.73	.67	.55
August	3.00	.42	2.08
September	.51	1.35	.03
October	.50	1.32	.59
November	.31	3.65	.54
December	.41	.44	.62
Total	<u>9.385</u>	<u>11.66</u>	<u>8.30</u>

II

ECOLOGICAL INTERACTIONS AMONG SEVERAL
LOCOWEED SPECIES AND THEIR SEED PREDATORS

David M. Nelson

INTRODUCTION

The objective of this report is to determine the nature of the ecological interactions among several species of locoweeds and their insect seed predators. From a management standpoint, my studies could be useful in determining which insects have potential as biological control agents to reduce the densities of toxic locoweeds on rangelands. Other portions of this report deal with the non-management aspects of the study. Among these the classification of insects on the basis of host plant preference is included. Host plant preference has been used extensively in the past in the classification of bruchid beetles. Also, new host records can be revealed in a study of this sort as well as the possibility of discovering a new species of beetle. All ecological information of this sort adds to the information already stored and may, someday, be used to complete a study of more profound nature.

METHODS AND MATERIALS

Six species of locoweed (Astragalus) were studied to determine their ecological interactions with seed beetles of the Family Bruchidae. Seed pods were collected from plants at seven study sites, which were selected on the basis of varying plant density and the species composition of locoweeds. Collections were made at weekly intervals from the time pods first appeared on the plants until they had disappeared late in the growing season. The pods were collected, sealed in paper sacks, then transported to the laboratory where they were transferred into glass jars covered by paper towels impregnated with kelthane and stored on shelves lined with similarly impregnated towels. Kelthane is used to prevent foreign insects from entering the culture jars. Emerging bruchid beetles were collected weekly from each seed culture, killed and identified.

For each Astragalus population at each collection site, absolute density and per cent cover values were determined. Due to differences in the spatial arrangement of plants within each study population, three different methods of determining density and cover were selected and applied for reasons of convenience and accuracy. Each of these methods yield results which are suitably comparable (Cottam and Curtis, 1956).

At site 1, density and cover values were measured using a grid system of 1m^2 quadrats. A loom baseline was established from which ten 50m transects were placed at a 90° angle. The first transect began at the 10m marker on the baseline and the last one at the 100m marker, transects originating at 10m intervals. Ten 1m^2 quadrats were established at 5m intervals along the lefthand side of the tape, the first one at the 4-5m interval on the tape and the last at the 49-50m interval. All Astragalus wootoni Sheldon. plants falling within these quadrats were counted and crown diameter was measured and recorded. Absolute density per hectare was calculated using the following formula (Cottam and Curtis, 1956):

$$\frac{\text{number of individuals counted}}{\text{total area sampled}} = \frac{X}{10,000\text{m}^2}$$

Crown diameters were converted to crown cover values by the formula πr^2 . Percent absolute crown cover was calculated using:

$$\frac{\text{mean crown cover} \times \text{number of individuals per hectare}}{10,000\text{m}^2} \times 100$$

For site 6, densities of Astragalus praelongus Sheldon. were determined by the plotless point-quarter method (Cottam and Curtis, 1956). Mean distance from sample points to A. praelongus plants was calculated using the following formula:

$$\text{mean distance} = \frac{\text{total distance measured}}{\text{number of distances measured}}$$

Mean area covered per plant was determined using:

$$(\text{mean distance})^2 = \text{mean area occupied by each plant}$$

This gave absolute density by the formula:

$$\frac{1}{\text{mean area covered}} = \frac{X}{10,000\text{m}^2}$$

Absolute cover was then calculated according to the equation given for site 1.

For four of the remaining five sites, plants were counted and their crown diameters were measured within single quadrats of varying sizes. For site 2 the quadrat size used was 1500m long and 30m wide and was located over a paved road. Astragalus lentiginosus plants were counted along both sides of the road, the road being centered lengthwise through the quadrat. Site 3 contained two species, A. lentiginosus and A. wootoni. Again the quadrat was centered lengthwise over the road but was only 50m long by 30m wide. Four Astragalus species were located within the quadrat at site 5, a 50m by 50m plot. These included A. praelongus, A. amphioxys Gray., A. lancearuis Gray., and A. sabulonum Gray. Site 7 was very similar to site 3 but only one species, A. lentiginosus, grew there. Again the quadrat was 50m long by 30m wide and was centered lengthwise over the road, plants being counted on both sides. Data from these quadrats were analyzed by using equations previously described. For site 4, absolute density

and cover values were not calculated because the site consisted simply of five A. wootoni clustered very closely together with no other Astragalus plants located nearby. In fact, I searched the surrounding area carefully and was unable to locate other Astragalus within a range of several hundred meters from this site.

For each study site in which a road was included in the area of the quadrat the average distance between plants was equal to or greater than the width of the road. For this reason, this method was considered valid. Roadside study sites were selected so frequently because these areas provided some of the most suitable populations for this study.

RESULTS

Table 1 presents absolute density values and absolute cover percentages for all Astragalus species at the various seed collection sites. Site 1 covered a very large area located north of Forest Service Road 545 one mile east of the first cattle guard encountered when leaving Sunset Crater National Monument bound for Wupatki National Monument. Astragalus wootoni, the only locoweed species in the area, occurred there at an absolute density of 11,200 plants per hectare. This was the most dense locoweed population found at any of the seven study sites. The absolute ground cover for these plants was 1.05 percent, making this area second in terms of cover for any of the locoweed populations studied.

Farther down Forest Service Road 545 toward Wupatki, a second cattle guard marked the boundary of site 2, which extended 1500m toward Wupatki and included both sides of the road. At this site, A. lentiginosus occurred alone in a sparsely distributed population having an absolute density of only 8.13 plants per hectare, by far the lowest density for A. lentiginosus at any of the sites where it occurred. An absolute cover value of .016 percent also made it the lowest in terms of cover for A. lentiginosus at these sites.

Again, measuring from the same cattle guard, 1.6 miles closer to Wupatki, a 50m X 30m quadrat was sampled which contained both A. lentiginosus and A. wootoni. At site 3, A. lentiginosus had the highest absolute density and absolute cover values of 133.2 plants per hectare and .262 percent respectively. Astragalus wootoni occurred at an absolute density of 86.6 plants per hectare and had an absolute cover value of .17 percent.

Site 4 was located along Forest Service Road 545, 1.4 miles south of the south boundary of Wupatki National Monument. Five tightly clustered A. wootoni plants occurred at this site with no other Astragalus located nearby.

Site 5 was located in Section 11 at Wupatki National Monument along the road to Black Falls at the point where Deadman Wash closely approached the

road. A 50m X 50m quadrat, which included a 50m section of the wash and extended 50m southeastward across the, was sampled in this area. Four species which ranged in absolute density from 10 plants per hectare for A. praelongus to 186 plants per hectare for A. amphioxys were located in this area. Astragalus sabulonum and A. lancearius were intermediate between these two with respect to density values. Absolute cover values were low for all four species, ranging from .001 to .074 percent.

Site 6 was located in the southwest corner of Section 11 about .8 miles from site 5. Astragalus praelongus occurred alone at this site along a small unnamed wash extending southward from the road to Black Falls. Absolute density for A. praelongus at this site was 368.4 plants per hectare and absolute cover values were 1.289 percent, both considerably higher than at site 5.

Site 7 was located along Forest Service Road 545 at Citadel Sink, immediately south of the parking area and along both sides of the road. Astragalus lentiginosus occurred in this area at an absolute density of 100 plants per hectare and an absolute cover value of .196 percent.

Table 2 lists the bruchid beetles (family Bruchidae: Coleoptera) that were reared from seed collections of each Astragalus species.

All Astragalus species mentioned in this report had bruchids reared from them. The bruchid beetles which were reared include: Acanthoscelides aureolus (Horn), Acanthoscelides mixtus (Horn), and Acanthoscelides pullus (Fall). All three of these species have been recorded infesting seeds of Astragalus lentiginosus, Astragalus praelongus, and Astragalus wootoni (Center and Johnson, 1976). All other host plants listed in Table 7 and mentioned in this report represent previously unknown host records for bruchid beetles.

All of the three new host plants were found only at site 5, near Black Falls. Only one bruchid was reared from seed cultures of Astragalus amphioxys. This represents a new host record for Acanthoscelides aureolus. Several

Acanthoscelides mixus were reared from cultures of Astragalus sabulonum which also represents new information. The final new host record was Astragalus lancearius from which several Acanthoscelides aureolus were reared. Astragalus lancearius is listed as a threatened species in the Smithsonian Institution publication, Endangered and Threatened Plants of the United States (Ayensu and DeFilipps, 1978).

Behavioral notes were prepared describing the habits displayed by bruchids attacking each plant species. Due to the similarity of both egg morphology and bruchid behavior, it was impossible to tell which bruchids behaved in which way and these observations are applied to all three species at this time.

On A. praelongus, oviposition frequently occurred beneath the calyx on the surface of the pod and near its midrib. Eggs at this location were attached by being wedged in amongst the pubescence. Other eggs were attached to the pod surface near its midrib by gluing, the glue apparently being of bruchid origin. When pods dehisced and seeds became exposed, eggs were observed glued to the flat sides of the seeds.

Larvae which hatched from the eggs then bored into the pod or seed directly below the eclosion hole located at one end of the egg. Those oviposited beneath the calyx usually migrated to the pod surface before entering the pod.

The larvae, which consumed only a single seed, pupated inside the seed before exiting from one end of the seed as an adult. The adult usually emerged from the pod by boring a hole through it near the midrib. Many times, other adults were observed using a previously established hole to exit. This behavior was often observed even when the pod had dehisced.

Bruchid behavior on A. wootoni was very much like it was on A. praelongus, with few exceptions. Apparently, adults often entered a previously established exit hole to oviposit directly on a seed. This was evidenced by the fact that, when pods were dissected, eggs were often found glued to the seeds. No preferred

emergence location was observed on the pods and bruchids seemed to choose the location of emergence at random.

On A. lentiginosus, bruchids behaved almost identically as they did on A. praelongus. The only observed difference was that there seemed to be a preference in exit hole location on the pods of A. praelongus, but no preference on A. lentiginosus. This same trend was seen on A. lancearius. No eggs could be located in A. sabulonum or A. amphioxys, but it is suspected that bruchids on these species behave in much the same way as the previous descriptions indicate.

DISCUSSION

Six species of locoweeds were studied to determine their interactions with beetles of the family Bruchidae. Three of these locoweeds host three different species of bruchid, all of which were previously known records. Three other locoweeds, however, were determined to be new hosts of two of these bruchids.

Future work on this study will include statistical analyses to determine which ecological factors influence Bruchids to attack a given population of locoweeds. Factors which will be tested include whether or not the locoweed is isolated from other species of locoweeds, the density of the population of locoweeds, and whether or not the bruchid must compete with other species of bruchids for the host plant. Upon completion of this work, a completed Master's Thesis will be presented to the National Park Service Southwest Regional Office.

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Table 1. Absolute density values and absolute cover percentages for all Astragalus species at each seed collection site.

<u>Seed Collection Site Number</u>	<u>Species Present</u>	<u>Absolute Density (plants/hectare)</u>	<u>Absolute Cover (%)</u>
1.	<u>Astragalus wootoni</u>	11,200	1.050
2.	<u>Astragalus lentiginosus</u>	8.1	.016
3.	<u>Astragalus lentiginosus</u> <u>Astragalus wootoni</u>	133.2 86.6	.262 .170
4.	<u>Astragalus wootoni</u> ¹	5 plants closely clustered	
5.	<u>Astragalus praelongus</u> <u>Astragalus amphioxys</u> <u>Astragalus sabulonum</u> <u>Astragalus lancearius</u>	10 186 50 14	.004 .074 .001 .050
6.	<u>Astragalus praelongus</u>	368.4	1.289
7.	<u>Astragalus lentiginosus</u>	100	.196

¹ No absolute density or cover values calculated.

Table 2. A list of beetles of the family Bruchidae that were reared from each Astragalus species. Species identification confirmed by C.D. Johnson.
 * indicates a new host record.

<u>HOST</u>	<u>SEED PREDATOR</u>
<u>Astragalus lentiginosus</u>	1. <u>Acanthoscelides aureolus</u> 2. <u>Acanthoscelides mixtus</u> 3. <u>Acanthoscelides pallus</u>
<u>Astragalus praelongus</u>	1. <u>Acanthoscelides aureolus</u> 2. <u>Acanthoscelides mixtus</u> 3. <u>Acanthoscelides pallus</u>
<u>Astragalus wootoni</u>	1. <u>Acanthoscelides aureolus</u> 2. <u>Acanthoscelides mixtus</u> 3. <u>Acanthoscelides pallus</u>
<u>Astragalus amphioxys</u>	*1. <u>Acanthoscelides aureolus</u>
<u>Astragalus lancearius</u>	*1. <u>Acanthoscelides aureolus</u>
<u>Astragalus sabulonum</u>	*1. <u>Acanthoscelides mixtus</u>

III

A SURVEY OF ARTHROPOD COMMUNITIES OF SUNSET
CRATER AND WUPATKI NATIONAL MONUMENTS (SPRING, 1979)
WITH COMMENTS ABOUT TWO PREVIOUS SURVEYS

Jon F. Peters, Research Assistant

Clarence Dan Johnson, Entomologist

INTRODUCTION

This spring survey of the arthropods of Wupatki and Sunset Crater National Monuments is the third and concluding phase of a study to characterize the arthropod composition within the two monuments. The previous studies were reported by Peters and Johnson (1978, 1979). In this study and in the prior two studies, four plant communities were sampled: Grassland, Juniper/Grassland, Ponderosa Pine, and Cold Desert Shrub. Sunset Crater National Monument contains only the Ponderosa Pine community, with the other three communities in Wupatki National Monument.

Few arthropod studies have been conducted on the monuments. In his famous study of the San Francisco Mountain area, Merriam (1890) reported the presence of two Tenebrionid beetle genera around what was to become Wupatki National Monument. Much later, Wyman and Bailey (1964) published a booklet in which they listed insect species that were known to the Navajo Indians living around the Wupatki area. Although this list was compiled by using conversations with Navajos and not with field experiments, the list seems to be a fairly accurate representation of the more visible insects in the area. A more recent study (Welbourn, 1979) was undertaken in 1974-1975 to study arthropods in several earth cracks of Wupatki National Monument. The 1974-75 study is the only modern survey of arthropods known to have taken place on Wupatki National Monument before Peters and Johnson (1978). No arthropod studies of Sunset Crater before 1977 are known.

To conduct this survey, seven sites were established within the four vegetation communities. The seventh site was established only in the spring of 1979 in the Ponderosa Pine community northeast of Sunset Crater to contrast with the Bonito Park area, also in Ponderosa Pine. This new site was established because it had a more continuous cinder cover than the Bonito Park site.

METHODS AND MATERIALS

The six sites that were established in the two monuments for the 1977 and 1978 studies were also used in the 1979 spring survey. One additional site, Site 5, was established in the Ponderosa Pine northeast of Sunset Crater for this study.

Two of these seven sites were located at the visitor centers and are designated Visitor Center-Sunset Crater (VCS) and Visitor Center-Wupatki (VCW). At each of these sites a black-light trap was operated 24 hours per day throughout the study period. The light traps used were Ellisco Insect Survey Traps, model number 110103. These traps required 110 volts and thus were placed near the visitor centers using 100 ft. extension cords. To catch smaller arthropods, the trap was modified somewhat by attaching a fine mesh screen to the bottom grate and packing foam around the bottom grate to keep any arthropods from bypassing the grate and settling on the bottom. The Sunset Crater Visitor Center is located in Ponderosa Pine at an elevation of 6927 feet; the Wupatki Visitor Center is predominantly Cold Desert Shrub or Great Basin Desert and is located at an elevation of 4870 feet.

The other five sites, designated S1, S2, S3, S4, and S5, were located throughout the two monuments in four major vegetation communities. Site 1 was located in Cold Desert Shrub at 4410 feet, Site 2 in Juniper/Grassland at 5430 feet, Site 3 in Grassland at 5360 feet, Site 4 in Ponderosa Pine on the edge of Bonito Park at 7005 feet, and Site 5 also in Ponderosa Pine but on the northeast side of Sunset Crater at 6786 feet. Locations of all seven sites are shown in Figure 1.

A transect 125 yards in length was established at each of the five non-Visitor Center sites, each with 25 pitfall traps. These pitfall traps consisted of a five inch diameter plastic bucket set in the ground with a 12 inch

by 12 inch particle-board lid. The lid was supported by three stones and protected captured arthropods from rain and excessive heat. This arrangement also produced a more alluring trap, since insects would be attracted to the protection the lid offered from heat, cold, rain, and the promise of a possible hiding place.

Arthropods were sampled at all seven sites once a week from 15 March to 17 May. At the visitor centers, captured arthropods were removed from the black-light traps using a funnel and put into a wide-mouth jar containing 70% ethyl alcohol. At the other five sites, any arthropods caught in the pitfall traps or by sweeping were collected and also stored in 70% ethyl alcohol. At the weekly visits to these five sites, 200 sweep strokes with a sweep net were made per site. The order in which sites were checked was reversed each week in an attempt to overcome a time bias when sweeping.

Black-lights and pitfall traps began operating 8 March 1979. The only exception was Site 4, which began operating 8 March but still had six pitfall traps under ice. It was not until 29 March that all pitfall traps at Site 4 were free of ice and water. Thus, the first sampling of these pitfall traps and sweeping for insects was 15 March, with the last sampling day for all sites and methods being 17 May 1979.

Borror et al. (1976) was employed for identification of insects and some additional arthropods. Stebbins (1966) was used for identification of reptiles.

RESULTS

Data from the spring arthropod study are compiled and summarized in Tables 1 through 10. Tables 1 and 2 list the number of insects caught in the black-light traps at Visitor Center-Sunset Crater and Visitor Center-Wupatki. Sites 1 through 5 have combined data for pitfall traps and sweepings summar-

ized in Tables 3 through 7, with each table corresponding to the appropriate site. Species of darkling beetles (Tenebrionidae: Coleoptera) captured in pitfall traps at Sites 1 through 5 are listed in Table 8 by site, week, and species. Table 9 is a listing of all reptiles caught in pitfall traps. All reptiles captured were lizards except for one occurrence of a Praire rattlesnake (Crotalus viridis viridis) at Site 3 on 2 May 1979. Finally, Table 10 lists all insect families with their recognized common names caught at Wupatki and Sunset Crater National Monuments during the spring study.

Tables 11, 12, and 13 summarize certain data collected throughout the three study periods during 1977-1979. Table 11 lists by species and monument location all species of darkling beetles (Tenebrionidae: Coleoptera) caught during all sampling periods. The total number of insects captured by all sites and methods over the three year study are in Table 12. Lastly, Table 13 is a list of all insect families and their common names collected at the two monuments during the three study periods.

None of the sampling periods were of equal length. The summer study period of 1977 began 5 July 1977 at most sites and finished 29 October 1977. The following year the study was initiated 6 May 1978 and ceased on 28 October 1978. The final sampling was begun 15 March 1979 and terminated on 17 May 1979. Thus, the 1978 study was about 6 months long and the 1979 study concentrated on the spring months only.

DISCUSSION

Sunset Crater Black Light Trap (VCS)

As in previous years, the black-light trap at Sunset Crater Visitor Center caught more insects and had more families represented than the black-light at Wupatki Visitor Center (Tables 1 and 2). Except for three moths cap-

tured before 12 April, there was no insect activity before mid-April. The spring of 1979 was cooler and more moist than the previous two years, and this may have delayed the emergence of many insects in this area. Probably, a general statement that few insects become active before mid-April in the Ponderosa Pine of Sunset Crater would be correct.

Dominant families of insects captured in the black-light trap include the Noctuid moths (Noctuidae), snout moths (Pyralidae), mosquitoes (Culicidae), and fungus gnats (Mycetophilidae). Nine beetle (Coleoptera) families were identified during the spring sample, but most occurred in relatively low numbers with no particular family being dominant.

A white-lined sphinx moth, Hyles lineata (F.), was captured on 12 April. In the following weeks, seven more individuals were captured between 19 April and 2 May. Three white-lined sphinx moths were captured in the black-light trap during the week of 19 April and on 2 May, and one during the week of 26 April.

Wupatki Black-light Trap (VCW)

Although the Wupatki black-light trap caught fewer insects and had fewer families represented than the Sunset Crater black-light trap, the fewer families present had more individuals per family. This would indicate that in the spring the Cold Desert Shrub community demonstrates less dominance than the Ponderosa Pine community.

With a warmer climate, insect activity was noticed at the black-light trap about a month before the Sunset Crater area; the 22nd of March in contrast to 12 April for the Sunset Crater black-light. Yearly weather fluctuations will probably modify an initial spring emergence of insects by two to four weeks, so these dates should be used only as relative emergence times for the insects of the monuments.

Two families of beetles were seen to predominate at the Wupatki Visitor Center black-light trap. Scarab or June beetles (Scarabaeidae) were the most abundant with ladybird beetles (Coccinellidae) also well represented.

Many large parasitic Ichneumonid wasps (Ichneumonidae: Hymenoptera) were captured during the spring sampling but neither winged male velvet ants (Mutillidae) nor Tiphid wasps (Tiphidae) were collected.

The most abundant insects collected at the trap were moths (Lepidoptera). Noctuid moths (Noctuidae) and snout moths (Pyralidae) had the highest number of individuals caught. Also present in high numbers were sphinx moths (Sphingidae).

Two species of sphinx moths were collected in the black-light trap. The white-lined sphinx moth, Hyles lineata (F.), was present in greatest numbers. It was captured in nearly all weeks between 29 March and 10 May. Another sphinx moth, Dictyosoma elsa (Strecker) was caught from 19 April to 10 May. This black and white sphinx moth had not been captured in previous years, but had been noticed at Wupatki before. No Manduca spp. sphinx moths were seen.

Another large moth caught was Glover's silk moth, Platysamia gloveri (Strecker). This Saturniid moth was captured in the black-light trap on 26 April and 10 May.

Pitfall Traps

Darkling beetles (Tenebrionidae: Coleoptera) were the most common beetles found in pitfall traps at most sites, as has been the case in previous years. Sites 3 and 4 had many more Tenebrionid beetles than the other sites. The only site which had a beetle family more abundant than Tenebrionid beetles was Site 1. In this case, an outbreak of Hister beetles (Histeridae) occurred on 19 April. All the Hister beetles caught were in only two pitfall traps.

Probably, a decaying animal attracted these beetles during the week, but no carcasses were found when observing the Hister beetles at Site 1.

Table 8 lists the Tenebrionid beetle species caught by date and site. At Sites 1 through 3, Melanastus nitidus and Eleodes hispilabris were very abundant. At Site 4, Eleodes extricata and E. obscura were most abundant. In contrast to Site 4, at Site 5 the very small Tenebrionid beetle M. nitidus was very dominant. Another difference between Sites 4 and 5 can be seen in Table 8. At Site 4, only one Tenebrionid beetle was captured before 12 April, whereas at Site 5 Tenebrionid beetles were common from 15 March. Thus, although Site 4 had more than twice as many Tenebrionid species as Site 5, the latter site showed Tenebrionid beetle activity at least four weeks earlier.

In addition to the Tenebrionid beetle species occurring on the monuments listed in Table 8, Welbourn (1979) lists Eleodes delicata (Blaisdell) and Steriphanus convexulus (LeConte) as also present on Wupatki National Monument. He also lists Glyptasida convexulus (LeConte) as present, and this may be the same species of Glyptasida listed in Table 8. Triplehorn (1975) reports a troglomorphic Tenebrionid beetle Eleodes leptoscelis as occurring northwest of Wupatki National Monument. However, it has not yet been found on the monument.

Several large, black, ground beetles in the genus Calosoma (Carabidae) were collected at Sites 1 and 3. They were captured at Site 1 on 15 and 29 March and 19 April. At Site 3 two individuals were caught on 15 March and 2 May. One Agonum sp. carabid beetle was captured at Site 5 on 26 April. Welbourn (1979) has reported that a Carabid beetle, Rhadine sp., occurs in certain parts of Wupatki National Monument.

Camel crickets (Gryllacrididae: Orthoptera) were caught at all sites except Site 2. These were all Ceuthophilus sp. Welbourn (1979) reported

C. yavapai (Hubbel) as occurring in some earth cracks on Wupatki National Monument and this is probably the species that occurs throughout the two monuments.

One adult Apantesis sp. tiger moth (Arctiidae) was captured at Site 3 on 29 March. These tiger moths were fairly common throughout the study periods in pitfall traps at several Wupatki sites both in larval and adult forms.

Extremely small click beetles (Elateridae) were caught at Site 5. These were not found at any other site during any of the sampling periods.

Sweeping

When insects were collected by sweeping, Sites 1 and 3 had more insect families and numbers present. This probably occurred because of the abundant spring rains and subsequent flowering at these two sites. Site 4 was under snow much of the spring and Site 2 remains the least diverse site in all sampling periods. Only one insect was caught during ten weeks of sweeping at Site 2. Surprisingly, at Site 5 many insects were caught by sweeping. Site 5 is completely covered by cinders with Ponderosa Pine (Pinus ponderosa) common and some Apache Plume (Fallugia paradoxa) present. Since there was very little vegetation to sweep, this result is unexpected (Table 7).

The grasses at Site 3 around 5 April were heavily trampled by cattle. This was the most important factor in explaining why sweep totals for late March and early April at Site 3 were so low. Since the grasses were crushed to the ground, very little could be swept. In addition, damage to pitfall traps at Site 3 this year was extreme compared with previous years. However, within three weeks after 5 April, the vegetation seemed to be recovering well.

At Sites 1 and 2, no large numbers of insects were captured by sweeping. As mentioned earlier, only one insect was captured at Site 2. Insects seem to be found most abundantly at Site 1 after 26 April. At Site 3, leaf beetles

(Chrysomelidae), and several families of flies (Diptera) were most abundant. Cattle activity interfered with normal growth patterns of plants and thus probably affected insects during the early spring at Site 3.

In the Ponderosa Pine, both Sites 4 and 5 also showed little insect activity on vegetation before 26 April. Although few insect families were present in large numbers at Site 4, fruit flies (Tephritidae) and other flies were most abundant. Plant bugs (Miridae: Hemiptera) and ladybird beetles (Coccinellidae) were most abundant at Site 5.

In general, the high winds and cool weather that is normally associated in the spring months on the monuments are not favorable to sweeping during this time. The geographic locations and elevations of the monuments influence insect activity greatly throughout the year, but especially in the spring.

Arthropods Other Than Insects

Only one scorpion was captured on the monuments. A small Vejovis sp. scorpion was caught at Site 1 on 22 March. Few scorpions were caught at Site 1 in 1978, but many were captured in 1977. Only at Site 1 were scorpions caught during the three sampling periods.

Several Scolopendra sp. centipedes were caught in pitfall traps at Site 3. One individual each was caught on 15 March, 12 April, and 2 May.

At Site 5, the dominant spiders in pitfall traps were Amaurobiid spiders (Amaurobiidae). Although no pseudoscorpions were noted this spring, Welbourn (1979) has reported two species occurring on Wupatki National Monument: Archeolarca sp. and Pseudogarypus species. Also, no sun-scorpions (Solpugida) were noted in this spring sample.

Other Observations

Large, black, cryptically colored grasshoppers (Acrididae) were active at

Site 3 on 19 April. Painted lady butterflies (Nymphalidae: Lepidoptera) were also observed at Sites 3 and 2 on this date in great numbers. Both Vanessa cardui and V. virginiensis, the American Painted Lady, are known to occur around Flagstaff and probably occur on the monuments.

An outbreak of cutworm moths (Noctuidae) occurred around 19 April on the monuments, feeding during the day at flowers for several weeks. Also seen were cabbage and sulfur butterflies (Pieridae) around this date.

Reptiles that were caught in pitfall traps and released are listed by site and date in Table 9. All were lizards except one Prairie rattlesnake (Crotalus viridis viridis) captured at Site 3 on 2 May. This was the first Prairie rattlesnake seen and the second rattlesnake caught at Site 3. In 1977, a Hopi rattlesnake (Crotalus viridis nuntius) was captured at Site 3. The Prairie and Hopi rattlesnakes are subspecies of the Western rattlesnake. Neither Bateman (1976) nor Overcast and Bateman (1979) list the Prairie and Hopi rattlesnakes as occurring on Wupatki National Monument. Site 3 had the highest diversity and abundance of reptiles of all sites.

SPRING SURVEY

CONCLUSIONS AND RECOMMENDATIONS

The spring sampling of arthropods on Wupatki and Sunset Crater National Monuments revealed several differences between the arthropod communities of the two monuments. Arthropod activity became noticeable four weeks earlier at Wupatki than Sunset Crater. Most traps began capturing appreciable numbers of arthropods at Wupatki about mid-March compared to mid-April for the Sunset Crater area. Secondly, the black-light trap at Sunset Crater demonstrated more families and total number of insects caught than the black-light trap at Wupatki. However, the Wupatki black-light trap had less dominance and more evenness

represented in its sample of insects than Sunset Crater. Thirdly, the white-lined sphinx moth, Hyles lineata, emerged at Wupatki 29 March compared with a later date of 12 April at Sunset Crater. Also, a second sphinx moth, Dictyosoma elsa, was present at Wupatki and not at Sunset Crater.

Outbreaks of insects occurred during the spring sampling in several insect groups. At Site 1, 35 Hister beetles were captured in pitfall traps before 19 April. Over 300 mosquitoes were captured in the black-light trap at Sunset Crater in one week preceding 2 May.

The two Ponderosa Pine sites, Sites 4 and 5, showed several differences and similarities. If pitfall trap data were considered, the sites were very dissimilar. Site 4 had twice as many tenebrionid beetle species as Site 5 and few species were the same at both sites. Also, the number of Tenebrionid beetles captured at Site 4 was much greater than at Site 5. This was to be expected, since Site 4 is much richer in vegetative cover and diversity. However, if sweeping data were analyzed the sites seem to have much in common. Site 5 had 11 families represented; Site 4 had ten families. Also, each site had about the same total of insects collected. This similarity in sweeping data may be superficial and have occurred because Site 5 warms earlier than Site 4; given several more weeks Site 4 probably would have surpassed by a considerable degree the richness of insect sweeping fauna of Site 5 since Site 4 has a much greater abundance and diversity of vegetative ground cover.

Finally, the effects of cattle at Site 3 this spring were striking. The heavy damage inflicted by the cattle on the grasses of the area suppressed insect activity greatly for several weeks. This in turn may have stressed insectivorous animals and may have had detrimental effects farther along the food chain. Desert areas like Wupatki certainly have a slow recovery period

for major disturbances. Care should be exercised when altering the monument areas with thought toward disturbance and recovery. Since Pronghorn Antelope (Antilocarpa americana) are often seen around Site 3, one has to wonder about possible deleterious competition with the cattle for available food and space on Wupatki National Monument. By grazing preferred foliage, the cattle may also be changing the composition of the vegetation of the area and hence the inter-relationship of its fauna.

THREE YEAR SURVEY SUMMARY AND CONCLUSIONS

The arthropod communities of Wupatki and Sunset Crater National Monuments vary considerably in abundance and diversity. The four arthropod communities were analyzed using Simpson's index of diversity (D_s) and Morisita's index of similarity (I_m or C_λ). Among the many findings, five major trends were evident:

1. The Cold Desert Shrub arthropod community is the least stable and predictable of the four communities studied. When 1977 and 1978 were contrasted using Morisita's index, the Cold Desert Shrub sites of Visitor-Center Wupatki and Site 1 showed a dramatic decline in similarity between the two years. These sites were also unstable in relation to adjacent seasons within the same year when compared between years.

The single most important factor affecting the Cold Desert Shrub is the pattern of rainfall. During the summer when arthropod activity is the most sensitive to rainfall, this community receives moisture most often in the form of scattered, isolated thundershowers. Both the plants and arthropods act as opportunists within this community, waiting for the correct amount of rain in order to become active. Thus, from year to year at a given site, it is ex-

tremely difficult to predict arthropod abundance since rainfall is so erratic and unpredictable. Temperature differences between years may also cause arthropod activity to vary.

2. The Ponderosa Pine arthropod community is the most stable and predictable of the four communities studied. A comparison of seasons between years showed little change from year to year.

Several factors produced this stability. Since most of the available plants within the Ponderosa Pine are evergreen, arthropods using these plants could depend on the plants being in a particular state each year. Also, the activity period for arthropods around Sunset Crater is only two months. The arthropods have little choice but to emerge mostly in July regardless of conditions, for if they attempt to wait for more favorable conditions they may find insufficient time remaining for completion of their life histories before cold weather arrives. Lastly, the July and August rains in the Ponderosa Pine are much more predictable and wide-spread than in the other communities.

3. Abiotic factors are more important in determining arthropod abundance within the Cold Desert Shrub community than the Ponderosa Pine. The Cold Desert Shrub community represents a more marginal habitat than the Ponderosa Pine community because of extreme temperatures and scant rainfall. Within the Cold Desert Shrub, rainfall and temperature determine arthropod levels of abundance in a much more critical manner than within the Ponderosa Pine.

4. Ground dwelling arthropods are more predictable in their occurrence than vegetation-dwelling arthropods. In part, this result is a product of the sampling method. Sweeping is affected by both wind and rain. Since high winds occur on the monuments much of the time, arthropods on vegetation would tend to be distributed close to the ground and would not be caught by sweep-

ing. If sweeping was done on a cloudy, wet day, this would also reduce the number of arthropods caught. Also, much of the ground on the monuments is covered by cinders and does not support the kind of vegetative cover amenable to sweeping. For these reasons, sweeping is not considered a good method for sampling arthropods on the monuments.

In contrast, ground dwelling insects can be caught by pitfall traps regardless of weather conditions and at any time of the day. As expected, the results from pitfall trap data are more uniform from year to year and more reliable than the sweeping data.

5. Site 2 (Juniper/Grassland) and Site 3 (Grassland) arthropod communities were similar. This would be predicted since the two sites are only a few miles apart and are at about the same elevation. The same species of grasses exist in both communities. Also, both would receive about the same amount of rainfall at the same time.

A more detailed analysis of these results will be forthcoming in a Master of Science thesis. A copy will be sent to the National Park Service.

Sunset Crater National Monument is very diverse. No arthropod sampling was done on the lava flows or on the cinder hills. Probably, the arthropod composition varies considerably within different areas around Sunset Crater. Therefore, the results of Sites 4, 5, and the black-light trap at VCS may be applicable to only a few areas of Sunset Crater National Monument.

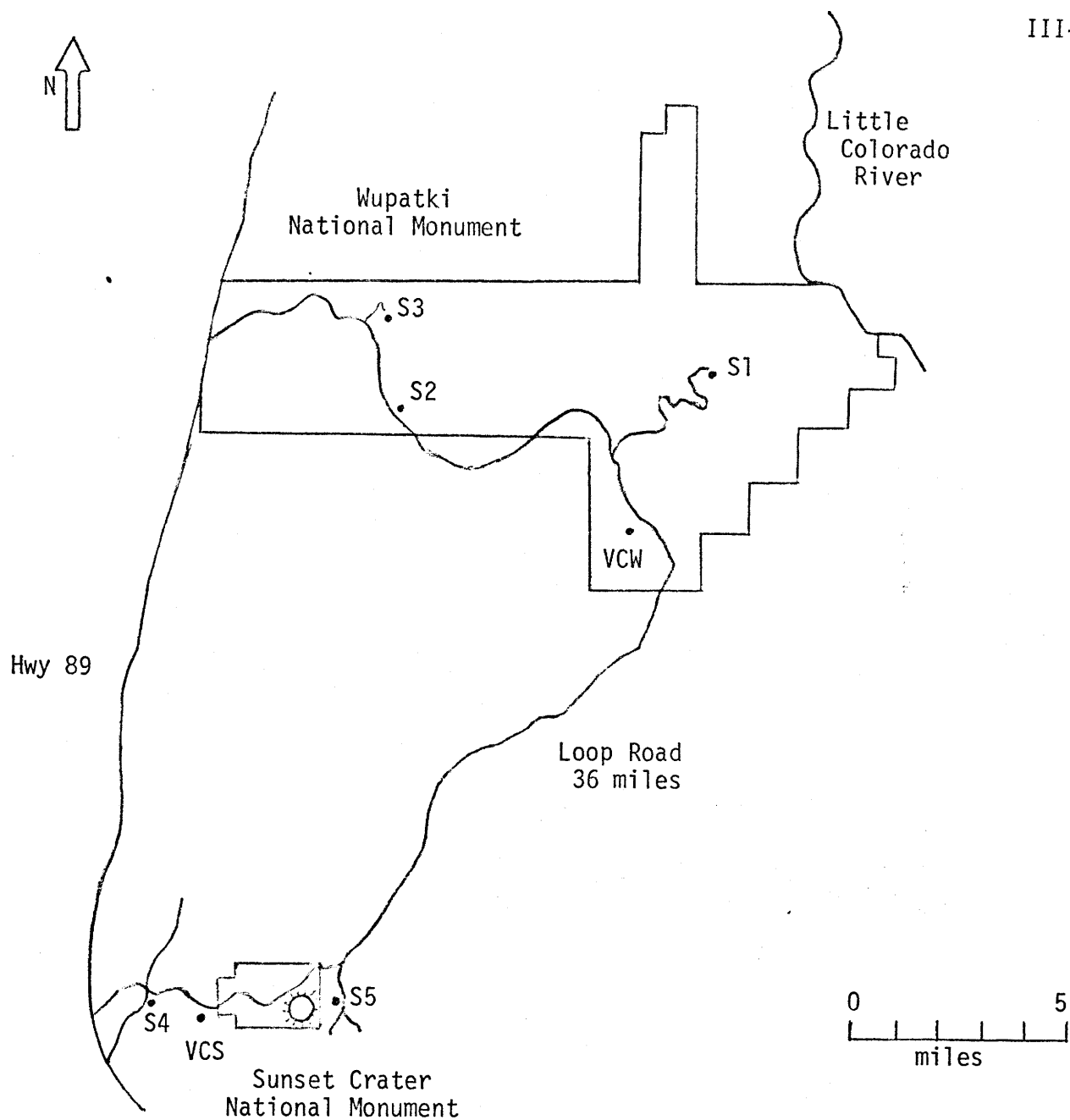
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KEY	Elevation (ft.)
VCS - Visitor Center-Sunset Crater	6927
VCW - Visitor Center-Wupatki	4870
S1 - Site 1: Cold Desert Shrub	4410
S2 - Site 2: Juniper/Grassland	5430
S3 - Site 3: Grassland	5360
S4 - Site 4: Ponderosa Pine	7005
S5 - Site 5: Ponderosa Pine	6786

Fig. 1. Map of Wupatki and Sunset Crater National Monuments showing location of sites used in the insect survey, 1979.

Table 1. VCS: Summarized Data for the Black Light Trap at Sunset Crater Visitor Center, 1979

		*		*		*		*		*		Total
		3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	
Coleoptera	Anobiidae								1			1
	Bostrichidae										2	2
	Chrysomelidae							1				1
	Coccinellidae						1		4		1	6
	Curculionidae						1					1
	Hydrophilidae					1	1	2				4
	Nitidulidae							1	1		1	3
	Scarabaeidae						1		5		1	7
	Scolytidae								1		1	2
Diptera	Asilidae					2	1					3
	Calliphoridae					1			2			3
	Culicidae							7	323		11	341
	Drosophilidae								1			1
	Mycetophilidae					5	17	17	80		26	145
	Syrphidae								2			2

Table continued

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Total
Tephritidae								1			1
Unknown							1			1	2
Hemiptera											
Lygaeidae						1				3	4
Hymenoptera											
Ichneumonidae								1			1
Tiphiidae					1	2	1				4
Lepidoptera											
Geometridae						2	2	2			6
Lasiocampidae						2	1	4		3	10
Noctuidae		1	1		6	15	52	87		46	208
Pterophoridae								1			1
Pyralidae	1				7	4	14	28		10	64
Sphingidae					1	3	1	3			8
Trichoptera											
Limnephilidae								1			1
TOTAL	1	1	1		24	51	100	548	—	106	832

* Black light found blown over.

Table 2. VCW: Summarized Data for the Black Light Trap at Wupatki Visitor Center, 1979.

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Total
Coleoptera											
Carabidae								1			1
Coccinellidae					1	18	1	2			22
Histeridae					1						1
Hydrophilidae						1					1
Scarabaeidae						3	2	25	13		43
Diptera											
Calliphoridae			1								1
Muscidae						1					1
Mycetophilidae		2			1		3		3		9
Unknown							4		2		6
Hemiptera											
Corixidae					4	1	7				12
Miridae		2									2
Pentatomidae									1		1
Hymenoptera											
Ichneumonidae		3	19	1	21	5	9	13			71
Lepidoptera											
Arctiidae								1			1

Table continued

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Total
Gelechiidae			1								1
Geometridae		3	9		7			1	1		21
Noctuidae		2	7		34	39	46	29	44		201
Pyrilidae	2	18	66	1	1	8	7	13	2		118
Saturniidae							1		1		2
Sphingidae			3		3	3	9	11	14		43
Unknown								1			1
TOTAL	2	30	106	2	73	79	89	97	81	—	559

* Black light trap not working during week.

Table 3. Combined Data for Site 1, Cold Desert Shrub: Pitfall Traps and Sweeping. (# per pitfall traps/# per sweeps)

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Pittraps	Sweeps	Total
Coleoptera													
Carabidae	3/		1/			1/					5		5
Coccinellidae								/1	/1	/1		3	3
Curculionidae	1/			1/	3/	1/	1/1		1/		8	1	9
Histeridae						35/					35		35
Staphylinidae		1/									1		1
Tenebrionidae	1/	2/	1/				1/	3/	3/		11		11
Diptera													
Acroceridae								/1				1	1
Muscidae						/1		/3				4	4
Tephritidae								/3		/1		4	4
Rhagionidae										/3		3	3
Unknown									/1			1	1
Hemiptera													
Miridae								/4	/1	/2		7	7
Homoptera													
Cicadellidae				/1								1	1
Psyllidae						/1						1	1
Hymenoptera													
Braconidae									/1			1	1
Formicidae								/1	/3	/4		8	8

Table continued

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Pittraps	Sweeps	Total
Ichneumonidae								/1				1	1
Mutillidae								1/	2/	1/	4		4
Pteromalidae										/2		2	2
Sphecidae								1/			1		1
Tiphiidae										1/	1		1
Lepidoptera													
Arctiidae				1/					1/		2		2
Noctuidae										/1		1	1
Pyrilidae					1/						1		1
Unknown	1/	8/		3/	2/	2/1	2/				18	1	19
Neuroptera													
Raphidiidae								/1				1	1
Orthoptera													
Blattidae						1/		1/			2		2
Gryllacrididae	6/	1/	2/				2/				11		11
Pit traps	12	12	4	5	6	40	6	6	7	2	100	—	—
Sweeps				1		3	1	15	7	14	—	41	—
TOTAL	12	12	4	6	6	43	7	21	14	16	—	—	141

Table 4. Combined Data for Site 2, Juniper/Grassland: Pitfall Traps and Sweeping. (# per pitfall traps/# per sweeps)

*

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Pittraps	Sweeps	Total
Coleoptera													
Buprestidae										/1		1	1
Curculionidae			1/			1/		1/	2/	1/	6		6
Nitidulidae								1/			1		1
Scolytidae									1/		1		1
Tenebrionidae	2/		6/		2/	4/	3/	3/			20		20
Diptera													
Sciaridae			1/								1		1
Lepidoptera													
Unknown	2/		1/								3		3
Pittraps	4		9		2	5	3	5	3	1	32	—	—
Sweeps					—					1	—	1	—
TOTAL	4		9		2	5	3	5	3	2	—	—	33

* High winds, no sweeping done.

Table 5. Combined Data for Site 3, Grassland: Pitfall traps and Sweeping. (# per pitfall traps/# per sweeps)

	*					**							
	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Pittraps	Sweeps	Total
Coleoptera													
Carabidae	1/							1/			2		2
Chrysomelidae								/1	1/	/4	1	5	6
Curculionidae		4/	1/		2/	1/		2/	3/	4/1	17	1	18
Melyridae										/4		4	4
Scarabaeidae			2/								2		2
Tenebrionidae	5/	3/	7/		27/	5/	1/	10/	7/	3/	68		68
Diptera													
Asilidae	/1											1	1
Muscidae							/1	/1				2	2
Simuliidae										/1		1	1
Tephritidae							/2	/2		/1		5	5
Unknown	/2									/8		10	10
Hemiptera													
Lygaeidae										/5		5	5
Pentatomidae									1/		1		1
Homoptera													
Cicadellidae							/1	/2		/2		5	5

Table continued

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Pittraps	Sweeps	Total
Hymenoptera													
Anthophoridae										/1		1	1
Chalcididae										/1		1	1
Formicidae								/1				1	1
Ichneumonidae										/1		1	1
Mutillidae					1/	1/		2/	2/	1/	7		7
Pompilidae								1/			1		1
Pteromalidae								/1		/3		4	4
Lepidoptera													
Arctiidae			1/								1		1
Noctuidae									1/		1		1
Orthoptera													
Acrididae							/1					1	1
Gryllacrididae		1/									1		1
Unknown								1/			1		1
Pittraps	6	8	11		30	7	1	17	15	8	103	—	—
Sweeps	3				—		5	8	—	32	—	48	—
TOTAL	9	8	11		30	7	6	25	15	40	—	—	151

* High winds, no sweeping done

** Rain, no sweeping done.

Table 6. Combined Data for Site 4, Ponderosa Pine: Pitfall traps and Sweeping (# per pitfall traps/# per sweeps)

	*	**		**									
	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Pittraps	Sweeps	Total
Coleoptera													
Chrysomelidae								1/			1		1
Curculionidae								2/	11/	3/	16		16
Tenebrionidae		1/			1/	10/	5/	24/	29/	37/	107		107
Diptera													
Acroceridae							/1					1	1
Muscidae							/1		/1			2	2
Tephritidae				/1					/1	/6		8	8
Tipulidae				1/							1		1
Unknown	/1						/1			/3		5	5
Hemiptera													
Lygaeidae										/1		1	1
Miridae							/2	/1				3	3
Homoptera													
Psyllidae										/2		2	2
Hymenoptera													
Braconidae							/1					1	1
Formicidae							/1					1	1
Unknown								/1				1	1

Table continued

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Pittraps	Sweeps	Total
Orthoptera													
Acrididae										1/	1		1
Gryllacrididae						3/		1/			4		4
Pittraps	—	1		1	1	13	5	28	40	41	130	—	—
Sweeps	1	—		1	—		7	2	2	12	—	25	—
TOTAL	1	1		2	1	13	12	30	42	53	—	—	155

* Pittraps not started since 6 were still under ice.

** Snow, no sweeping done.

Table 7. Combined Data for Site 5, Ponderosa Pine: Pitfall traps and Sweeping. (# per pitfall traps/# per sweeps)

		* *										Pittraps	Sweeps	Total
		3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17			
Coleoptera														
	Carabidae				1/			1/				2		2
	Cleridae							/1			/1		2	2
	Coccinellidae							/4					4	4
	Curculionidae						/1						1	1
	Elateridae				11/		1/	2/	1/	2/	3/	20		20
	Tenebrionidae	12/	3/		3/		8/	3/	2/	5/	1/	37		37
Diptera														
	Dolichopodidae		1/									1		1
	Muscidae								/1				1	1
	Tephritidae						/1	/1			/1		3	3
Hemiptera														
	Lygaeidae										/1		1	1
	Miridae							/5					5	5
Homoptera														
	Psyllidae							/1					1	1
Hymenoptera														
	Formicidae							/3			/1		4	4

Table continued

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Pittraps	Sweeps	Total
Ichneumonidae					/1							1	1
Lepidoptera Pieridae							/1					1	1
Orthoptera Gryllacrididae		1/			1/		1/	2/	1/		6		6
Pittraps	12	5		15	1	9	7	5	8	4	66	—	—
Sweeps			—		—	3	16	1		4	—	24	—
TOTAL	12	5		15	1	12	23	6	8	8	—	—	90

* Snow, no sweeping done.

Table 8. Summarized Data for Darkling Beetles (Tenebrionidae: Coleoptera) Caught in Pitfall Traps at All Sites, 1979.

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Total
SITE 1											
<u>Eleodes extricata</u>								2			2
<u>Eleodes hispilabris</u>	1	1	1				1	1			5
<u>Melanastus nitidus</u>		1							3		4
SUBTOTAL SITE 1	1	2	1				1	3	3		<u>11</u>
SITE 2											
<u>Eleodes extricata</u>	1										1
<u>Eleodes hispilabris</u>					1						1
<u>Eleodes longicollis</u>							1	1			2
<u>Melanastus nitidus</u>	1		6		1	4	1	2			15
<u>Zopherus gracilis</u>							1				1
SUBTOTAL SITE 2	2		6		2	4	3	3			<u>20</u>

Table continued

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Total
SITE 3											
<u>Conointis</u> sp.										1	1
<u>Eleodes extricata</u>			1					1	1		3
<u>Eleodes hispilabris</u>	4	2	4		14	3		3	2		32
<u>Eleodes longicollis</u>					4	1		2	2	1	10
<u>Embaphion</u> spp.			1		4	1	1	1			8
<u>Melanastus nitidus</u>	1	1	1		5			3	2	1	14
SUBTOTAL SITE 3	5	3	7		27	5	1	10	7	3	<u>68</u>
SITE 4											
<u>Coelocnemis magnum</u>		1						1	1		3
<u>Eleodes extricata</u>						8	1	9	12	7	37
<u>Eleodes hispilabris</u> *							1	4		8	13
<u>Eleodes obscura</u>							2	9	15	19	45
<u>Eleodes obsoleta</u>									2		2

Table continued

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Total
<u>Embaphion</u> spp.					1	1	1	1		2	6
<u>Melanastus nitidus</u>						1					1
<u>Neobaphion planipennis</u>										1	1
SUBTOTAL SITE 4		1			1	10	5	24	30	37	<u>108</u>
SITE 5											
<u>Coelocnemis magnum</u>								1	1	1	3
<u>Coniontis</u> sp.							1				1
<u>Melanastus nitidus</u>	12	3		3		8	2	1	4		33
SUBTOTAL SITE 5	12	3		3		8	3	2	5	1	<u>37</u>
TOTAL ALL SITES	20	9	14	3	30	27	13	42	45	41	244

* This species designation is doubtful; several species may actually exist.

Table 9. Summarized Data for All Reptiles Caught in Pitfall Traps at All Sites, 1979. *

	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/2	5/10	5/17	Total	
SITE 1: Cold Desert Shrub <u>Uta stansburiana</u>	1										1	
SITE 2: Juniper/Grassland <u>Cnemidophorus velox</u>							1	1		1	3	
<u>Holbrookia maculata</u>							1			1	2	
<u>Sceloporus undulatus</u>							1		1		2	
SITE 3: Grassland <u>Cnemidophorus velox</u>										1	1	
<u>Crotalus viridis viridis</u>								1			1	
<u>Crotaphytus collaris</u>								1		1	2	
<u>Holbrookia maculata</u>	4	4		3	3	3		1			18	
<u>Phrynosoma douglassi</u>						1		2			3	
SITE 5: Ponderosa Pine <u>Sceloporus undulatus</u>						1	1			1	3	
TOTAL	5	4		3	3	5	4	6	1	5	36	

* All were released and may have been captured in subsequent weeks

Table 10. List of Insects Collected at Wupatki and Sunset Crater National Monuments During 1979.

Order/Family	Common Name
COLEOPTERA	
Anobiidae	Anobiid beetles
Bostrichidae	Branch, Twig boring beetles
Buprestidae	Metallic wood-boring beetles
Carabidae	Ground beetles
Chrysomelidae	Leaf beetles
Cleridae	Checkered beetles
Coccinellidae	Ladybird beetles
Curculionidae	Snout beetles, Weevils
Elateridae	Click beetles
Histeridae	Hister beetles
Hydrophilidae	Water scavenger beetles
Melyridae	Soft-winged flower beetles
Nitidulidae	Sap beetles
Scarabaeidae	Scarab, June beetles
Scolytidae	Bark beetles
Staphylinidae	Rove beetles
Tenebrionidae	Darkling beetles
DIPTERA	
Acroceridae	Small-headed flies
Asilidae	Robber flies
Calliphoridae	Blow flies
Culicidae	Mosquitoes
Drosophilidae	Pomace flies

List continued

Order/Family	Common Name
DIPTERA	
Muscidae	House flies
Mycetophilidae	Fungus gnats
Rhagionidae	Snipe flies
Sciaridae	Dark-winged fungus gnats
Syrphidae	Syrphid flies
Tephritidae	Fruit flies
Tipulidae	Crane flies
HEMIPTERA	
Corixidae	Water boatmen
Lygaeidae	Seed bugs
Miridae	Plant bugs
Pentamidae	Stink bugs
HOMOPTERA	
Cicadellidae	Leafhoppers
Psyllidae	Jumping plantlice
HYMENOPTERA	
Anthophoridae	Digger, Cuckoo bees
Braconidae	Braconid wasps
Chalcididae	Chalcidid wasps
Formicidae	Ants
Ichneumonidae	Ichneumonid wasps
Mutillidae	Velvet ants
Pompilidae	Spider wasps
Pteromalidae	Pteromalid wasps

List continued

Order/Family	Common Name
HYMENOPTERA	
Sphecidae	Thread-waisted wasps
Tiphiidae	Tiphiid wasps
LEPIDOPTERA	
Arctiidae	Tiger moths
Gelechiidae	Gelechiid moths
Geometridae	Measuring, Inch worms
Lasiocampidae	Tent caterpillars
Noctuidae	Noctuid moths
Pieridae	White, Sulphur butterflies
Pterophoridae	Plume moths
Pyrilidae	Snout moths
Saturniidae	Giant silkworm moths
Sphingidae	Sphinx moths
NEUROPTERA	
Raphidiidae	Raphidiid snakeflies
ORTHOPTERA	
Acrididae	Short-horned grasshoppers
Blattidae	American cockroaches
Gryllacrididae	Camel crickets
TRICHOPTERA	
Limnephilidae	Northern caddisflies

Table 11. List of All Species of Darkling Beetles (Tenebrionidae: Coleoptera)
Caught at All Sites During Sampling Periods 1978 - 1979.

Species	Monument Location	
	(W= Wupatki; S= Sunset Crater)	
1. <u>Coelocnemis magnum</u>	W	S
2. <u>Conointis</u> sp.	W	S
3. <u>Edrotes ventricosus</u>	W	
4. <u>Eleodes extricata</u>	W	S
5. <u>E. hispilabris</u>	W	S *
6. <u>E. longicollis</u>	W	S
7. <u>E. nigrina</u>		S
8. <u>E. obscura</u>		S
9. <u>E. obsoleta</u>		S
10. <u>Embaphion</u> spp.	W	S
11. <u>Eusattus reticulatus</u>	W	S
12. <u>Glyptasida</u> sp.	W	
13. <u>Gonasida elata</u>	W	
14. <u>Melanastus nitidus</u>	W	S
15. <u>Neobaphion planipennis</u>		S
16. <u>Stenomorpha corrugans</u>		S
17. <u>S. marginata</u>	W	
18. <u>S. obovata</u>	W	
19. <u>Zopherus gracilis</u>	W	S
Total	14	14

* At Site 4, this species designation is doubtful; several species may actually exist.

Table 12. Summarized Totals of All Insects Caught by All Sampling Methods During 1977 - 1979.

Site	1977		1978		1979	
	Pittraps	Sweeps	Pittraps	Sweeps	Pittraps	Sweeps
Site 1	114	141	170	270	100	41
Site 2	134	587	77	112	32	1
Site 3	897	208	410	304	103	48
Site 4	974	2000	1418	1519	130	25
Site 5	—	—	—	—	66	24
Subtotal	2,119	2,936	2,075	2,205	431	139
VCS	22,776		19,654		832	
VCW	18,277		38,296		559	
Subtotal	41,053		57,950		1,391	
Total	46,108		62,230		1,961	

Table 13. List of All Insects Collected at Wupatki and Sunset Crater National Monuments During Sampling Seasons, 1977 - 1979.

Order/Family	Common Name
COLEOPTERA	
Alleculidae	Comb-clawed beetles
Anobiidae	Anobiid beetles
Anthicidae	Antlike flower beetles
Anthribidae	Fungus weevils
Bostrichidae	Branch, Twig borers
Buprestidae	Metallic wood-boring beetles
Cantharidae	Soldier beetles
Carabidae	Ground beetles
Cerambycidae	Long-horned beetles
Chrysomelidae	Leaf beetles
Cicindelidae	Tiger beetles
Cleridae	Checkered beetles
Coccinellidae	Ladybird beetles
Colydiidae	Cylindrical bark beetles
Cucujidae	Flat bark beetles
Curculionidae	Snout beetles, Weevils
Dermestidae	Dermestid, Skin beetles
Dytiscidae	Predaceous diving beetles
Elateridae	Click beetles
Heteroceridae	Variegated mud-loving beetles
Histeridae	Hister beetles
Hydrophilidae	Water scavenger beetles
Lampyridae	Fireflies, Lightning bugs

List continued

Order/Family	Common Name
COLEOPTERA	
Lucanidae	Stag beetles
Lycidae	Net-winged beetles
Melandryidae	False darkling-beetles
Melyridae	Soft-winged flower beetles
Nitidulidae	Sap beetles
Pedilidae	Pedilid beetles
Phalacridae	Shining flower beetles
Phengodidae	Glow-worms
Pyrochroidae	Fire-colored beetles
Scaphidiidae	Shining fungus beetles
Scarabaeidae	Scarab, June beetles
Scolytidae	Bark beetles
Silphidae	Carrion beetles
Staphylinidae	Rove beetles
Tenebrionidae	Darkling beetles
Trogostidae	Bark-gnawing beetles
DIPTERA	
Acroceridae	Small-headed flies
Asilidae	Robber flies
Bibionidae	March flies
Bombyliidae	Bee flies
Calliphoridae	Blow flies
Cecidomyiidae	Gall midges
Chironomidae	Midges

Order/Family	Common Name
DIPTERA	
Conopidae	Thick-headed flies
Culicidae	Mosquitoes
Dolichopodidae	Long-legged flies
Drosophilidae	Pomace flies
Empididae	Dance flies
Leptogastridae	Grass flies
Muscidae	House flies
Mycetophilidae	Fungus gnats
Phoridae	Humpbacked flies
Pipunculidae	Big-headed flies
Rhagionidae	Snipe flies
Sarcophagidae	Flesh flies
Sciaridae	Dark-winged fungus gnats
Sepsidae	Black scavenger flies
Simuliidae	Black flies
Syrphidae	Syrphid flies
Tephritidae	Fruit flies
Therevidae	Stiletto flies
Tipulidae	Crane flies
HEMIPTERA	
Coreidae	Leaf-footed bugs
Corixidae	Water boatman
Cydnidae	Burrower bugs
Lygaeidae	Seed bugs
Miridae	Plant bugs
Nabidae	Damsel bugs

Order/Family	Common Name
HEMIPTERA	
Notonectidae	Backswimmers
Pentatomidae	Stink bugs
Phymatidae	Ambush bugs
Reduviidae	Assassin bugs
Scutelleridae	Shield-backed bugs
Tingidae	Lace bugs
HOMOPTERA	
Acanaloniidae	Acanaloniid planthoppers
Aphididae	Aphids
Cercopidae	Froghoppers, Spittlebugs
Cicadellidae	Leafhoppers
Cicadidae	Cicadas
Flatidae	Flatid planthoppers
Fulgoridae	Fulgorid planthoppers
Membracidae	Treehoppers
Psyllidae	Jumping plantlice
HYMENOPTERA	
Anthophoridae	Digger, Cuckoo bees
Apidae	Honey, Bumble bees
Braconidae	Braconid wasps
Chalcididae	Chalcidid wasps
Encyrtidae	Encyrtid wasps
Eucharitidae	Eucharitid wasps
Eulophidae	Eulophid wasps
Eupelmidae	Eupelmid wasps

Order/Family	Common Name
HYMENOPTERA	
Eurytomidae	Seed chalcids
Evanidae	Ensign wasps
Figitidae	Figitid wasps
Formicidae	Ants
Halictidae	Halictid bees
Ichneumonidae	Ichneumonid wasps
Megachilidae	Leaf cutting bees
Mutillidae	Velvet ants
Perilampidae	Perilampid wasps
Pompilidae	Spider wasps
Pteromalidae	Pteromalid wasps
Siricidae	Horntail wasps
Sphecidae	Thread-waisted wasps
Tiphiidae	Tiphid wasps
Vespidae	Paper wasps
LEPIDOPTERA	
Arctiidae	Tiger moths
Ctenuchidae	Day-flying moths
Drepanidae	Hook-tip moths
Ethmiidae	Ethmiid moths
Gelechiidae	Gelechid moths
Geometridae	Measuring, Inch worms
Lasiocampidae	Tent caterpillars
Noctuidae	Noctuid moths
Nymphalidae	Brush-footed butterflies
Pieridae	White, Sulphur butterflies

Order/Family	Common Name
LEPIDOPTERA	
Pterophoridae	Plume moths
Pyralidae	Snout moths
Saturniidae	Giant silkworm moths
Sphingidae	Sphinx moths
NEUROPTERA	
Chrysopidae	Green lacewings
Hemerobiidae	Brown lacewings
Inocelliidae	Inocelliid snakeflies
Myrmeleontidae	Antlions
Raphidiidae	Raphidiid snakeflies
ODONATA	
Coenagrionidae	Narrow-winged damselflies
ORTHOPTERA	
Acrididae	Short-horned grasshoppers
Blatellidae	German cockroaches
Blattidae	American cockroaches
Gryllacrididae	Camel crickets
Gryllidae	Crickets
Mantidae	Praying mantids
Tettigoniidae	Long-horned grasshoppers
TRICHOPTERA	
Limnephilidae	Northern caddisflies
THYSANOPTERA	
Phlaeothripidae	Lily bulb thrips
Thripidae	Common thrips

List continued

Order/Family

Common Name

THYSANURA

Lepismatidae

Silverfish

Machilidae

Jumping bristletails

IV

THE EFFECTS OF ROADS
ON THE
MOVEMENTS OF SMALL MAMMALS

Gary C. Bateman

INTRODUCTION

With regard to the management of the precious natural resources that it is charged to protect, the National Park Service is in a paradoxical situation. On the one hand, legislation which created the Park Service calls for preservation of wildlife and other natural features occurring on our national parks and monuments for the enjoyment of future generations. On the other hand, the motto of the National Park Service is "Parks are for the People." These dual charges sometimes result in conflict since maximum public use may result in significant degradation and alteration of the very resources the park or monument was created to protect. Numerous examples come to mind, with the kinds of problems ranging from serious confrontations between backpackers and grizzly bears in Glacier National Park to a destruction of the "wilderness experience" for some white-water river runners resulting from their encounters with motorized watercraft in the Grand Canyon. Sound park management policies are required to minimize the frequency of these conflicts. It follows that good management decisions are based upon sound data.

One feature of virtually every national park and monument which is likely to undergo significant modification with increased public visitation is its system of roads. Relatively little is known regarding the effects of roads on animal populations. Studies investigating such effects have been concerned chiefly with mortality due to vehicular travel (Davis, 1940; Haughan, 1944; Hodson, 1966; Bellis and Graves, 1971; Carbaugh et al., 1975) and have emphasized species important as game animals. A few studies have pointed out the role served by roadsides as corridors for dispersal of small mammals since habitats here are linear, continuous, and often different from those in surrounding areas (Huey, 1941; Getz et al., 1978).

With increasing demand for environmental assessments of man's activities

have come increasing numbers of investigations of potential impacts. Verts (1957) described rodent populations on strip-mined lands in Illinois and Hudgins (1976) and Reynolds (1980) have discussed impacts of various land management procedures on populations of small mammals. More specifically, Rost (1975) found that deer and elk in Colorado tended to avoid areas within 0.2 km of roads and that even dirt roads, used only by four-wheel drive vehicles, trailbikes and hikers, were also avoided. Such avoidance implies that roads may serve as barriers to wildlife, but few studies investigating this hypothesis have dealt with smaller species of mammals, most being concerned with big game.

Apparently only three studies concerned with the possibility that roads might serve as barriers to small mammals have been conducted (Oxley et al., 1974; Wilkins, 1977; Kozel and Fleharty, 1979). In each it appeared that roads did somewhat influence normal movements, but the extent to which this occurred was variable and results from the studies are somewhat difficult to compare. None of these studies was conducted in the arid Southwest.

This study, conducted at Wupatki National Monument, Coconino County, Arizona was designed to determine the influence of roads on movement patterns of small mammals. In order to allow relatively objective comparisons among data sets obtained within this study and between the results of this study and those to be conducted in the future, methods of analysis were designed to yield a quantitative estimate, known as the Index of Interference, of the influence of roads on mammal movements. As values for this Index become available for various habitats and geographic regions, they may provide useful insight as to how the placement and design of roads may be best accomplished with minimal impact on wildlife. That this project is of relevance is indicated by the fact that a national symposium on environmental concerns in rights-of-way management was held at Mississippi State University in 1976. The proceedings of that symposium indicate the many facets of this problem (Tillman, 1976).

METHODS

Mammal Trapping

To assess the effects of roads upon the movements of small mammals, as indicated by capture, mark and release techniques, live trapping grids were established. All grids were of similar configuration but some variations in trap spacing did exist. Basically each grid was comprised of three rows (A, B and C), each of 25 trap sites marked by wooden survey markers bearing an identifying mark. The three rows of traps ran parallel to the right-of-way (ROW) to be studied and were identified using the same scheme on all grids. Two lines ran along one side of the road, the farthest from the road being designated Row A, while that nearest the road was Row B. On the opposite side of the road was Row C; it was set back from the edge of the road by a distance equal to that between Row B and the road edge. Distances between rows within each grid were held constant, thus the distance separating A and B was equal to that between B and C. A schematic diagram of a trapping grid is presented in Figure 1.

The traps, constructed of sheet metal, were of the standard "Sherman-type" and measured 3 x 3 x 10 inches. A single trap was placed at each trap station. Traps were baited and set during the late afternoon and checked as early as feasible the following morning. Each trap was supplied with a liberal amount of rolled oats and milo and a wad of cotton to reduce the probability of cold stress on cold nights.

Captured rodents were identified, sexed, toe-clipped to permit individual recognition upon recapture, and released at the site of capture. Upon subsequent recapture any movements between rows, as revealed by trapping were detectable.

Analysis of Trapping Data

Since each trapping grid was situated within a single habitat type and since rows were separated by a constant distance, one would expect to obtain approximately equal numbers of inter-row movements (IRM) within each grid. That is, the numbers of movements between Rows A and B ($A \leftrightarrow B$ movements) should approximate numbers of movements between B and C ($B \leftrightarrow C$ movements) barring any influence by the road directly, such as aversion due to substrate texture, or indirectly, such as alterations in vegetational structure and composition due to roadside ditches or earthen embankments associated with the road edge.

However, if roads do exert some influence then relative numbers of $A \leftrightarrow B$ and $B \leftrightarrow C$ movements should differ. To assess this an Index of Interference was devised to allow comparisons, as among roads having differing physical features (e.g. substrate and width); among rodents of differing age, species and sex; and among habitats of differing physiognomy (e.g. open grasslands vs. closed canopy forests). The Index is calculated by:

$$\text{Index of Interference} = \frac{(A \leftrightarrow B) - (B \leftrightarrow C)}{(A \leftrightarrow B)}$$

where $A \leftrightarrow B$ is the number of recorded movements between Rows A and B, in either direction, and $B \leftrightarrow C$ is a verified road-crossing. Movements between rows A and C were, of course, possible and some did occur, but no expected probabilities for such events were calculable, hence they were not treated statistically. It would have been possible to fragment an $A \leftrightarrow C$ movement into its $A \leftrightarrow B$ and $B \leftrightarrow C$ components; in each case this would serve only to increase the value of the denominator in the above formula, thus decreasing the calculated value of the Index.

If the presence of a road between trapping rows does inhibit rodent IRM, this index will have positive values ranging from near 0 to 1, with the maximum

value indicating that the road is acting as a complete barrier to rodent movements, at least as revealed by live trapping techniques. If, on the other hand, the road somehow "encourages" movements between B and C, then the index will have negative values which may range from near 0 to $-\infty$. If the null hypothesis, that there is no effect due to the road, holds the index will have values near 0 as the A↔B IRM will be roughly equal to B↔C IRM. The statistical significance between differences of A↔B and B↔C IRM was tested using the Chi-square statistic.

Vegetation Sampling

Certain features of the vegetation within each grid were measured using a combination of line intercept and belt transect sampling techniques. At each grid location a baseline 240 meters (m) in length was established along Row B. At 60 m intervals on this line, transects, erected at a 90° angle to the baseline and heading away from the road, were extended for a distance of 25 m. Each such transect, there were five on each grid, was used in determining plant coverage values by the line intercept method. Additionally, the transects were subdivided into five 5 m lengths and with the placement of a string running parallel to the transect and displaced 1 m to the right, five 5 square m subplots were formed. These subplots were used in obtaining data regarding density and frequency of plants on the grid.

The data on plant frequency, density and cover were tabulated and appropriate calculations made to determine absolute frequency, absolute density and absolute cover values. The relative importances of individual plant species were determined by calculating values for relative frequency, relative density and relative cover; the sum of these three values for each species was divided by three, allowing determination of an overall "importance value."

RESULTS

Trapping Sites

Four trapping quadrats were established during this study. One, located along the Sunset-Crater Wupatki Loop Road (USFS 545) near the eastern boundary of SCNM, was surveyed on 17 February 1979 and trapped for a single night in February and once in March. Only one capture, of a Peromyscus maniculatus, was recorded; hence trapping was discontinued in the Ponderosa Pine (Pinus ponderosa) type because of low mammal densities. [Numerous researchers from the Department of Biological Sciences at Northern Arizona University have found this to be the usual situation for nocturnal rodents in ponderosa forests.] The remaining grids were established within the Cold Desert Shrub vegetation type (Green and Rominger, 1976) of Wupatki National Monument.

Site 1, hereinafter referred to also as Headquarters Site, was situated roughly 300 m southeast of the junction of Road 545 and the road to Wukoki Ruins. It spanned Road 545, with Rows A and B lying to the east of this road. The paved surface of this road was 24 feet wide and trap rows were set back a distance of 20 feet on each side to allow placement of traps in fairly "natural" surroundings. Thus, the distance between adjacent rows was 64 feet at this grid, while the distance between traps within rows was 49 feet.

Site 2, called Wukoki Site, was on the road to Black Falls 0.5 mile east of its junction with the road to Wukoki Ruin. This area was at an elevation of 4650 feet and Rows A and B were on the south side of this gravel/cinder surfaced road. The width of the ROW was 24 feet; setback on each side was 8 feet. Thus, the distance between rows was 40 feet. Trap spacing within rows was 49 feet.

Site 3, referred to as Peshlaki in honor of a local Navajo family by that name, was just north of the entrance to Wupatki National Monument on Road 545. Elevation was 4850 feet and trap rows A and B were along the east side of the asphalt surfaced road. Again the paved surface was 24 feet and setback was 18 feet. Overall distance between rows was 60 feet and the inter-trap distance within rows was only 25 feet.

General Trapping Results

Seven trapping visits, each two nights in duration, were spent at the Headquarters Site. Trapping began on 19 February and was completed on 20 June. During this period, 74 individual rodents, representing five species, were trapped 170 times for an average of 2.30 captures per individual (Table 1). Overall trapping success for the 1050 trap nights of effort was 16.2 percent. The lowest trapping success was 4 percent on 19 February and the high was 26.7 percent on 14 April. The relative proportions of various species comprising this community of nocturnal rodents and the numbers of captures for each species at this site are indicated in Table 2.

At the Wukoki Site a similar amount of trapping effort was expended, this grid being operated 14 times for a total of 1050 trap nights (Table 1). Eighty rodents representative of the same five species occurring at the Headquarters site were captured 178 times for an average of 2.23 captures per individual, a figure very similar to that for the Headquarters grid. Overall trapping success was also nearly identical, running 17 percent at Wukoki. The composition of this rodent community is indicated in Table 3.

At Peshlaki trapping was conducted on only two nights, 23 and 24 August. Success was quite high at 38 percent, a fact attributable to the very high rodent densities generally prevalent at this time of year in the Cold Desert

Shrub of Wupatki National Monument (Bateman, 1980; Sec. VI). Fifty-seven captures of 44 individuals were recorded for an average of only 1.30 captures per individual. This low capture rate per individual is merely a reflection of the short duration of trapping at this site. In fact only 13 animals were recaptured, but recall that there was only one night's trapping during which an individual could be recaptured. The relative proportions of this rodent community consisting of the various species present are indicated in Table 4.

Summary of the Inter-row Movements (IRM)

At Headquarters grid 96 recaptures were made but only 24 IRM, as here defined, were made since many individuals were retrapped at the original capture site or at another trap in the same row. Of the 24 IRM recorded, only 9 (37.5%) represented road crossings. Ten (42%) of the 24 IRM were made by Perognathus amplus (Arizona pocket mouse) which accounted for 42 percent of the total rodent community and 39 percent of the total captures (Table 2). These two figures are remarkably close to what one might "expect" by chance. On the other hand, P. amplus accounted for only 1 (11%) of the 9 road-crossing IRM (B↔C) made at Headquarters, a figure seemingly quite low in view of the numbers of individuals and captures of this species at this site. The Index of Interference of this road when calculated for P. amplus was 0.89, indicative of a strong barrier to movements.

The kangaroo rat (Dipodomys ordii) accounted for just 19 percent of the total individuals captured and 21.5 percent of the total captures, but members of this species made 5 (56%) of the 9 IRM resulting in road crossings, a number seemingly high for a relatively uncommon and infrequently captured species. The Interference Index of this road for Dipodomys ordii was -4.00, the only negative index value obtained during this study.

IRM of other rodents occurring at the Headquarters study area are presented in Table 2 and show no convincingly strong patterns. The overall Index of Interference calculated from data obtained at Headquarters was 0.40.

At Wukoki more IRM were recorded (31) than at any other site. The number of road-crossing IRM (9) was almost the same as for the Headquarters site (8). Thus, the Index of Interference calculated for this site was somewhat higher (0.65) than that for the Headquarters site. Perognathus amplus, the predominant nocturnal mammal, accounted for 67.5 percent of the individuals captured here and 65.7 percent of all captures (Table 3). The total number of IRM for this species (16) was 51.6 percent of all those recorded at Wukoki. The non-road crossing IRM of P. amplus were somewhat fewer than expected (47.8% of total) while the road-crossing IRM (62.5% of the total) were about as expected, based upon relative population size and frequency of capture. The Index of Interference for P. amplus was 0.55 at this site.

Peromyscus maniculatus was represented by 21 percent of all rodents captured at Wukoki and the species accounted for 20.2 percent of all captures here. The percentage of total IRM (31) attributable to the deer mouse was somewhat higher than expected, as 9 of 31 (29%) IRM were made by this species. The Index of Interference for the deer mouse was 0.71.

No other rodents showed any obvious patterns of movement with respect to the road at this study area. It appears that kangaroo rats were less likely to cross the road here than at Headquarters, but the numbers of IRM are few and the data, therefore, inconclusive.

At Peshlaki IRM were very few, only 5 being recorded in the two nights of trapping. Inter-row movements thus accounted for 38.5 percent of all recaptures but no road crossing IRM were recorded. The Index of Interference at this site was 1.00, the highest value obtained during this study. Four of

the IRM (80%) were made by Perognathus amplus, the most abundant and frequently captured rodent on the area (Table 4). Arizona pocket mice accounted for 63.6 percent of all rodents captured at Peshlaki and made up 66.7 percent of all captures. The species composition of the nocturnal rodent community was identical to those at Headquarters and Wukoki although the relative importance of particular species may have varied between sites.

Vegetation Sampling

The three trapping sites were sampled to determine vegetational structure and composition on 27 July 1979. All three sites are considered to represent the Cold Desert Shrub Community (Green and Rominger, 1976), but somewhat different fascies were present at each (Tables 5-11).

Jointfirs (Ephedra spp.), Russian thistle (Salsola kali), sagebrush (Artemisia), and rubber rabbitbrush (Chrysothamnus nauseosus) were the most important components of the vegetation at the Headquarters site. Thus, shrubs were predominant here, with grasses and herbs playing a lesser role. The absolute ground cover was 15.22 percent with 193 individuals being present in the area sampled (Table 5). This area had the greatest value for absolute ground cover and the lowest number of individuals within the sampled area. The individual plants were, on this basis, larger than the averages for the other two sites.

Over twice as many plants occurred in the sample plots at Wukoki as compared to those at Headquarters, but the absolute ground cover was only about 80 percent of that at the latter site (Table 7). This pattern results from the smaller average size of plants at Wukoki, many of them being grasses, especially Hilaria jamesii which made up over one half of all individuals counted. Hilaria and Coldenia were not only present in large numbers at

Wukoki, but they also occurred at high frequencies. In spite of these aspects of dominance neither was especially important in contributing ground cover (Table 7). Rubber rabbitbrush accounted for almost half of all the ground cover with lesser amounts being provided by Ephedra and Artemisia.

At Peshlaki many more individual plants occurred on the sample plots, but absolute ground cover was relatively little affected (Table 9). Coldenia nuttallii, a relatively small annual forb was present in large numbers on the plots when they were sampled in late July, 1979. In terms of numbers, frequency and cover this plant was ranked very high overall, giving it the largest importance value (Table 10). Russian thistle was also important at this site as were galleta, bursage (Franseria acanthicarpa), jointfir (Ephedra torreyana), rabbitbrush and sand dropseed (Sporobolus airoides).

The rankings, by importance value, of the ten most important plants at each of the three study sites are presented in Table 11.

DISCUSSION

The same complement of nocturnal rodent species occurred at each of the three study sites established in the Cold Desert Shrub vegetation type. The Arizona pocket mouse, Perognathus amplus, was the most abundant species, accounting for roughly two thirds of all individuals captured. Peromyscus maniculatus was next in abundance, with the remaining three species, Dipodomys ordii, Peromyscus truei and Oryzomys leucogaster, being somewhat variable in order of abundance on the three plots. The results agree quite closely with previous studies (Bateman, 1976, 1978, 1980) with differences between study sites being attributable, at least in part, to minor differences in floristic composition, vegetational structure and substrate.

In every case during this study the rodent communities, taken as a whole, at a particular trapping site appeared to be affected by the presence of roads. Roads inhibited the movements of the rodents as indicated by the relatively high values calculated for the Index of Interference (Table 12). This pattern held true at all three sites, even though statistical significance was only demonstrable for the Wukoki and Peshlaki Sites. The overall trend in the data collected at the Headquarters Site was similar, but the effect of the road was not statistically significant. This latter fact is seemingly attributable to the "unusual" behavior of the kangaroo rat at the Headquarters Site (to be discussed later).

When the IRM from the three study areas are all combined for analysis, they yield an Index of Interference of 0.61. There were 43 A $\leftrightarrow$ B movements recorded and only 17 B $\leftrightarrow$ C (road crosses). Thus, it appears that the likelihood of a rodent's moving between trap rows having no road interposed between them is roughly two and one-half times as great as its probability of being caught on both sides of a road. The roads studied here, even though fairly narrow, did

inhibit to some degree the normal movements of rodents occurring adjacent to them.

There was variation in this inhibitory effect with all species not being equally affected by the roads. Four of the five species had more A↔B movements than B↔C movements (Table 12) indicating a degree of inhibition. Only for Perognathus amplus was the number of IRM large enough to demonstrate statistical significance, although data for Peromyscus maniculatus were strongly suggestive of such an effect. Ord's kangaroo rat actually showed more road-crossing IRM than non road-crossing IRM, suggesting that individuals of this species were actually attracted by roads for some reason. Some hypotheses for this aberrant, relative to other rodents studied, behavior are offered here. Kangaroo rats have been shown to forage preferentially in open areas (Rosenzweig, 1973) where their rapid and erratic saltatorial locomotion seemingly allow them to effectively escape predation. Also, they are known to seek out clumps of seeds (Lockard and Lockard, 1971; Brown et al., 1975; Price, 1978) such as might accumulate in small natural depressions, on the lee sides of mounds or shrubs, and perhaps in this case, along small scale topographic features associated with road edges, such as ditches and shoulders. Also there is a general tendency for weedy plants to be more abundant along roadsides, which suffer repeated disturbances due to road maintenance activities. A major adaptive feature of weeds is their large energetic investment in reproduction. That is, they ordinarily produce large numbers of seeds. Several of the rodents occurring on the trap-sites are largely granivorous in terms of their dietary preference, but the pocket mouse and kangaroo rat are specialists at granivory. Pocket mice in general seem adapted to gathering scattered seeds, or those in small clumps, found in a variety of ecological situations, but are not so likely to be found out in the open as are kangaroo rats, seeming to forage preferentially

beneath vegetational cover. Kangaroo rats may forage actively along the roadways at Wupatki National Monument and because of their ability to escape predation in open situations, they should not be inhibited from entering, and crossing, these roadways. This may explain the negative value for the Index of Interference calculated for this species.

It is difficult to assess the effects of the road surface on the rodents in this study. The Headquarters (paved) and Wukoki (graveled/cindered) sites seem most comparable since they are close together and were trapped for comparable lengths of time. The Index of Interference at Headquarters was 0.40 and that at Peshlaki was 0.65, values suggesting greater interference by the unpaved road. Intuitively, this goes counter to expectation and some explanation seems required. One thing to recall is that kangaroo rats were, apparently, attracted to the roadway at the Headquarters site. This has the effect of decreasing the Index of Interference at this site when using data gathered on all species. If the data for kangaroo rats are deleted from the analysis, the Index at the Headquarters site increases from 0.40 to 0.71. This latter value seems closer to expectation, assuming animals would be less likely to cross a paved surface than an unpaved one. Oxley et al. (1974) studying forest dwelling small mammals reported that road surface was not a critical inhibiting factor to road crossing. From their data, however, I note that there seem to have been relatively more crossings of graveled roads than of paved ones. They did point out that road surface (asphalt vs. gravel) does affect traffic volume and speed, thus influencing road mortality. This latter point should be of interest to those concerned with wildlife management considerations.

Another factor which may bear upon the likelihood of small mammals to cross roads involves the type of habitat ordinarily occupied. That is, one might expect species normally found in open habitats having little in the way of a shrub or tree canopy to more readily enter and cross an open roadway, whereas forest inhabitants might be reluctant to enter exposed situations, such as

an open right-of-way.

The only two published studies dealing directly with the effects of roads upon movements of small mammals (Oxley et al., 1974; Kozel and Fleharty, 1979) do not provide data in a form making it possible to compare their results with those from this study. The data obtained in this study do not support the hypothesis that plant cover influences the tendency of rodents to cross roads. This finding is not surprising in this case since all three study sites were within the same major vegetational type, which was picked for its relative homogeneity. While some minor differences in floral composition and ground cover values did exist among the sites (Tables 5-11), these were relatively minor and the species of rodents occurring at all sites were identical. Consequently the Indices of Interference showed no apparent relationship to such obvious vegetational features as ground cover. Probably the between-site differences in vegetation were too small to allow detection of any habitat effect.

Other factors which might affect the ways in which rodents react to roads may include: 1) population density, more crossings might occur under crowded conditions; 2) age, younger animals often make long dispersal movements prior to establishing a home range; 3) season, related to 1 and 2; 4) lunar phase, numerous studies have shown that rodents are less likely to forage in open situations on brightly lit nights; and 5) sex, males commonly range more widely than females. We are undertaking a study to determine the effects of some of these factors.

This study has demonstrated that in most cases, roads interfere with the normal movements of rodents. An Index of Interference developed to quantify this effect varied from 0.40 to 1.00 at the three study sites. A value of 1.00 indicates that a road was acting as an absolute barrier to rodent movements, under the conditions existing during the study period. Implications

of this inhibitory effect are several.

Roads may significantly inhibit normal dispersal movements and as Blair (1953) points out, "The movement of young animals away from the nest before they, in turn, reproduce is the principal means by which dispersal of individuals (and hereditary characters) through the species population is accomplished." These dispersal movements serve to spread new mutations through a population, allowing selection to act upon them according to local environmental pressures. In the absence of significant dispersal, panmixis is prevented, local demes become accentuated and inbreeding is fostered. The extent of inbreeding necessary to lead to deleterious effects in wild populations of small mammals is unknown, but with increasing disruption of natural habitats by man made barriers it is likely to increase in many populations.

The general body of theory relating to island biogeography (MacArthur and Wilson, 1963, 1967 and many other papers) offers several suggestions as to what one may expect when normal dispersal movements are hindered. Admittedly, areas separated by roads are not true islands, but they do fall somewhere along the island-mainland continuum, exactly where depending upon the degree of isolation. Islands have fewer species than expected for mainland areas of comparable size. This is partially a result of their smaller average population sizes per species and, consequently, a greater average extinction probability per species. Thus, true oceanic islands tend to be depauperate in terms of species numbers; peninsulas, being somewhat isolated (surrounded on most sides by water), show this effect to a lesser degree and mainlands tend to have the most diverse biotas. Any factor(s) tending to reduce extinction probability should generally increase species diversity within an area. Thus, attempts should be made to set aside large natural areas to maintain wildlife populations (Diamond, 1973; May, 1975; Sullivan and Shaffer, 1975; Diamond and May, 1976).

Especially pertinent in this regard is Diamond's caveat that wide highway swaths cut through such natural areas might effectively reduce them to two half-size areas, this effect being somewhat dependent upon the nature of the habitat(s) involved.

Factors enhancing dispersal between segments of a population should act to reduce extinctions due to chance population fluctuations, a result of the "rescue-effect" of Brown and Kodric-Brown (1977). Under critical conditions, where areas inhabited by endangered wildlife populations are involved, provision must be made to ensure dispersal between isolated subpopulations. This might be most readily accomplished by leaving corridors of favorable habitat between the isolates involved.

Admittedly, the situation at Wupatki National Monument with regard to endangerment of natural wildlife populations does not appear to be as bleak as might be construed from the above paragraphs. Indeed it is very likely that the system of small roadways existing there has minimal impact on populations of terrestrial vertebrates (except for some mortality) given the relatively low traffic volume handled by the roads. This study does demonstrate, however, in a quantitative and objective manner that roads do seem to interfere with normal movements of some small rodents. The Index of Interference derived here will permit comparisons to be more easily drawn between this study and others planned for the future, which will involve different habitats, species, and roadway characteristics, than has heretofore been possible. In view of the flourishing nature of our highway system's growth it seems necessary to consider the impacts of such factors in the very near future.

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Figure 1. Diagrammatic representation of the live trapping grids. Distances between Rows A and B and Rows B and C are equal. Distance between columns refers to within-row trap spacing. Road width refers to the actual road surface and setback is the distance between the surfaced roadway and the trap rows adjacent to the roadway.

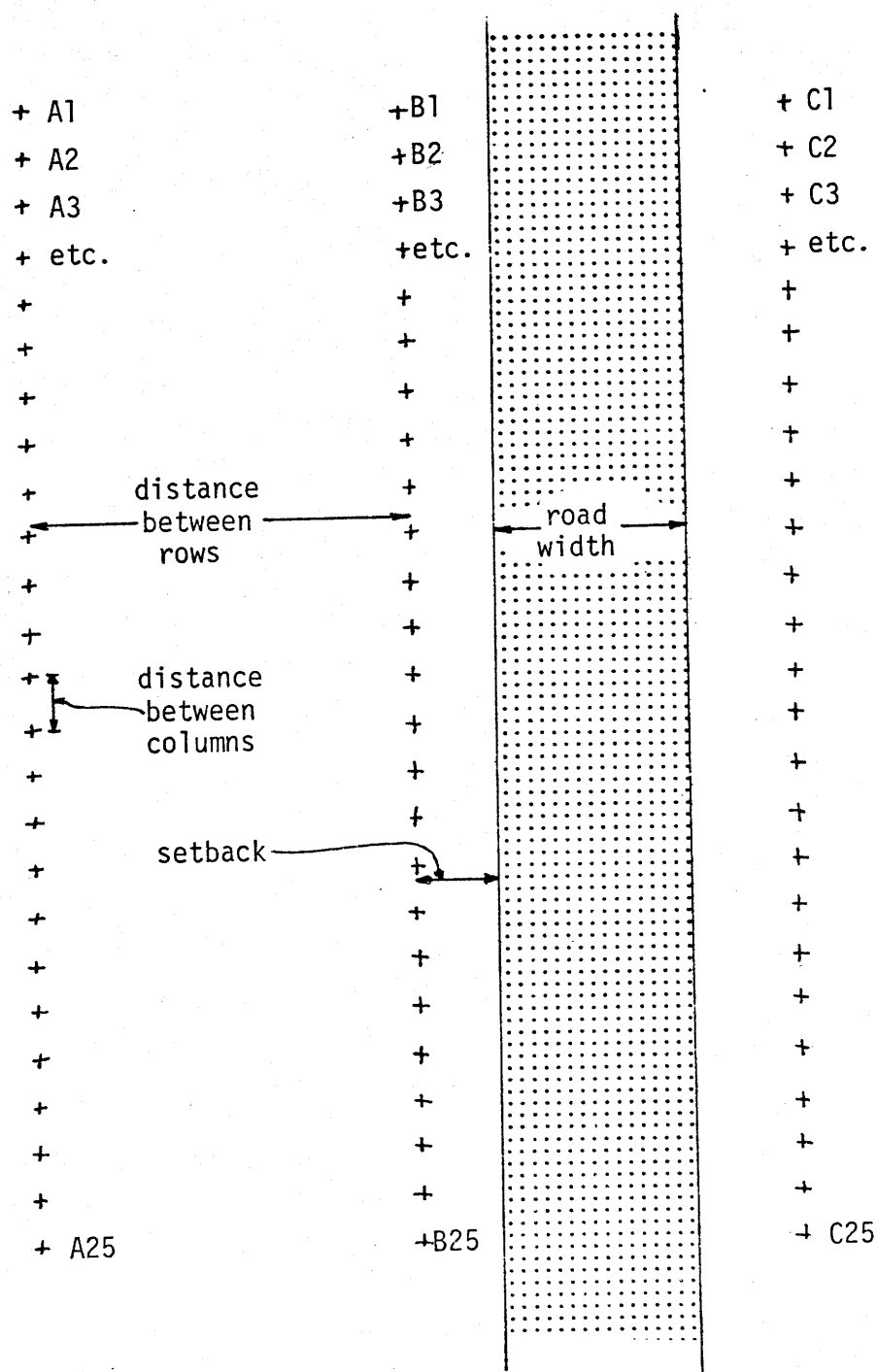


Table 1. Summary table characterizing roads and trapping grids at each site. Also indicated are trapping effort, trapping success, the spatial distribution of captures/row, numbers of IRM/grid and the Index of Interference.

	<u>Headquarters</u>	<u>Wukoki</u>	<u>Peshlaki</u>
Road surface	paved	gravel/cinder	paved
Road width ¹	24	24	24
Setback ²	20	8	18
Distance between rows	64	40	60
Distance between columns	49	49	25
Date began trapping	19 Feb.	15 Mar.	22 Aug.
Last trapping date	20 June	25 July	23 Aug.
Number trapping periods	14	14	2
Total trap nights	1050	1050	150
Total captures	170	178	57
Trapping success (%)	16.2	17.0	38
Total number individuals	74	80	44
$\bar{x}$ captures/individual	2.30	2.23	1.30
Captures in A (%)	62 (36.5)	77 (43.3)	21 (36.8)
Captures in B (%)	33 (19.4)	42 (23.6)	19 (33.3)
Captures in C (%)	75 (44.1)	59 (33.1)	17 (29.8)

Table 1 (continued).

	<u>Headquarters</u>	<u>Wukoki</u>	<u>Peshlaki</u>
A ↔ B	15	23	5
B ↔ C	9	8	0
Total IRM ³	24	31	5
Index of Interference	0.40	0.65	1.00

¹All distances are in feet.

²Distance from edge of road to trap row.

³IRM = inter-row movements, includes A ↔ B and B ↔ C, but not A ↔ C.

Table 2. Relative densities and frequencies of capture for the five rodent species at the Headquarters Site. Total individuals equals 74; captures 172. Movements between rows are also given.

	Individuals (% of total)	Capture (%)	A↔B	B↔C	A↔C
<u>Perognathus amplus</u>	41.89	38.95	9	1	3
<u>Dipodomys ordii</u>	18.92	21.51	1	5	
<u>Peromyscus maniculatus</u>	25.68	24.42	2	1	1
<u>Peromyscus truei</u>	12.16	14.53	3	2	3
<u>Onychomys leucogaster</u>	<u>1.35</u>	<u>0.58</u>	—	—	—
			15	9	7

Table 3. Relative densities and frequencies of capture for the rodents at the Wukoki Site. The total number of individuals captured here was 80 and 178 captures were made. Movements between rows are also indicated.

	Individuals (% of total)	Capture (%)	A ↔ B	Movements B ↔ C	A ↔ C
<u>Perognathus</u> <u>amplus</u>	67.50	65.73	11	5	5
<u>Dipodomys</u> <u>ordii</u>	3.75	8.43	2	1	
<u>Peromyscus</u> <u>maniculatus</u>	21.25	20.22	7	2	
<u>Peromyscus</u> <u>truei</u>	5.00	3.37	1		
<u>Onychomys</u> <u>leucogaster</u>	2.50	2.24	<u>2</u>	—	—
			23	8	5

Table 4. Relative densities and frequency of capture for the rodents at Peshlaki Site. Forty-four individuals were captured 57 times at this site. Movements between rows are also given.

	Individuals (% of total)	Capture (%)	A ↔ B	Movements B ↔ C	A ↔ C
<u>Perognathus amplus</u>	63.64	66.67	4		
<u>Dipodomys ordii</u>	4.54	3.51			
<u>Peromyscus maniculatus</u>	22.73	21.05	1		
<u>Peromyscus truei</u>	2.27	3.51			
<u>Onychomys leucogaster</u>	6.82	5.26	—	—	—
			5	0	0

Table 5. Absolute values for frequency (%), density (plants/125m²) and cover (%) of plant species sampled at the Headquarters trapping site. Plants are ranked by their importance value.

<u>Species</u>	<u>Absolute Frequency</u>	<u>Absolute Density</u>	<u>Absolute Cover</u>
<u>Ephedra torreyana</u>	48	18	6.34
<u>Salsola kali</u>	60	68	0.88
<u>Artemisia folifolia</u>	40	25	2.69
<u>Chrysothamnus nauseosus</u>	32	16	3.30
<u>Atriplex spp.</u>	48	26	1.61
<u>Muhlenbergia porteri</u>	28	9	.10
<u>Oryzopsis hymenoides</u>	24	8	
<u>Sphaeralcea subhastata</u>	12	5	0.14
<u>Aster arenosus</u>	8	6	0.06
<u>Bouteloua eriopoda</u>	4	5	
<u>Eriogonum deflexum</u>	8	2	
<u>Ephedra viridis</u>	8	2	
<u>Hilaria jamesii</u>	4	1	
<u>Sporobolus airoides</u>	4	1	
<u>Astragalus lentiginosus</u>	4	<u>1</u>	<u>0.10</u>
		193	15.22

Table 6. Relative frequency, density and cover values and importance value for plant species sampled at the Headquarters trapping site. All values are given as percent of total. Plants are ranked by importance value.

<u>Species</u>	<u>Relative Frequency</u>	<u>Relative Density</u>	<u>Relative Cover</u>	<u>Importance Value</u>
<u>Ephedra torreyana</u>	14.46	9.33	41.66	21.82
<u>Salsola kali</u>	18.07	35.23	5.79	19.70
<u>Artemisia folifolia</u>	12.05	12.95	17.67	14.22
<u>Chrysothamnus nauseosus</u>	9.64	8.29	21.67	13.2
<u>Atriplex</u> spp.	14.46	13.47	10.57	12.83
<u>Muhlenbergia porteri</u>	8.43	4.66	0.64	4.58
<u>Oryzopsis hymenoides</u>	7.23	4.15		3.79
<u>Sphaeralcea subhastata</u>	3.61	2.59	0.95	2.38
<u>Aster arenosus</u>	2.41	3.11		1.84
<u>Bouteloua eriopoda</u>	1.20	2.59	0.42	1.40
<u>Eriogonum deflexum</u>	2.41	1.05		1.15
<u>Ephedra viridis</u>	2.41	1.04		1.15
<u>Hilaria jamesii</u>	1.20	0.52	0.63	.78
<u>Sporobolus airoides</u>	1.20	0.52		.57
<u>Astragalus lentiginosus</u>	1.20	0.52		.57

Table 7. Absolute values for frequency (%), density (plants/125m²) and cover (%) of plant species sampled at the Wukoki trapping site.

<u>Species</u>	<u>Absolute Frequency</u>	<u>Absolute Density</u>	<u>Absolute Cover</u>
<u>Hilaria jamesii</u>	56	247	2.69
<u>Chrysothamnus nauseosus</u>	68	44	5.42
<u>Coldenia nuttallii</u>	44	151	0.44
<u>Ephedra torreyana</u>	4	1	1.64
<u>Artemisia filifolia</u>	12	3	0.81
<u>Salsola kali</u>	24	11	0.04
<u>Oryzopsis hymenoides</u>	12	9	0.26
<u>Sphaeralcea subhastata</u>	12	5	
<u>Mentzelia pumila</u>	12	3	
<u>Sporobolus airoides</u>	4	2	
<u>Aster arenosus</u>	4	2	
<u>Bouteloua eriopoda</u>	4	1	
<u>Eriogonum deflexum</u>	4	1	
		480	11.30

Table 8. Relative frequency, density and cover values and importance values for plant species sampled at the Wukoki trapping site. All values are given as percent of total. Plants are ranked by importance value.

<u>Species</u>	<u>Relative Frequency</u>	<u>Relative Density</u>	<u>Relative Cover</u>	<u>Importance Value</u>
<u>Hilaria jamesii</u>	21.21	51.46	23.81	32.16
<u>Chrysothamnus nauseosus</u>	25.75	9.17	47.98	27.63
<u>Coldenia nuttalli</u>	16.67	31.46	3.90	17.34
<u>Ephedra torreyana</u>	1.51	0.21	14.53	5.42
<u>Artemisia filifolia</u>	4.54	0.63	7.16	4.11
<u>Salsola kali</u>	9.09	2.29	0.35	3.91
<u>Oryzopsis hymenoides</u>	6.06	1.88	2.27	3.40
<u>Sphaeralcea subhastata</u>	4.54	1.04		1.86
<u>Mentzelia pumila</u>	4.54	0.63		1.72
<u>Sporobolus airoides</u>	1.51	0.42		0.64
<u>Aster arenosus</u>	1.51	0.42		0.64
<u>Bouteloua eriopoda</u>	1.51	0.21		0.57
<u>Eriogonum deflexum</u>	1.51	0.21		0.57

Table 9. Absolute values for frequency (%), density (plants/125m²) and cover (%) of plant species sampled at the Peshlaki trapping site. Plants are ranked by their importance value.

<u>Species</u>	<u>Absolute Frequency</u>	<u>Absolute Density</u>	<u>Absolute Cover</u>
<u>Coldenia nuttallii</u>	72	150	6.16
<u>Salsola kali</u>	88	215	2.34
<u>Hilaria jamesii</u>	56	169	1.94
<u>Franseria acanthicarpa</u>	76	106	0.72
<u>Ephedra torreyana</u>	20	5	1.72
<u>Chrysothamnus nauseosus</u>	32	18	0.54
<u>Sporobolus airoides</u>	12	26	0.94
<u>Oryzopsis hymenoides</u>	12	4	
<u>Aster arenosus</u>	8	3	0.06
<u>Euphorbia parryi</u>	8	3	
<u>Eriogonum deflexum</u>	8	2	
<u>Mentzelia pumila</u>	1	2	0.32
<u>Streptanthella longirostris</u>	4	1	
		704	14.74

Table 10. Relative frequency, density and cover values and importance value for plant species sampled at the Peshlaki trapping site. All values are given as percent of total. Plants are ranked by importance value.

<u>Species</u>	<u>Relative Frequency</u>	<u>Relative Density</u>	<u>Relative Cover</u>	<u>Importance Value</u>
<u>Coldenia nuttallii</u>	18.18	21.37	41.78	27.11
<u>Salsola kali</u>	22.22	30.63	15.84	22.90
<u>Hilaria jamesii</u>	14.14	24.07	13.13	17.11
<u>Franseria acanthicarpa</u>	19.19	15.10	4.88	13.06
<u>Ephedra torreyana</u>	5.05	0.71	11.67	5.81
<u>Chrysothamnus nauseosus</u>	8.08	2.56	3.69	4.78
<u>Sporobolus airoides</u>	3.03	3.70	6.40	4.37
<u>Oryzopsis hymenoides</u>	3.03	0.57		1.20
<u>Aster arenosus</u>	2.02	0.43	0.43	0.96
<u>Euphorbia parryi</u>	2.02	0.43		0.82
<u>Eriogonum deflexum</u>	2.02	0.28		0.77
<u>Mentzelia pumila</u>	1.01	0.28	2.17	1.15
<u>Streptanthella longirostris</u>	1.01	0.14		0.38

Table 11. Ranking, by importance values, of the ten most important plant species at the three study sites.

<u>Species</u>	<u>Headquarters</u>	<u>Wukoki</u>	<u>Peshlaki</u>
<u>Ephedra torreyana</u>	1	4	5
<u>Salsola kali</u>	2	6	2
<u>Artemisia filifolia</u>	3	5	
<u>Chrysothamnus nauseosus</u>	4	2	6
<u>Atriplex spp.</u>	5		
<u>Muhlenbergia porteri</u>	6		
<u>Oryzopsis hymenoides</u>	7	7	8
<u>Sphaeralcea subhastata</u>	8	8	
<u>Aster arenosus</u>	9		9
<u>Bouteloua eriopoda</u>	10		
<u>Hilaria jamesii</u>		1	3
<u>Coldenia nuttallii</u>		3	1
<u>Franseria acanthicarpa</u>			4
<u>Sporobolus airoides</u>		10	7
<u>Euphorbia parryi</u>			10
<u>Mentzelia pumila</u>		9	

Table 12. Summary of IRM obtained during this study listed by site and species. Values of χ^2 and statistical significance are also indicated. Statistical significance indicated by asterisk.

BY SITE:	<u>A ↔ B</u>	<u>B ↔ C</u>	<u>χ^2</u>	<u>P</u>
Headquarters	15	9	1.50	.3>p>.2
Wukoki	23	8	7.26	.01*
Peshlaki	5	0	5.00	.05*
All Areas	43	17	11.26	.001*
 <u>BY SPECIES:</u>				
<u>Perognathus amplus</u>	24	6	10.80	.01*
<u>Dipodomys ordii</u>	3	6	1.00	.5>p>.3
<u>Peromyscus maniculatus</u>	10	3	3.77	.1>p>.05
<u>Peromyscus truei</u>	4	2	0.67	.5>p>.3
<u>Onychomys leucogaster</u>	<u>2</u>	<u>0</u>	<u>2.00</u>	<u>.2>p>.1</u>
All Species	43	17	11.26	.001*

V

THE SEASONAL DIETS OF, AND POTENTIAL COMPETITION
AMONG SELECTED DOMESTIC AND NATIVE HERBIVORES
ON WUPATKI NATIONAL MONUMENT AS DETERMINED
BY FECAL ANALYSIS

Bruce Palmer

INTRODUCTION

The diet of a freely grazing animal has been considered by Chamrad (1979) to be a product of its food plant preferences and the available forage, forage preference being an animal dependent factor and forage availability a range attribute. The potential for competition for food between sympatric herbivores exists if the populations of two or more species are essentially selecting the same food items. When there is an abundance of vegetation and a variety of plant species, coexisting herbivores can maintain ecological distance and reduce competition through the phenomenon of selective feeding (Hansen and Ueckert, 1970) - a combination of foraging behavior, forage selection and animal morphology enabling each species to utilize the environment in a somewhat different manner (Ellis and Travis, 1975). However, under conditions of limited vegetational resources, it is probable that the availability of forage becomes more important to the feeding animal than food plant preferences (Anderson et al., 1965). Competition among sympatric herbivores may be particularly high if they have not evolved together, an especially likely possibility between domestic and wild herbivores (Ellis and Travis, 1975). Since food preferences are generally believed to be related to good nutrition, animals forced to feed upon non-preferred food may suffer decreases in survival, longevity, fecundity, body size and proportions, and rate of development (Hansen and Ueckert, 1970). Hence, what is the potential for competition under one set of environmental circumstances may become the reality of competition under another.

Much work has been done to determine the diets of herbivores in order to document the existence and degree of competition between sympatric

herbivores of both native and introduced species. Methods of dietary analysis have included field observations of tame, free roaming foraging animals (Doran, 1943; Ellis and Travis, 1975; Neff, 1974; Peterson and Woolfolk, 1965; Reppert, 1960), those penned within their natural habitat (Currie and Goodwin, 1966; Schwartz and Nagy, 1976), and those caged within the laboratory (Arnold and Reynolds, 1943; Cochran and Stains, 1961; Currie and Goodwin, 1966). Determination of herbivore diets has been based on the amount of time spent feeding at a particular plant species (Dixon, 1934 from Reppert, 1960), by the total number of bites taken of a food plant (Neff, 1974; Reppert, 1960), and by vegetational surveys before and after grazing (Currie and Goodwin, 1966). More realistic measures of an animal's diet have been accomplished by using microhistological analyses of crop (Hansen and Ueckert, 1970), stomach/rumen (Anderson et al., 1965; Boeker et al., 1972; Hayden, 1966; Sparks, 1968; Todd and Hansen, 1973; and Turkowski, 1975), colon (Todd and Hansen, 1973), and fecal (Hansen et al., 1977; Hansen et al., 1973; Hansen and Gold, 1977; Hubbard and Hansen, 1976; and Olsen and Hansen, 1977) samples after the application of these techniques was refined from the original works of Baumgartner and Martin (1939) and Dusi (1949). The diets of sympatric herbivores have been compared by the use of similarity indices to determine the degree of dietary overlap. Kulczynski's similarity index (Oosting, 1956) was used by Hubbard and Hansen (1976) and Hansen et al., (1977) to compare the diets of horses (Equus caballus), deer (Odocoileus heminus), and cattle (Bos taurus), by Hansen and Ueckert (1970) to compare the diets of seven orthopteran species and Richardson's ground squirrel, [Citellus (= Spermophilus) richardsonii] and by Olsen and Hansen (1977) to compare the diets of horses, cattle, elk (Cervus elaphus), domestic sheep (Ovis aries), and pronghorn (Antilocapra americana). Gauch's formula (Gauch, 1973), which modified

Kulczinski's, was used by Hansen and Gold (1977) to compare the diets of blacktail prairie dogs (Cynomys ludovicianus), desert cottontails (Sylvilagus audubonii), and cattle, and by Hansen and Reid (1975) to compare the diets of elk, deer and cattle. A formula developed by Horn (1966) was used by Schwartz and Nagy (1976) to compare the diets of pronghorn, domestic sheep, cattle and bison (Bison bison). Dissimilarity indices were also developed and used by Hansen et al. (1973) to compare the diets of cattle, bison and domestic sheep. Each study, carried out in its own unique locale, with its own particular set of environmental conditions, yielded a slightly new perspective on the competition for food among herbivores.

In the vicinity of Wupatki National Monument, the soil conditions are rather variable due largely to an extensive surface layer of volcanic cinders deposited by the eruption of Sunset Crater, circa 1065 AD. The cinder layer varies in depth, overlying sandy to gravelly loam, with limestone, sandstone, and stony basalt outcroppings. The presence of cinders, along with elevational changes and the patterns of precipitation and water drainage, results in a mosaic of vegetational patchiness in respect to species distribution, diversity and overall plant biomass (Phase I Report - Bateman, 1976). Under these existing vegetative conditions, the artificial presence of domestic livestock on Wupatki National Monument may have a substantial impact on range quality and the populations of native herbivore species. The purpose of this research was to determine, through fecal analysis, the seasonal diets of selected domestic and native herbivores on Wupatki National Monument. This information was then used to ascertain the degree of dietary similarity among these herbivores.

MATERIALS AND METHODS

Fecal analysis required microscopic examination of prepared fecal materials. The digestive process reduced the mean weight of plant food fragments rather than eliminating the whole fragment (Anthony and Smith, 1974; Todd and Hansen, 1973; Voth and Black, 1973). Silica cells, vascular tissues, trichomes, guard cells, and epidermal cells of the food plants underwent the least destruction during digestion and were prominent in the fecal materials. These cells and their subsidiary structures usually retained cellular characteristics unique to their species (Stewart, 1967). Identification of the plant foods was made by microscopic comparisons with a reference collection of known plant species. The relative proportions of fragments of each food plant taken was a good approximation of the relative dry weight amounts of each plant species consumed (Dearden et al., 1975; Free et al., 1970; Hansen et al., 1973; Sparks and Malechek, 1968; and Todd and Hansen, 1973) with the possible exception of the more succulent foods which tended to undergo a more complete digestion (Anderson et al., 1965).

Biweekly collections of the feces of domestic cattle, horse, black-tailed jackrabbit (Lepus californicus), desert cottontail, pronghorn, and mule deer were made on Wupatki National Monument from February 1979 through January 1980. No feces of sheep or goat (Capra hircus) were found. Each fecal sample consisted of either a small portion of cattle or horse manure or a single pellet from jackrabbit, cottontail, pronghorn or deer. The only reliable method of distinguishing mule deer from pronghorn fecal pellets is a pH test as described by Howard (1967). This method proved impractical since it requires very fresh fecal material and a minimum of several pellets. As a result those fecal pellets which could have been from pronghorn or mule

deer were grouped together. Each fecal sample obtained from one herbivore species was a minimum of two meters from a previously collected sample. This was to help insure that collections were from different individuals. An effort was made to obtain four fresh fecal samples representing each herbivore species from the Cold Desert Shrub, Juniper/Grassland and Grassland communities during every collection period. Samples were obtained from the center of large areas of each vegetative community to minimize the probability of collecting fecal materials transported between communities or from the neighboring Coconino National Forest, although such transport may have occurred in some cases. Fecal samples were collected from the Cold Desert Shrub Community in the vicinity of Peshlaki Spring, Heiser Spring, and Wukoki Ruin. From the Juniper/Grassland Community, samples were taken between the monument boundary opposite Hull Canyon at Forest Service Road 545 and South Mesa. Fecal samples from the Grassland Community were collected from Antelope Prairie, Cedar Canyon and the vicinity of Lomaki Ruin. All samples were placed in plastic bags and frozen until processed.

The fecal samples and plant samples to be used as reference were both prepared for mounting on microscope slides in the same manner. A combination of the techniques employed by Dusi (1949), Sparks and Malechek (1968) and Ward (1970) was followed. After being air dried, the sample was pulverized using a mortar and pestle. This material was then ground over a 60 mesh screen to insure uniform particle size for a quantitative analysis. A small portion of the resulting powdered sample was placed on a microscope slide with 4 or 5 drops of Kleermount, a general mounting medium. Using a needle, the sample fragments were spread evenly over the slide and a cover slip was added. One slide per fecal sample was prepared. Three fields per slide were located under a compound microscope at 100x magnification. Each field

analyzed possessed a minimum of seven plant fragments. The fragments were examined and compared to the reference collection using a magnification of 400x.

The plants used in the reference collection represented 31 of the more abundant shrubs, herbs and grasses found on the grazing areas of the monument and are listed in table 1. Microscope slides of various plant parts, including stem, leaves and seeds which were collected at various times throughout the year were prepared for use as reference materials. Photomicrographs of the reference collection were made to aid in identification of plant fragments in the fecal materials. However, with the exception of easily recognizable features, these proved to be of minimal value due to the restrictions imposed by the limited depth of field.

The number of particles representing each plant species present in all 100x fields was used to determine the percent composition of diet contributed by each species. The percentage of fecal samples in which a plant species occurred was recorded as the frequency index. Mean percent of diet and the frequency index were recorded both seasonally and annually for each herbivore species in all three vegetative communities.

An importance ranking was determined for all identifiable food plant species taken by each herbivore in the Cold Desert Shrub, Juniper/Grassland and Grassland Communities. This ranking was based solely on the total annual percent consumption of each plant species.

Annual dietary preference indices were computed as the ratio of the mean percent composition of a food plant in an herbivore's diet to the percent abundance of that plant species (Ward and Keith, 1962). A value greater than 1.00 indicates a degree of selection for that plant species, while a value equal to or less than 1.00 suggests indifference or avoidance. Preference

indices were determined for each herbivore in each vegetative community. Percent abundances for many of the commonly occurring plant species in the three major communities were obtained from the Phase I and the Phase IV (Bateman, 1981) Reports. Table 2 lists the relative plant abundance data obtained from these sources. Only those plant species for which abundance information was available were included in the ranking of preferred plant species.

To determine the degree of dietary overlap between each domestic and native herbivore, the similarity measure developed by Gauch (1973) was applied to compare the diets. Using the equation:

$$PS(jk) = 100 \cdot \frac{2 \sum_{i=1}^I \min(P_{ij}, P_{ik})}{\sum_{i=1}^I (P_{ij} + P_{ik})}$$

where PS is the percent similarity of diets and P_{ij} and P_{ik} are the importance values (percentage of diet) for food plant species i for the total of all plant species I , in the diets of the two herbivore species j and k , dietary overlap is expressed as percent similarity, being based on the percent contribution of all food plant species to the diets of both herbivores being compared.

RESULTS

The results of the analyses of the fecal samples are presented in tables 3 through 14. All data are reported both seasonally and annually for each herbivore species in the Cold Desert Shrub, Juniper/Grassland and Grassland Communities. The number of identified plant fragments of each botanical constituent is expressed as percent composition of diet. The percentage of browse, forbs and grasses in the dietary analysis is the summation of the mean percent of diet of all plants in each category of plant life form type.

The frequency indices listed under total browse, total forbs and total grasses are the summations of the frequency indices of all plants in each category and may be interpreted as the average number of plant species of each type of forage per fecal sample. The mean number of plant species per sample is the summation of the frequency index. These tables also indicate the total number of plant species which were identified in the diet of each species of herbivore.

Tables 15 through 19 list all plant species taken by each herbivore and ranked within communities in order of importance as a food plant. Yearly preference indices and preference rankings of selected plant species for each herbivore are presented by community in tables 20 through 24. Table 25 gives seasonally by community, the percent similarity of diets between each domestic and native herbivore species.

Desert Cottontail

Cold Desert Shrub Community

Browse type food plants comprised a greater component of the annual diet of the cottontail in the Cold Desert Shrub Community than either forbs or grasses (table 3). All seven browse species present in the reference collection were identified in the fecal samples of the cottontail; collectively these accounted for 27.6% of the diet on an annual basis.

Seasonally, the proportion of browse in the cottontail's diet reached its lowest point (17.2%) during the summer months (July through September), when only three browse species were taken. Browse utilization peaked during the winter (January through March) at 35.1%. Atriplex was the most important food plant of all those in the reference collection. Being taken throughout the year, Atriplex was identified in 84% of all fecal samples from the Cold

Desert Shrub, providing a total of 11.6% of the cottontail's annual diet.

Chrysothamnus sp. and Gutierrezia sp. were the next two most important browse species, each providing 5.0% of the cottontail's annual diet.

The forb component (20.8%) of the annual diet of the cottontail, was composed predominantly of Sphaeralcea sp., Euphorbia sp. and Eriogonum sp. Forb consumption was nearly twice as high during spring (April through June), 25.9%, and summer, 26.8%, as during fall (October through December), 15.6%, and winter, 15.1%. Sphaeralcea sp. ranked third in overall importance as a food plant in the Cold Desert Shrub, providing 7.8% of the cottontail's annual diet.

Grasses comprised 14.7% of the annual diet of the cottontail in the Cold Desert Shrub. Hilaria jamesii and Aristida fendleriana were the only grasses taken in significant quantities, 7.8% and 4.9% respectively, in the annual diet. Several other species of grasses were found to be present in the fecal samples throughout the year. Seasonally, there was a rise in the quantity and number of grass species consumed during spring and summer. Hilaria jamesii proved to be the most frequently encountered food plant in the Cold Desert Shrub of all species in the reference collection, being present in 88% of all fecal samples.

Juniper/Grassland Community

Annually, browse comprised 21.3% of the cottontail's diet in the Juniper/Grassland Community, a slightly lower percentage than either forbs, 22.2%, or grasses, 24.6% (table 4). Though consumed in substantial quantities during the winter, 32.1%, and fall, 28.6% browse use declined in the spring, 18.3%, and dropped sharply in the summer, 6.2%. Atriplex was the most important food of the cottontail in the Juniper/Grassland, providing 6.6% of its annual

diet and occurring in 57% of all fecal samples. Chrysothamnus sp., Gutierrezia sp. and Juniperus monosperma each provided a substantial portion of the browse component of the cottontail's diet, 4.3%, 3.5% and 3.4% respectively.

Forb usage peaked during the summer, providing 30.8% of the cottontail's diet, while in the winter the forb dietary component provided only 12.0% of the total diet. Euphorbia sp., Zinnia grandiflora, Sphaeralcea sp. and Chenopodium sp. were the main forb constituents throughout the year.

Grasses proved to be a very important dietary constituent in every season, providing 24.7% of the annual diet. Hilaria jamesii, Bouteloua gracilis and Aristida fendleriana were the main annual contributors, providing 5.8%, 5.7%, and 4.2% respectively.

Grassland Community

Annually, browse and forbs provided approximately equal amounts of the diet of the cottontail in the Grassland Community, 22.4% and 21.6% respectively (table 5). Browse, consisting primarily of Chrysothamnus sp. and Atriplex spp. was of greater importance to the cottontail during winter, 26.4% and fall, 25.9% than spring, 18.0% and summer, 15.1%. Chrysothamnus sp., the most important browse food plant, provided 8.4% of the annual diet, being present in 79% of all fecal samples.

During each season, forbs provided a substantial part of the diet. Sphaeralcea sp., Euphorbia sp. and Zinnia grandiflora received the greatest utilization. Salsola kali received moderate use by the cottontail during spring and summer when the overall importance of forbs nearly doubled from winter and fall. Sphaeralcea sp. provided the greatest annual dietary component of all plants in the reference collection, 9.2%, but was present in only 28.9% of all fecal samples.

Grasses formed the largest portion of the cottontail's diet in all but the winter months when browse species were taken in slightly greater quantities. With an annual dietary contribution of 29.0% by eight grass species, Stipa neomexicana, Hilaria jamesii, Bouteloua eriopoda, and Aristida fendleri-ana were found to be the most important to the cottontail throughout the year. Being found in 75% of the fecal samples from the Grassland, S. neomexicana provided 7.6% of the cottontail's annual diet.

The annual diet of the cottontail averaged over the three vegetative communities of Wupatki National Monument consisted of fairly equal proportions of browse (23.4%), forbs (21.5%) and grasses (22.7%). Browse species were annually the most important segment of the cottontail's diet in the Cold Desert Shrub, while grasses provided the largest annual dietary component in the Juniper/Grassland and Grassland Communities.

Seasonal fluctuations in the primary type of vegetation consumed followed similar patterns within each community. Browse was nearly twice as important in winter and fall as in spring and summer, forb utilization roughly doubled from winter-fall to spring-summer and grasses provided a fairly stable base, decreasing slightly in the winter months. Atriplex spp., Chrysothamnus sp. and Gutierrezia sp. were important browse species in each community. Sixty-nine percent of the fecal samples from all three communities were found to have Atriplex present. The use of forbs reflected to some degree their availability in the three communities. However, Sphaeralcea sp. and Euphorbia sp. ranked high in importance in all communities. Zinnia grandiflora proved to be of value to the cottontail in the Juniper/Grassland and Grassland Communities and Chenopodium sp. in the Juniper/Grassland and Cold Desert Shrub Communities. Salsola kali was of seasonal importance, being taken in moderate amounts by the cottontail in all three communities

during spring and summer. A variety of grasses was taken in each community. Hilaria jamesii received high utilization in each of the three communities, being present in 74% of all fecal samples. Bouteloua eriopoda ranked high in importance in the Juniper/Grassland and Grassland Communities, Aristida fendleriana in the Cold Desert Shrub and Juniper/Grassland Communities Bouteloua gracilis in the Juniper/Grassland Community and Stipa neomexicana in the Grassland Community.

Black-tailed Jackrabbit

Cold Desert Shrub Community

Annual consumption of browse in the Cold Desert Shrub Community by jackrabbits totaled 46.3%, more than twice the combined annual dietary contribution of both forbs and grasses (table 6). All browse species represented in the reference collection provided a substantial portion of the jackrabbit's diet. The species of greatest annual importance were Atriplex spp., which provided 12.3% of the jackrabbit's diet and were present in 86% of all fecal samples, Artemisia spp. at 8.2% were present in only 36% of all fecal samples, and Chrysothamnus sp. which provided 8.1% of the jackrabbit's diet. Browse formed the primary type of vegetation consumed during each season, while total browse utilization doubled from summer, 25.9%, to winter, 58.1%.

Forbs, with an annual dietary contribution of 7.3%, formed a minor component of the jackrabbit's diet. Being taken throughout the year, Chenopodium sp. and Sphaeralcea sp. comprised the majority of the forbs in the diet. During spring and summer, with an increase in the number of forb species taken, overall forb consumption also tended to rise and Salsola kali reached some importance as a food resource.

Grasses, primarily Aristida fendleriana, Hilaria jamesii and Bouteloua eriopoda, compared 14.9% of the jackrabbit's annual diet. Sporobolus airoides was of significance during summer and fall. Overall utilization of grasses dropped to 4.2% dietary contribution during the winter months from the high utilization of 20.4% during the summer.

Juniper/Grassland Community

Chrysothamnus sp., Atriplex spp., Gutierrezia sp. and Juniperus monosperma were all prominent browse species utilized by the jackrabbit in the Juniper/Grassland Community (table 7). Browse supplied 36.5% of the jackrabbit's annual diet. However, during the winter months 62.0% of the diet was determined to be composed of various species of browse, while in the summer, overall browse utilization dropped to 12.0%.

Forbs comprised 4.1% of the jackrabbit's annual diet. No forbs were identified in the fecal samples collected during the winter months. Numerous forb species, each supplying a relatively small dietary contribution, collectively provided 9.2% of the jackrabbit's summer diet.

Grasses comprised 28.5% of the jackrabbit's annual diet in the Juniper/Grassland Community. During the summer, when numerous grass species were utilized, grasses formed a greater dietary component, 47.3%, than did either browse or forbs. In winter overall utilization of grasses dropped to 11.9%. Annually, the most frequently consumed grasses in the Juniper/Grassland, ranked in order of importance, were Bouteloua eriopoda, Hilaria jamesii and Aristida fendleriana. However, this order varied with the seasons. During winter and spring H. jamesii formed a substantial component of the diet supplied by the grasses and was found to be present in 77.5% of all fecal samples. In the summer, H. jamesii became much less significant,

while B. eriopoda, A. fendleriana and Stipa neomexicana were the main contributors to the jackrabbit's diet.

Grassland Community

Annually, browse and grasses contributed approximately equally to the diet of the jackrabbit in the Grassland Community, making up 34.1% and 33.1% of the diet respectively (table 8). The heaviest utilization of browse occurred during the winter months, when it provided 47.5% of the jackrabbit's diet. During the summer, browse was of less importance, supplying 16.2% of the food. The same five browse species were found to be present in the jackrabbit's diet during each season of the year, though the relative utilization of each varied to some degree between seasons. Annually, Chrysothamnus sp., at 13% and present in 86% of the fecal samples and Atriplex spp., at 11.4% and present in 79% of the fecal samples, were the primary browse species utilized by the jackrabbit.

Forbs formed a minor component of the jackrabbit's annual diet, 5.1%, in the Grassland Community.

Grasses figured prominently in the jackrabbit's diet during each season, realizing the heaviest utilization (44.2%) in summer and the least, (20.4%) in winter. Stipa neomexicana, Bouteloua eriopoda and Hilaria jamesii were of major significance.

Vegetation utilization patterns by jackrabbits remained consistent among all three communities. Browse formed the largest annual dietary component, this being composed primarily of Chrysothamnus sp. and Atriplex spp.

Grasses were of progressively more importance from the Cold Desert Shrub to Juniper/Grassland to Grassland Communities. The particular grasses which formed the greater part of this component of the jackrabbit's diet across

communities were Hilaria jamesii, B. eriopoda and Aristida fendleriana. The utilization of H. jamesii dropped sharply from spring to summer in each community. The utilization patterns of browse and grasses showed a strong inverse relationship: summer diets had high grass and low browse frequencies; winter diets showed high browse and low grass use.

Forbs provided a low percentage of the jackrabbit's annual diet in all communities, though seasonally forbs made their greatest contribution during the summer.

Mule Deer/Pronghorn

Cold Desert Shrub Community

A total sample size of eleven determined the findings for the annual diet of deer/pronghorn in the Cold Desert Shrub (table 9). Fecal pellets were collected during every season except the summer. Browse figured prominently in all fecal samples, averaging 40.3% of the deer/pronghorn's annual diet. Artemisia spp. contributed 13.7% of the annual diet, a greater percentage than any other food plant, but was found to be present in only 55% of all fecal samples. Atriplex spp. at 10.1% and Juniperus monosperma at 8.8%, each present in 82% of the fecal samples were browse species of considerable value to the mule deer/pronghorn, though a variety of browse species was accepted.

Forbs contributed 8.8% of the annual diet of the deer/pronghorn in the Cold Desert Shrub Community. Eriogonum sp. was the most frequently encountered forb in the fecal samples. Grasses provided 19.6% of the deer/pronghorn's annual diet. Hilaria jamesii which constituted 6.8% of the deer/pronghorn's diet and Aristida fendleriana which provided 5.2% were both present in 72% of all fecal samples.

Juniper/Grassland Community

The annual diet of the mule deer/pronghorn from the Juniper/Grassland Community was determined from the analysis of a total of 13 fecal samples which were collected during the winter, summer and fall (table 10).

Browse comprised 46.9% of the annual diet of the deer/pronghorn.

Juniperus monosperma and Atriplex spp. were the major components of this segment of the diet, providing 23.9% and 12.9% respectively. Juniperus monosperma was represented in all fecal samples.

Forbs were of their greatest value to the mule deer/pronghorn during the summer, at which time they provided 16.1% of the diet. Of several species taken in moderate quantities during the summer, Sphaeralcea sp. ranked highest in importance. Overall, numerous species of forbs were determined to be present in the deer/pronghorn fecal samples for an annual dietary contribution of 9.8%.

Annual utilization of grasses was 14.2%. Hilaria jamesii, Bouteloua eriopoda, Aristida fendleriana and Oryzopsis hymenoides, listed in order of annual importance, were the only grass species known to be present in the diet of the mule deer/pronghorn in the Juniper/Grassland Community.

A total of 24 mule deer/pronghorn fecal pellets was collected from the Cold Desert Shrub and Juniper/Grassland Communities. No samples were found within the Grassland Community.

Browse clearly comprised the largest portion of the deer/pronghorn diet for both communities. Juniperus monosperma and Atriplex spp. were very important browse species. Juniperus monosperma occurred in 91% of all fecal samples. Artemisia spp. proved to be of high importance in only the Cold Desert Shrub and Chrysothamnus sp. of some value only in the Juniper/Grassland. Fallugia paradoxa was of moderate importance in both communities.

A variety of forbs was taken in minor quantities in both communities. Sphaeralcea sp. and Eriogonum sp. being of the greatest importance. Grasses formed a significant portion of the mule deer/pronghorn's diet, being of slightly greater importance in the Cold Desert Shrub than in the Juniper/Grassland. Hilaria jamesii, Aristida fendleriana and Bouteloua eriopoda were the most frequently taken grasses in both communities. Hilaria jamesii was present in 75% of all fecal samples.

Seasonal trends were obscured by the small sample size from each community and the fact that in neither community were samples collected in every season of the year.

Cow

Cold Desert Shrub Community

Fecal samples from cattle were collected from the Cold Desert Shrub Community during the fall/winter grazing period. Browse provided 27.6% of the cattle's diet from October through March (table 11). Of the five browse species identified from the cattle fecal samples, Atriplex spp. contributed the greatest segment to this portion of the diet. Present in all fecal samples, Atriplex provided 17.8% of the cattle's overall diet and ranked second in importance of all food plants in the Cold Desert Shrub.

Sphaeralcea sp., which provided 5.0% of the cattle's overall diet, was the main contributor of the three forb species which provided a total of 7.6% of the diet.

Of the grasses, Hilaria jamesii was present in all fecal samples and contributed 17.8% to the overall diet, making it the primary food plant species in the Cold Desert Shrub. Other grasses consumed were: Aristida

fendleriana (7.7%), Sporobolus airoides (5.7%), Bouteloua eriopoda (4.5%) and Sporobolus flexuosus (1.6%). Collectively grasses formed 37.3% of the cattle's diet.

Juniper/Grassland Community

Atriplex spp., which provided 12.3% of the cattle's overall diet in the Juniper/Grassland Community, was present in 93% of all fecal samples (table 12). This species made the largest contribution to the browse segment of the cattle's diet, 15.9%. The overall forb component of the cattle's diet was only 3.0%.

Eight species of grasses were identified from the cattle feces. Of these, Hilaria jamesii, the most important food plant, made a dietary contribution of 15.5% and was present in all fecal samples. Bouteloua eriopoda provided 10.3% of the cattle's diet and was present in 79% of all fecal samples. Sporobolus flexuosus provided 8.3% and was present in 70% of all fecal samples. Aristida fendleriana, which provided 8.3%, was present in 63% of all fecal samples. An average of 4.43 grass species was present in each fecal sample.

Grassland Community

Within the Grassland Community, browse plant species provided 13.4% of the cattle's overall diet (table 13). Atriplex spp. made a dietary contribution of 10% and was present in 80% of all fecal samples. The forb dietary component was quite insignificant, providing only 1.0% to the cattle's overall diet.

Grasses made an overall dietary contribution of 60.5%. The main grass species which provided this substantial segment of the cattle's diet were:

Stipa neomexicana, which constituted 17.0% of the cattle's diet and was present in all fecal samples, Hilaria jamesii, 15.7% and present in all samples, Bouteloua eriopoda, 12.1% and present in 89% of the samples and Aristida fendleriana, 8.0% and present in 64% of all fecal samples.

Fecal samples from cattle were collected from all vegetative communities from 15 November through 15 April. Cattle grazing was not permitted on Wupatki National Monument during the summer months. Samples from the first collection period in April, when cattle were still present on the grazing areas of the monument, were grouped with the samples from the winter period. A total of 132 fecal samples was analyzed.

Grasses formed the major component of the overall diet of the cattle in each of the three vegetative communities. The relative importance of each grass species was related to the community in which the animal fed. Hilaria jamesii was taken in high quantities in each community and was identified in all fecal samples. Bouteloua eriopoda and Aristida fendleriana also ranked high in importance in each community. Sporobolus airoides formed a significant dietary component in only the Cold Desert Shrub, Sporobolus flexuosus was significant only in the Juniper/Grassland and Stipa neomexicana was significant in only the Grassland Community.

The overall dietary contribution by browse varied among communities, being inversely proportional to the degree of utilization of grasses. The greatest use of browse was in the Cold Desert Shrub Community, the least in the Grassland. Atriplex spp. were the most important browse species in the three communities, being represented in 90% of all fecal samples. Several other browse plants were taken in minor quantities.

Forbs constituted a small portion of the cattle's diet in the Juniper/Grassland and Grassland Communities and only a slightly more significant component in the Cold Desert Shrub.

Seasonal changes in the diet of the cattle were basically minor, with slightly higher percentages of forbs and grasses being utilized during the fall than during winter.

Horse

Cold Desert Shrub

A total of 14 horse fecal samples was collected from the Cold Desert Shrub Community. Samples were collected which represented all but the fall season. No additional feces were found in any other community. Grasses comprised the greatest segment of the horse's diet, 48.1% (table 14). Hilaria jamesii provided 18.0% of the horse's overall diet, Bouteloua eriopoda, 11.0%, Aristida fendleriana, 9.9% and Sporobolus airoides, 8.2%. Hilaria jamesii was present in all fecal samples. The dietary contribution of browse, 14.1%, was almost entirely composed of Atriplex spp. Forbs provided 6.7% of the horse's diet, with Salsola kali, at 4.4%, the most frequently utilized forb. There were no significant dietary changes between seasons.

DISCUSSION

Each plant in the reference collection had at least one clearly diagnostic cell structure. However, there were often several cells of one plant that closely resembled those of various other plants. Though almost any plant cell was theoretically identifiable by its cuticular characteristics, many

cells were sufficiently damaged by digestive activity or obscured by other plant fragments so as to make their identification nearly impossible. The large proportion of unidentified fragments from the fecal samples of all herbivores reflected, in part, the problem of differentiating between some cells of several plant species. In addition, many plants - browse, forbs and grasses alike, which occurred on the monument were not included in the reference collection. Though most of these only comprised a small part of the total vegetation, a few, or many in aggregate, may have been responsible for a substantial portion of a herbivore's diet. It appeared likely that forbs were responsible for the greatest proportion of the unknown dietary component. Most forb species were of low abundance, seasonal in occurrence and patchily distributed on Wupatki, making their addition to the reference collection very difficult. If all fragments could have been identified there may have been a change in the order of the importance rankings of some of the food plant species. However, the greatest proportion of error would probably be with those plants which made up a small percentage of a herbivore's diet. Any general trends and average percent composition of the major dietary components should not have been greatly affected.

Both leaves and berries with seed of Juniperus monosperma were taken by many herbivores. However, since the seed itself was indigestible, it often passed whole through a herbivore's system. For herbivores which eliminate in pellet form, the presence of these seeds may have caused their fecal pellets to easily break up, creating a negative bias in the random collection of fresh fecal material. In addition, since these seeds were often visible in a fecal pellet, a bias during collection could have been introduced.

Microscopic examination of fecal samples in which J. monosperma seeds were present often did not reveal any juniper in the analysis. It was presumed that the initial grinding of the fecal samples did not crush the seeds into small enough fragments to be included with the small portion of powdered fecal material which was placed on a microscope slide. The presence of J. monosperma in the diets of the herbivores was probably underestimated in the fecal analysis and the relative importance of juniper may actually have been higher than indicated.

Interpretation of the preference index must be made carefully. Preference indices were determined by the ratio of the percent consumption of a plant species to the relative availability of that species. The relative cover values used for the Cold Desert Shrub and Juniper/Grassland Communities were obtained from the 1981 Report. For the Grassland, relative cover values were adjusted from absolute cover data from the Phase I Report. The number of transects used in each community to obtain cover values and the methods of analysis differed somewhat between the two reports. The data from the few transects analyzed would not reflect the heterogeneity in time and space of the area. As noted in the Phase I Report (Bateman, 1976), a plant's distribution and abundance varied greatly within communities and patterns in the Cold Desert Shrub were especially complex. The relative cover values used in table 2 under the vegetation type groups, corresponding to browse, forbs, and grasses, were determined from observations in the Phase I Report. These figures may reflect a truer picture of the relative availability of each vegetation type than would the summation of the cover values of individual species. The potential for inconclusiveness of the relative cover data for individual plant species was amplified by the

mobility of the herbivores which allowed them to search out areas of high concentrations of preferred plant species. Preference indices for vegetation types may provide a better indication of food preferences than the preference indices for individual plant species. Preference indices may have been more refined if the percent frequency of a plant species in a herbivore's diet was used in conjunction with its percent dietary volume as was suggested by Chamrad (1979).

The large proportion of unidentified plant fragments in the fecal samples introduced a degree of error into the interspecific comparisons of diets. If the percent consumption of all food plants for each herbivore were known, it would probably result in some reduction in the dietary similarity figures. Each herbivore encountered low density plant species according to its particular habits, methods of foraging, individual preferences, and the association of one plant species with other plants. Therefore, many of those plants which comprised a low percentage of a herbivore's diet may not have been present in the diet of another herbivore species. This would have decreased the degree of dietary similarity among the herbivore species.

Percent similarity of diet indicated the degree of dietary overlap between two herbivore species in terms of the occurrence of each food plant in their diets and the relative percent contribution of each plant species. However, no indication of the preference for, or availability of food plants entered into the similarity equation. In a situation where two herbivores fed extensively on the same food resources and had a high percent similarity index, but the food resources were not limiting, there would be a potential for competition but not direct competition. In the case where food resources were limited, the competition between sympatric herbivores for a common preferred food base, may have forced each species to select other, less

preferred foods and so increase their dietary differences. This would result in a lower overall percent similarity of diet index under circumstances of severe competition.

Due to the problems inherent in the use of similarity of diet indices, the difficulty in obtaining relative abundance data for many food plant species on the monument, and the high percentage of unknowns in the dietary analysis, the determinations of diet, food preferences, and potential competition between domestic and native herbivores were carried out through the analysis of the relationships between percent consumption of each vegetation type by each herbivore in each community, seasonal shifts in diet, and the availability of each vegetation type within each community. The results of previous dietary studies were reviewed to obtain a better understanding of the food habits of each herbivore on Wupatki National Monument.

Desert Cottontail

A review of the literature concerning the diet of the desert cottontail indicated a remarkable degree of dietary adaptability. The cottontail utilizes a wide variety of plants as they become seasonally available and adapts readily to local conditions of specific plant abundances and environmental conditions (Hansen and Gold, 1977; Turkowski, 1975). Dietary studies found that the cottontail consumes a high percentage of the available number of taxa of potential food plants in its habitat (Flinders and Crawford, 1977; Hansen and Gold, 1977; and Turkowski, 1975) and that the female takes a slightly greater number of plant species than the male (Turkowski, 1975). Turkowski (1975) determined that the plant species per se were not as important to the cottontail as were the conditions of the plants, particularly

moisture content and growth stage. Newly sprouted plants are highly palatable, being high in moisture, crude protein and nutritive values. Despite this dietary versatility in food plant selection, the overall diet of the desert cottontail in all studies reviewed (Flinders and Crawford, 1977; Hansen and Gold, 1977; and Turkowski, 1975) appeared to be comprised of approximately 20% shrubs, 42% herbs and 38% grasses. During the spring the relative importance of grasses usually increased significantly.

Due to this high degree of dietary flexibility, factors limiting overall cottontail distribution are only secondarily related to food abundance. Increases of cottontails on moderately grazed ranges were attributed by Flinders and Hansen (1975) to an increase in shrub densities which provide cover rather than enhancing the food resource. Kundaeli and Reynolds (1972) found cottontail use of pinyon-juniper woodland strongly related to shrub density and not overall food abundance. Within the Sonoran desert, Turkowski (1975) found cottontail survival was limited more by the availability of moisture than food. However, Turkowski (1975) also found a significant reduction in litter size of the cottontail under conditions of limited vegetational resources, which were the result of below normal rainfall. It was the reduction in the quality of the food plants as represented by the number of plant species consumed, rather than the total plant biomass consumed, which caused the drop in the realization of the reproductive potential of the desert cottontail.

Forbs, which constituted the major dietary component of the desert cottontail in previously conducted studies, provided approximately one-third of the identified portion of the cottontail's diet within the three communities of Wupatki. As previously stated, it is presumed that the forb component in the unidentified segment of the cottontail's diet was probably higher in

relation to that of shrubs and grasses. Forbs were consumed in the Cold Desert Shrub and Grassland Communities in greater proportions than they were available in the habitat. In the Juniper/Grassland, forbs were taken in approximately the same proportions in which they occurred in the community. However, the overall proportion of forbs in the diet of the cottontail remained roughly equal between communities. This indicates a higher relative preference for forbs when they were not readily available in the habitat as when they were moderately abundant. Total forb utilization by the cottontail corresponded reasonably well with the trends identified in previous dietary studies on this herbivore. The grass and browse component each provided approximately one-third of the cottontail's diet in the Juniper/Grassland and Grassland Communities. Taking into account the proportion of unidentified fragments in the analysis of the cottontail's diet, these results are compatible with the literature. In the Cold Desert Shrub, grasses comprised a dietary component of less than half that provided by browse. This does not correspond well with the literature or with the trends of cottontail dietary preferences that have been identified within the other communities of Wupatki. Grasses were taken in significantly reduced quantities and were replaced with a higher than "normal" proportion of browse. Shrub availability far exceeded that of grasses and forbs in the Cold Desert Shrub. The relative ground cover of grasses was 24%, however, this only represented 5% absolute ground cover (Phase I Report). The contribution of browse to the cottontail's annual diet in the Juniper/Grassland Communities did not reflect relative increases of shrub abundance as strongly as the increase in the Cold Desert Shrub Community. This implied that perhaps grasses were in short supply and high demand in the Cold Desert Shrub and may be a point of potential competition with other herbivores.

Black-tailed Jackrabbit

The diets of the black-tailed jackrabbit have been studied more extensively than the diets of any other North American lagomorph (Hansen and Flinders, 1969). Studies have been conducted throughout much of its range and like that of the desert cottontail, have revealed a remarkable degree of dietary adaptability. Many of the major food plants taken by the jackrabbit in different areas of its distribution do not occur throughout its geographic range (Hansen and Flinders, 1969). Forage maturity and availability influence dietary trends of the black-tailed jackrabbit (Sparks, 1968). Jackrabbits have a preference for green succulent plants when they are available (Hansen and Flinders, 1969) and readily take all new green growths (Currie and Goodwin, 1966). Forbs are more highly preferred than either grasses or shrubs (Arnold and Reynolds, 1943; Sparks, 1968). Hayden (1966) stressed that the overriding factors which influenced food plant selection were the environment and the necessity of maintaining a balance of body water. In all studies reviewed (Currie and Goodwin, 1966; Flinders and Hansen, 1977; Hayden, 1966; and Sparks, 1968), seasonal fluctuations in the major type of vegetation consumed followed the same basic patterns. The greatest consumption of grasses occurs in the spring and summer, forbs receive the heaviest utilization during summer and early fall, and shrubs are taken in greatest quantities during fall and winter. However, there were some discrepancies in the literature concerning the relative proportions of vegetation types which comprise the annual diet of the black-tailed jackrabbit. Sparks (1968) determined that the yearly diet consisted of approximately 50% grasses, 40% forbs and 10% shrubs. Hayden (1966) reported the jackrabbit consumed approximately equal amounts of forbs and grasses with browse being taken in lesser quantities. Flinders and Crawford

(1977) determined that forbs comprised 12% of the jackrabbit's annual diet and that the remainder was of approximately equal quantities of grasses and shrubs. The overall diet of the black-tailed jackrabbit consists of numerous species of food plants. Hayden (1966) accounted for this high number of plant species, most of which were only minor constituents, by the random feeding habits of the jackrabbit as it pauses to sample a plant and then moves on to another. The jackrabbit often travels over a large area while feeding, encountering a variety of potential food plants (Sparks, 1968). Black-tailed jackrabbits prefer feeding out in the open where they are able to detect danger from moderate distances but which does not render them conspicuous from great distances (Hansen and Flinders, 1969). Jackrabbits were reported by Flinders and Hansen (1975) to be most abundant in pastures under moderate and light summer grazing treatment. In these areas, livestock grazing had reduced the vegetative stand while still maintaining sufficient plant growth to provide food and cover.

The overall patterns of vegetation utilization by the black-tailed jackrabbit in the Juniper/Grassland and Grassland Communities of Wupatki were rather similar. Browse and grasses comprised approximately equal proportions of the annual diet of the jackrabbit in the Grassland Community. In the Juniper/Grassland, browse provided somewhat more than the grasses to the jackrabbit's diet. Forbs were identified in rather low proportions in the fecal samples from all communities, however, it was assumed that the majority of the unidentified dietary component was composed of forbs. Within the Cold Desert Shrub, Juniper/Grassland and Grassland, a large percentage of the plant species found in each community which were present in the reference collection were identified in the diet of the jackrabbit in the respective communities.

Seasonal variations in the relative quantities of browse and grasses consumed in the Juniper/Grassland and Grassland were compatible with similar patterns observed in the literature. Shrub utilization peaked during the winter months when grasses formed a substantially reduced portion of the diet. During the summer, the dietary contribution by grasses far exceeded that provided by browse.

In the Cold Desert Shrub, browse comprised the greatest component in the jackrabbit's diet during every season of the year. The relative proportions of browse and grasses followed seasonal fluctuations similar to those of the other communities, except that the utilization of grasses remained low throughout the year. The relative and absolute abundances of grasses in the Cold Desert Shrub were far below those in the Juniper/Grassland and Grassland Communities. Perhaps the apparent selection for browse species in the Cold Desert Shrub may have been a reflection of plant availability.

Mule Deer/Pronghorn

Studies have shown browse to be the primary type of food plant consumed by mule deer (Anderson et al., 1965; Boeher et al., 1972; Hansen, 1976; Julander, 1962; Short, 1977). Food plant selection changes seasonally, with grasses being taken in significant quantities during summer and fall (Boeker et al., 1972; Hansen and Reid, 1975). Utilization of forbs varies depending upon the amount of rainfall, which in turn affects forb availability in the habitat. During years of normal precipitation in the southwest, forbs are taken in small amounts, primarily in spring and summer (Anderson et al., 1965; Boeker, et al., 1972; Hansen and Reid, 1975). Under conditions of unusually heavy precipitation which cause an increase in all forage, forbs are consumed

in greater quantities than either browse or grasses during every season of the year (Anderson et al., 1965). The utilization of forbs and grasses during spring and summer provides a reduction of browsing pressure on primary browse species during their active growing season (Boeker et al., 1972). Mule deer tend to sample a large variety of forage when available even though the bulk of their diet is supplied by a few major food plant species (Anderson et al., 1965; and Boeker et al., 1972). A diet of exclusively browse all year long is adequate for mule deer survival and reproduction (Boeker et al., 1972). However, a diet comprised largely of Juniperus, a common browse plant, is insufficient in digestible proteins (Anderson et al., 1965). Forbs are nutritionally superior to browse (Boeker et al., 1972) and when present in high quantities could have a significant effect on increasing deer body weight and reproduction (Anderson et al., 1965).

Forage consumption by pronghorns varies considerably throughout their range depending on the availability of food plants (Schwartz and Nagy, 1976). Ellis and Travis (1975) determined that the summer diet of the pronghorn consists of 15% shrubs, 70% forbs and 15% grasses and the winter diet is 27% shrubs, 20% forbs and 53% grasses. Schwartz and Nagy (1976) analyzed the pronghorn's diet under conditions of light and heavy grazing by cattle and found the overall diet to be composed of 3% shrubs, 48% forbs and 48% grasses. Shrub utilization is heaviest on overgrazed ranges due to the lack of forbs. Grass utilization increases on ranges where shrubs are not abundant. Beale and Smith (1970) found the winter diet of the pronghorn to consist of approximately 90% browse. During the early spring was the only time when grasses were found to be significant, providing approximately 40% of the pronghorn's diet. Forb utilization peaked in summer. During a wet year, forbs made a

dietary contribution of approximately 90% and in a dry year, approximately 2%.

Anthony and Smith (1974) found that at least fifteen fecal pellets from deer were needed to analyze its diet for a particular season. The actual number needed in any given locale depends on dietary and vegetational diversities. Small sample size and the necessity of combining mule deer and pronghorn fecal pellets collected on Wupatki made the determination of individual diets for each herbivore not possible. As a whole, the diet of mule deer/pronghorn consisted primarily of browse with grasses and forbs being taken in lesser amounts. The close proximity of the different vegetative communities on Wupatki negated the comparisons of relative plant abundance to food plant consumption for these highly mobile herbivores.

Cattle

Dietary analyses of cattle under various types of habitats and range conditions have determined that grasses comprise the primary dietary item (Clary et al., 1978; Hansen et al., 1977; Hansen and Gold, 1977; Hansen and Reid, 1975; Olsen and Hansen, 1977; Reppert, 1960; Short, 1977). Browse is consumed in moderate to low proportion when readily available in the habitat (Hansen and Reid, 1975; Olsen and Hansen, 1977, Reppert, 1960; Short, 1977). Forbs are significant in the cattle's diet only during summer and early fall (Hansen and Gold, 1977; Reppert, 1960). In general, cattle demonstrate indiscriminate use of most grasses, weeds and shrubs according to Reppert (1960). Food plant selection by cattle is not very specific. Their muzzle is broad and flat and the tongue is used to draw large clumps of vegetation into the mouth where the teeth sever it from the stalk (Ellis and Travis, 1975).

However, definite preferences for green vegetation over old were expressed during the growing season and leaves of shrubs were preferred to stems (Reppert, 1960). Clary et al. (1978) found that under the "proper" livestock management of range rest-rotation and adequate size of range units, moderate physical feature of rockiness of soil, distance from water, and steepness of slope did not restrict cattle movement in their utilization of forage.

On all ranges of Wupatki National Monument cattle consumed grasses in much greater quantities than either shrubs or forbs. Grasses comprised 73% of the identified fragments from fecal samples collected in the Juniper/Grassland and 82% of the fragments from samples from the Grassland. In these two communities, grasses were taken at levels slightly below that expected according to their availability. The percentage of browse consumed by the cattle in the Juniper/Grassland and Grassland communities was reconcilable with the literature, considering this analysis was for a fall-winter grazing period. Fifty-one percent of the identified component of the cattle's diet from the Cold Desert Shrub was provided by grasses. The relative preference for grasses was substantially higher in the Cold Desert Shrub than in the Juniper/Grassland and Grassland Communities. Forbs comprised a significant dietary component in only the Cold Desert Shrub where their preference index was just under that for grasses. However, the relative scarcity in the habitat and low occurrence of forbs in the diet in the Juniper/Grassland imply that forbs are not very important to cattle during this period of the year. The high relative consumption of browse and forbs and the high preference index for forbs and grasses indicated that perhaps the cattle grazing in the Cold Desert Shrub Community of Wupatki would have preferred to consume grasses in high quantities, but were forced by availability to do otherwise.

Horse

Little research concerning the food habits of free-roaming horses has been conducted (Hansen, 1976). That which has been done has shown that grasses provide by far the main bulk of their diet. Grasses contribute 80% to 95% to the diet of horses (Hansen et al., 1977; Hubbard and Hansen, 1976; Olsen and Hansen, 1977) with only minimal shifts in the utilization of the different vegetation types with changes in habitat (Hubbard and Hansen, 1976) or with the passing of the seasons (Hansen, 1976). However, one study by Hansen (1976) has revealed some flexibility in the horse's diet. On the White Sands Missile Range in southern New Mexico, the feral horse population had an overall dietary contribution by grasses of approximately 50%. The major constituents of the remainder of the diet were Salsola kali, 19%, Prosopis juliflora (mesquite), 16%, and Atriplex spp., 5%. This horse population was observed to be increasing steadily (Hansen, 1976).

The limited number of horse fecal samples from Wupatki National Monument was all collected from the Cold Desert Shrub Community. The majority of these samples was taken from a small area near Wukoki Ruin. This particular location could probably be considered as a grassland/shrub subsection of the Cold Desert Community (based on visual observation). Approximately 70% of the identified portion of the horse's diet was composed of grasses. Atriplex was the major shrub component and Salsola kali the predominant herb. These results were compatible with the literature in light of Hansen's 1976 study.

Similarities of Diets

A herbivore that lacks strong food preferences generally always finds something to eat (Hansen and Uerkert, 1970) and, therefore, the availability

of a particular forage is not critical to its survival (Hansen and Gold, 1977). The high frequency of occurrence of a plant species in a habitat increases its probability of being contacted by a grazing animal (Chamrad, 1979). Sympatric herbivores encounter some of the same plant species, each reducing the potential food source of the other. Though herbivores may eat many of the same items, the species of plant foods are often taken in different proportions, reducing the potential for competition for those plants which are preferred by each herbivore. Differences in food plant preferences are one means of increasing ecological separation of historically sympatric herbivores and are presumably related to the nutritional needs of the animal (Ellis and Travis, 1975). However, due to seasonal variations in plant abundances and nutritional quality, many herbivores avoid competitive exclusion by remaining "broad-spectrum" (Hansen and Gold, 1977) feeders. So, underlying this dietary plasticity is a strong potential for competition between all sympatric herbivores. The extent to which two herbivores from a common locale share the same dietary components is an indication of their potential for competition. Similarity of diet indices are a measure of this overlap. The degree of actual competition is dependent upon the specific conditions of the habitat at a particular time.

The herbivores studied on Wupatki National Monument shared many of the same major dietary items. Those food plants which received the greatest utilization were also some of the more abundant plant species on the monument. Overall, Atriplex spp. and Hilaria jamesii were the dominant food plants in the common diet of all herbivores in terms of frequency and percent composition. The great abundance of H. jamesii in all vegetative communities of Wupatki and its low palatability (Phase I Report) seem to indicate that the high consumption of this grass was a direct result of its availability. Atriplex, a

common shrub on the monument is fairly palatable to most herbivores (Phase I Report). Though the outer tissues of Atriplex are hypersaline, the inner tissues are rich in nonsalty starch (Kenagy, 1972). Slight to moderate browsing upon Atriplex spp. increases branching of this shrub, providing food and cover for many native herbivores (Flinders and Hansen, 1975). However, the continuous clipping of twigs by cottontails (Hansen and Gold, 1977) and jackrabbits (Currie and Goodwin, 1966) and/or overgrazing by livestock would locally suppress or eliminate this species (Hansen and Flinders, 1969; Hansen and Gold, 1977). Visual observations of Atriplex plants on Wupatki show that in many areas they have received very heavy utilization as food plants. In addition, many plants were seen which were severely trampled by cattle.

Hilaria jamesii and Atriplex spp. accounted for a large percentage of the similarity of diet values in most comparisons of the diets of the domestic and native herbivores.

Dietary similarity indices and comparisons among the diets of the native and domestic herbivores, with reference to the literature, have revealed some possible areas with an overall substantial potential for competition (Table 25). In the Cold Desert Shrub Community where the absolute abundance of grasses was quite low, 5% ground cover, the strong preference for grasses by cattle and horses further reduced the availability of grasses for cottontail, jackrabbit and deer/pronghorn. Due to the limited availability of grasses, cattle consumed relatively high proportions of browse plant species which further increased the degree of dietary overlap between these domestic and native herbivores. During the early spring when green growth began to appear, all herbivores had very strong preference for green forage. While green forage is at a premium, any consumer that removes it is competing with

all other herbivores (Sparks, 1968). The relative availability of forbs on the monument is considerably less than that of browse and grasses (Phase I Report). In the spring when all herbivores avidly sought any green forage, the availability of forbs was reduced even more. It has been reported that a deficiency of forbs in the diets of cottontail and deer during late pregnancy strongly influences their reproductive output (Julander, 1962; Turkowski, 1975).

MANAGEMENT IMPLICATIONS

In keeping with the implied and expressed philosophy of the National Park Service--"to preserve for all future generations," livestock grazing in any form should be eliminated from Wupatki National Monument. Livestock grazing is an important form of habitat disturbance. Depending on the area, vegetation and level of grazing intensity, livestock may enhance and/or detract from habitat suitability for other herbivores (Flinders and Hansen, 1975). The results of this dietary analysis indicate that, though there are differences in the basic diets of these animals, under the existing vegetative conditions in the vicinity of Wupatki, the potential competition between these native and domestic herbivores as defined by similarity of diet warrants consideration.

In the event that it is not feasible to stop all livestock grazing on Wupatki National Monument in the near future, alterations in range management may have some effect in reducing the potential competition with native herbivores. The Cold Desert Shrub Community is poor range for cattle and horses due to the very low abundance of grasses. The removal or drastic reduction in the time and number of cattle grazing in the community would benefit all native herbivores, increasing the availability of grasses and the younger

twig tips of the shrubs. The potential competition between livestock and the native herbivores may be less in the Juniper/Grassland and Grassland Communities than in the Cold Desert Shrub. However, removal of cattle from all rangelands by early spring when competition for green forage intensifies, would assist the native herbivore populations. Spring is a critical period for native populations; the meeting of nutritional needs at this time has a substantial effect on reproduction and survival of offspring. A great void remains in the knowledge of the impact of grazing and other management practices on the total biota of an area (Clary, 1975).

SUMMARY AND CONCLUSION

The analysis of the seasonal diets of the desert cottontail, black-tailed jackrabbit, mule deer/pronghorn, cattle and horse in each of the Cold Desert Shrub, Juniper/Grassland and Grassland Communities of Wupatki National Monument was accomplished by the microscopic examination of fecal materials. The major dietary items of the cottontail were: in the Cold Desert Shrub Atriplex spp., Hilaria jamesii, and Sphaeralcea sp.; in the Juniper/Grassland Atriplex spp., H. jamesii, Bouteloua eriopoda, and Euphorbia sp.; and in the Grassland Sphaeralcea sp., Chrysothamnus sp., Stipa neomexicana and Atriplex spp. Those of the jackrabbit were: in the Cold Desert Shrub Atriplex spp., Chrysothamnus sp., and Aristida fendleriana; in the Juniper/Grassland Chrysothamnus sp., Atriplex spp., B. eriopoda, and Gutierrezia sp.; and in the Grassland Chrysothamnus sp., Atriplex spp., S. neomexicana and B. eriopoda. For deer/pronghorn they were: in the Cold Desert Shrub Artemisia spp., Atriplex spp., Juniperus monosperma and H. jamesii; and in the Juniper/Grassland J. monosperma, Atriplex spp., and H. jamesii. Cattle heavily used H. jamesii, Atriplex spp. and A. fendleriana in the Cold Desert Shrub;

H. jamesii, Atriplex spp., B. eriopoda and Sporobolus flexuosus in the Juniper/Grassland, and S. neomexicana, H. jamesii, B. eriopoda and Atriplex spp. in the Grassland. Major dietary items of the horse in the Cold Desert Shrub included H. jamesii, B. eriopoda, Atriplex spp. and A. fendleriana.

The presence of livestock on Wupatki National Monument constituted a significant habitat disturbance. The potential competition for food resources between the domestic and native herbivores was determined by the use of similarity indices and by a comparison of the seasonal diets of each herbivore within and between communities and with dietary information in the literature. Atriplex spp. and Hilaria jamesii were the food plants which accounted for the overall greatest proportion of dietary overlap among domestic and native herbivores. Potential competition heightened during the early spring when each herbivore expressed strong preferences for the newly emerged green forage. The acquisition of sufficient nutrient-rich forage during that period increases reproductive output. Livestock grazing has the potential of a more severe adverse impact on the native herbivore populations in the Cold Desert Shrub than either the Juniper/Grassland or Grassland Communities. The overall deficiency in grass availability in the Cold Desert Shrub resulted in a heavier than normal utilization of browse species by both domestic and native herbivores.

The dietary plasticity exhibited by each of the herbivores under varying habitat regimes complicated the analysis of potential competition between sympatric species. Within some reasonable limits (which have not been determined) of grazing intensity (time by number of head) defined by the habitat, certain species of domestic livestock may be able to utilize rangeland in a complementary fashion with native herbivore populations. Basic

differences in the preferred diet of each herbivore, coupled with a certain amount of species specific dietary adaptability, could result in minimal impact on the natural environment.

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Table 1. Plants used in the reference collection, representing some of the more abundant plants found on the grazing areas of the monument.

tree

Juniperus monosperma (one-seed juniper)

shrubs

Alhagi camelorum (camelthorn)
Artemisia filifolia (sand sagebrush)
Artemisia frigida (fringed sagebrush)
Atriplex canescens (four-wing saltbush)
Atriplex confertifolia (shadscale)
Chrysothamnus sp. (rabbitbrush)
Ephedra sp. (jointfir)
Fallugia paradoxa (Apache plume)
Gutierrezia sp. (snakeweed)

herbs

Amsonia peeblesii (amsonia)
Astragalus sp. (locoweed)
Chenopodium sp. (wild-buckwheat)
Euphorbia sp. (spurge)
Phacelia sp. (phacelia)
Psilostrophe sparsiflora (greenstem paperflower)
Salsola kali (Russian-thistle)
Sphaeralcea sp. (globe-mallow)
Zinnia grandiflora (zinnia)

grasses

Andropogon hallii (sand bluestem)
Aristida fendleriana (Fendler three-awn)
Bouteloua curtipendula (side-oats grama)
Bouteloua eriopoda (black grama)
Bouteloua gracilis (blue grama)
Hilaria jamesii (galleta)
Oryzopsis hymenoides (Indian ricegrass)
Sitanion hystrix (squirreltail)
Sporobolus airoides (alkali sacaton)
Sporobolus flexuosus (mesa dropseed)
Stipa neomexicana (New Mexico feathergrass)

Table 2. Relative cover used to determine herbivore food plant preference indices. Obtained from Phase I and Phase IV Reports (Bateman, 1976, 1981).

	<u>Cold Desert Shrub</u>	<u>Juniper/ Grassland</u>	<u>Grassland</u>
<u>Artemisia</u> spp.	66.4		
<u>Atriplex</u> spp.	9.5	1.7	
<u>Chrysothamnus</u> sp.	2.7	22.0	86.3
<u>Ephedra</u> sp.	10.3		
<u>Fallugia paradoxa</u>	1.5		
<u>Gutierrezia</u> sp.		1.0	
total browse	71.0	16.0	36.0
<u>Astragalus</u> sp.	0.6		
<u>Eriogonum</u> sp.	4.2		
<u>Euphorbia</u> sp.			0.1
<u>Psilostrophe sparsiflora</u>		0.9	0.1
<u>Salsola kali</u>	0.2		2.5
<u>Sphaeralcea</u> sp.		0.2	4.3
<u>Zinnia grandiflora</u>			0.1
total forbs	5.0	22.0	2.0
<u>Bouteloua eriopoda</u>		4.6	0.1
<u>Hilaria jamesii</u>		43.3	3.5
<u>Oryzopsis hymenoides</u>			0.1
<u>Stipa neomexicana</u>			1.7
total grasses	24.0	62.0	62.0

Table 3. Seasonal summary of food items by percent and frequency for the cottontail in the Cold Desert Shrub Community.

	Jan. - Mar.		Apr. - June		July - Sept.		Oct. - Dec.		Annual	
	mean % of diet	fre- quency index	mean % of diet	fre- quency index	mean % of diet	fre- quency index	mean % of diet	fre- quency index	mean % of diet	fre- quency index
<u>Artemisia</u> spp.	2.7	0.17					1.9	0.17	1.2	0.08
<u>Atriplex</u> spp.	11.6	0.79	13.3	1.00	9.2	0.71	12.4	0.88	11.6	0.84
<u>Chrysothamnus</u> sp.	6.1	0.63	6.1	0.67	3.9	0.38	3.7	0.29	5.0	0.49
<u>Ephedra</u> sp.	3.2	0.29	1.0	0.08			4.9	0.50	2.3	0.29
<u>Fallugia paradoxa</u>	2.0	0.17							0.5	0.04
<u>Gutierrezia</u> sp.	5.9	0.46	6.7	0.67	4.1	0.46	3.2	0.33	5.0	0.48
<u>Juniperus monosperma</u>	3.6	0.29					4.2	0.29	2.0	0.15
total browse	35.1	2.80	27.1	2.42	17.2	1.55	30.3	2.46	27.6	2.37
<u>Astragalus</u> sp.			2.7	0.29	2.1	0.29			1.2	0.15
<u>Chenopodium</u> sp.			0.5	0.04					0.1	0.01
<u>Eriogonum</u> sp.	5.1	0.25	4.8	0.33	3.7	0.47	4.1	0.33	4.4	0.33
<u>Euphorbia</u> sp.	2.7	0.17	5.9	0.50	6.3	0.47	4.3	0.38	4.8	0.36
<u>Salsola kali</u>			4.6	0.50	5.1	0.59			2.4	0.27
<u>Sphaeralcea</u> sp.	7.3	0.33	7.4	0.46	9.1	0.47	7.2	0.50	7.8	0.40
<u>Zinnia grandiflora</u>					0.5	0.04			0.1	0.01
total forbs	15.1	0.75	25.9	2.12	26.8	2.33	15.6	1.21	20.8	1.53
<u>Andropogon hallii</u>			0.5	0.04					0.1	0.01
<u>Aristida fendleriana</u>	3.1	0.33	6.2	0.67	6.1	0.63	4.2	0.38	4.9	0.50
<u>Bouteloua curtipendula</u>					1.7	0.08			0.4	0.02
<u>Bouteloua eriopoda</u>			1.3	0.12					0.3	0.03
<u>Hilaria jamesii</u>	7.4	0.88	6.1	0.92	7.8	0.88	9.7	0.83	7.8	0.88
<u>Oryzopsis hymenoides</u>			1.0	0.08	0.5	0.04			0.4	0.03
<u>Sporobolus airoides</u>	1.2	0.13			1.9	0.17			0.8	0.07
total grasses	11.7	1.34	15.1	1.83	18.0	1.80	13.9	1.21	14.7	1.54
unidentified components (%)	38.1		31.9		38.0		40.2		36.9	
total fecal samples	24		24		24		24		96	
total plant species	13		15		14		11		21	
mean number of plant species per sample	4.89		6.37		5.68		4.88		5.44	

Table 4. Seasonal summary of food items by percent and frequency for the cottontail in the Juniper/Grassland Community.

	Jan. - Mar.		Apr. - June		July - Sept.		Oct. - Dec.		Annual	
	mean % of diet	fre- quency index	mean % of diet	fre- quency index	mean % of diet	fre- quency index	mean % of diet	fre- quency index	mean % of diet	fre- quency index
<u>Atriplex spp.</u>	6.7	0.67	7.3	0.83	3.4	0.21	8.9	0.58	6.6	0.57
<u>Chrysothamnus sp.</u>	6.6	0.46	3.4	0.33	1.5	0.21	5.6	0.50	4.3	0.38
<u>Ephedra sp.</u>	3.8	0.38	2.7	0.33			2.8	0.33	2.3	0.10
<u>Fallugia paradoxa</u>	2.7	0.17	1.4	0.08			1.0	0.04	1.3	0.07
<u>Gutierrezia sp.</u>	5.9	0.46	2.3	0.21	1.3	0.13	4.4	0.46	3.5	0.31
<u>Juniperus monosperma</u>	6.4	0.58	1.2	0.17			5.9	0.46	3.4	0.30
total browse	32.1	2.72	18.3	1.95	6.2	0.55	28.6	2.37	21.3	1.73
<u>Astragalus sp.</u>			2.3	0.21	2.2	0.25			1.1	0.11
<u>Chenopodium sp.</u>	1.7	0.13	3.5	0.29	4.6	0.29	5.0	0.25	3.7	0.24
<u>Eriogonum sp.</u>	2.3	0.21			2.1	0.13	3.2	0.21	1.9	0.14
<u>Euphorbia sp.</u>	2.4	0.30	4.8	0.46	5.9	0.67	5.9	0.50	4.8	0.47
<u>Psilostrophe sparsiflora</u>			2.1	0.21	2.7	0.13			1.2	0.08
<u>Salsola kali</u>			2.7	0.38	2.8	0.25			1.4	0.16
<u>Sphaeralcea sp.</u>	3.7	0.38	3.4	0.25	4.2	0.58	4.1	0.38	3.9	0.40
<u>Zinnia grandiflora</u>	1.9	0.13	4.8	0.46	6.3	0.50	3.7	0.42	4.2	0.38
total forbs	12.0	1.15	23.6	2.26	30.8	2.80	21.9	1.76	22.2	1.98
<u>Aristida fendleriana</u>	3.1	0.33	4.9	0.42	4.6	0.46	4.1	0.42	4.2	0.41
<u>Bouteloua curtipendula</u>	1.4	0.13	1.0	0.08	2.4	0.17			1.2	0.09
<u>Bouteloua eriopoda</u>	6.6	0.75	5.8	0.38	5.3	0.71	5.2	0.63	5.7	0.61
<u>Bouteloua gracilis</u>	1.8	0.17	2.2	0.17	1.8	0.13	2.1	0.21	2.0	0.17
<u>Hilaria jamesii</u>	6.9	0.79	6.4	0.58	3.8	0.42	5.9	0.71	5.8	0.63
<u>Oryzopsis hymenoides</u>	1.3	0.08	1.7	0.13	2.1	0.21	2.4	0.21	1.9	0.16
<u>Sitanion hystrix</u>			1.3	0.04					0.3	0.01
<u>Sporobolus flexuosus</u>	1.0	0.13	2.9	0.33	2.9	0.29	2.4	0.21	2.3	0.24
<u>Stipa neomexicana</u>			2.1	0.21	1.7	0.08	1.3	0.08	1.3	0.09
total grasses	22.1	2.38	28.3	2.34	24.6	2.47	23.4	2.47	24.6	2.41
unidentified components (%)	33.8		29.8		38.4		26.1		31.8	
total fecal samples	24		24		24		24		96	
total plant samples	18		22		19		18		23	
mean number of plant species per sample	6.25		6.55		5.82		6.60		6.12	

Table 5. Seasonal summary of food items by percent and frequency for the cottontail in the Grassland Community.

	Jan. - Mar.		Apr. - June		July - Sept.		Oct. - Dec.		Annual	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index	diet	index
<u>Atriplex</u> spp.	9.3	0.65	6.4	0.74	5.1	0.57	7.6	0.65	7.1	0.66
<u>Chrysothamnus</u> sp.	8.9	0.75	7.9	0.91	6.4	0.57	10.2	0.91	8.4	0.79
<u>Ephedra</u> sp.	2.1	0.20	1.0	0.09					0.8	0.07
<u>Gutierrezia</u> sp.	3.2	0.25	1.3	0.09	3.6	0.38	4.4	0.34	4.1	0.26
<u>Juniperus monosperma</u>	2.9	0.20	1.4	0.13			3.7	0.30	2.0	0.16
total browse	26.4	2.05	18.0	1.96	15.1	1.52	25.9	2.20	22.4	1.94
<u>Astragalus</u> sp.			1.2	0.13	1.8	0.14			0.8	0.69
<u>Eriogonum</u> sp.							1.2	0.09	0.3	0.02
<u>Euphorbia</u> sp.	3.6	0.40	6.4	0.34	7.1	0.52	4.1	0.39	5.3	0.41
<u>Salsola kali</u>			4.9	0.39	5.2	0.48			2.5	0.22
<u>Sphaeralcea</u> sp.	8.1	0.60	7.4	0.74	12.1	0.86	9.2	0.91	9.2	0.24
<u>Zinnia grandiflora</u>	3.2	0.40	3.3	0.30	4.9	0.38	2.7	0.22	3.5	0.32
total forbs	14.9	1.40	23.2	1.90	31.1	2.38	17.2	1.61	21.6	1.90
<u>Aristida fendleriana</u>	3.7	0.35	4.3	0.43	4.1	0.33	4.2	0.39	4.1	0.38
<u>Bouteloua curtipendula</u>					2.5	0.19			0.6	0.05
<u>Bouteloua eriopoda</u>	3.9	0.45	4.9	0.43	5.2	0.57	5.4	0.43	4.9	0.47
<u>Bouteloua gracilis</u>			2.1	0.13	2.3	0.19	1.7	0.13	1.5	0.11
<u>Hilaria jamesii</u>	8.4	0.90	6.2	0.52	5.2	0.71	6.0	0.74	6.5	0.71
<u>Oryzopsis hymenoides</u>	2.6	0.25	3.1	0.22	3.6	0.33	2.8	0.22	3.0	0.25
<u>Sporobolus flexuosus</u>			1.0	0.09			2.1	0.17	0.8	0.07
<u>Stipa neomexicana</u>	4.2	0.40	8.1	0.87	8.8	0.86	9.1	0.78	7.6	0.75
total grasses	22.8	2.35	29.7	2.69	31.7	3.18	31.3	2.86	29.0	2.79
unidentified components	35.9		29.1		22.1		25.6		27.0	
total fecal samples	20		23		21		23		87	
total plant species	13		17		15		15		19	
mean number of plant species per sample	5.80		6.55		7.08		6.67		6.63	

Table 7. Seasonal summary of food items by percent and frequency for the jackrabbit in the Juniper/Grassland Community.

	<u>Jan. - Mar.</u>		<u>Apr. - June</u>		<u>July - Sept.</u>		<u>Oct. - Dec.</u>		<u>Annual</u>	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index	diet	index
<u>Artemisia spp.</u>							1.9	0.04	0.5	0.01
<u>Atriplex spp.</u>	11.1	0.45	10.2	0.70	5.9	0.29	8.6	0.83	9.0	0.75
<u>Chrysothamnus sp.</u>	17.8	0.95	9.7	0.74	1.9	0.21	14.3	0.97	10.9	0.92
<u>Ephedra sp.</u>	7.1	0.64	1.8	0.17			4.1	0.67	3.3	0.48
<u>Fallugia paradoxa</u>	5.2	0.18	0.5	0.04			0.5	0.08	1.6	0.10
<u>Gutierrezia sp.</u>	13.2	0.77	5.2	0.43	2.1	0.38	6.7	0.38	6.8	0.63
<u>Juniperus monosperma</u>	7.6	0.36	3.2	0.30	2.1	0.13	4.7	0.25	4.4	0.34
total browse	62.0	3.35	30.6	2.38	12.0	1.01	40.8	3.22	36.5	3.23
<u>Astragalus sp.</u>			1.3	0.22	1.4	0.17			0.7	0.13
<u>Chenopodium sp.</u>			0.5	0.04	1.5	0.08	1.2	0.08	0.8	0.07
<u>Eriogonum sp.</u>			0.5	0.04	0.5	0.04			0.3	0.03
<u>Euphorbia sp.</u>					1.6	0.08	0.5	0.04	0.5	0.10
<u>Psilostrophe sparsiflora</u>					0.5	0.04			0.1	0.01
<u>Salsola kali</u>			0.5	0.04	1.9	0.21			0.6	0.08
<u>Sphaeralcea sp.</u>			0.5	0.04	1.3	0.04	1.4	0.13	0.8	0.07
<u>Zinnia grandiflora</u>					0.5	0.04	0.5	0.04	0.3	0.03
total forbs			3.3	0.38	9.2	0.70	3.6	0.29	4.1	0.52

Table 6. Seasonal summary of food items by percent and frequency for the jackrabbit in the Cold Desert Shrub Community.

	Jan. - Mar.		Apr. - June		July - Sept.		Oct. - Dec.		Annual	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index	diet	index
<u>Artemisia</u> spp.	16.2	0.53	7.7	0.33			9.1	0.57	8.2	0.36
<u>Atriplex</u> spp.	10.1	0.53	13.1	0.95	11.9	0.89	13.9	1.00	12.3	0.86
<u>Chrysothamnus</u> sp.	6.2	0.71	7.2	0.71	7.8	0.63	11.3	0.61	8.1	0.66
<u>Ephedra</u> sp.	9.3	0.94	6.4	0.76	2.1	0.32	5.9	0.70	5.9	0.68
<u>Fallugia paradoxa</u>	6.1	0.35	2.8	0.24	1.0	0.11	4.1	0.26	3.5	0.24
<u>Gutierrezia</u> sp.	5.9	0.41	4.1	0.48	3.1	0.26	5.7	0.48	4.7	0.41
<u>Juniperus monosperma</u>	4.3	0.30	2.1	0.19			7.8	0.70	3.6	0.31
total browse	58.1	3.77	43.3	3.66	25.9	2.21	57.8	4.32	46.3	3.52
<u>Astragalus</u> sp.			1.0	0.14	1.7	0.21			0.7	0.09
<u>Eriogonum</u> sp.	1.7	0.18	1.9	0.14	2.2	0.21	4.1	0.26	2.5	0.16
<u>Euphorbia</u> sp.			1.0	0.10	1.1	0.11	0.5	0.04	0.7	0.10
<u>Psilostrophe sparsiflora</u>					0.5	0.05	0.5	0.04	0.3	0.03
<u>Salsola kali</u>			1.8	0.19	2.3	0.26			1.0	0.11
<u>Sphaeralcea</u> sp.	1.0	0.12	2.2	0.19	2.7	0.26	2.4	0.17	2.1	0.19
total forbs	2.7	0.30	7.9	0.76	10.5	1.10	7.5	0.51	7.3	0.68
<u>Andropogon hallii</u>					0.5	0.05			0.1	0.01
<u>Aristida fendleriana</u>	1.0	0.12	9.5	0.81	11.2	0.63	6.4	0.48	7.0	0.53
<u>Bouteloua curtipendula</u>					1.0	0.05			0.3	0.01
<u>Bouteloua eriopoda</u>			1.0	0.10	1.5	0.16	1.1	0.13	2.8	0.10
<u>Bouteloua gracilis</u>										
<u>Hilaria jamesii</u>	3.2	0.53	4.7	0.62	2.1	0.32	1.5	0.17	2.9	0.40
<u>Oryzopsis hymenoides</u>					1.0	0.11	0.5	0.09	0.4	0.05
<u>Sporobolus airoides</u>					3.1	0.26	2.3	0.17	1.4	0.11
total grasses	4.2	0.65	15.2	1.53	20.4	1.58	11.8	1.04	14.9	1.21
unidentified components (%)	35.0		33.6		43.2		22.9		31.5	
total fecal samples	17		21		19		23		80	
total plant species	11		15		18		16		20	
mean number of plant species per sample	4.72		5.95		4.89		5.87		5.41	

Table 7. Seasonal summary of food items by percent and frequency for the jackrabbit in the Juniper/Grassland Community. (continued)

	Jan. - Mar.		Apr. - June		July - Sept.		Oct. - Dec.		Annual	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index	diet	index
<u>Andropogon hallii</u>			0.5	0.04	1.0	0.04			0.4	0.03
<u>Aristida fendleriana</u>	1.2	0.14	4.2	0.39	8.3	0.67	2.6	0.25	4.1	0.48
<u>Bouteloua curtipendula</u>	1.0	0.09	0.5	0.04	1.1	0.04	1.3	0.08	1.0	0.08
<u>Bouteloua eriopoda</u>	2.4	0.27	5.3	0.61	16.0	1.00	4.9	0.58	7.2	0.82
<u>Bouteloua gracilis</u>	0.5	0.05	1.1	0.09	1.1	0.13	1.3	0.13	1.0	0.13
<u>Hilaria jamesii</u>	5.1	0.64	12.4	0.91	3.2	0.54	3.2	0.58	6.0	0.87
<u>Oryzopsis hymenoides</u>	1.2	0.18	2.2	0.17	3.1	0.21	2.9	0.25	2.4	0.27
<u>Sitanion hystrix</u>			2.1	0.09	1.0	0.04			0.8	0.04
<u>Sporobolus airoides</u>										
<u>Sporobolus flexuosus</u>	0.5	0.05	2.7	0.39	4.7	0.25	3.2	0.29	2.8	0.32
<u>Stipa neomexicana</u>			1.9	0.39	7.8	0.33	1.4	0.08	2.8	0.18
total grasses	11.9	1.42	32.9	3.12	47.3	3.25	20.8	2.24	28.5	3.22
unidentified components (%)	26.1		33.2		31.5		34.8		30.9	
total fecal samples	22		23		24		24		71	
total plant species	13		21		22		19		25	
mean number of plant species per sample	4.77		5.88		4.96		5.78		6.97	

Table 8. Seasonal summary of food items by percent and frequency for the jackrabbit in the Grassland Community.

	Jan. - Mar.		Apr. - June		July - Sept.		Oct. - Dec.		Annual	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index	diet	index
<u>Atriplex spp.</u>	11.3	0.65	14.7	1.00	7.1	0.59	12.4	0.90	11.4	0.79
<u>Chrysothamnus sp.</u>	22.7	1.00	14.1	0.84	6.4	0.95	9.8	0.67	13.0	0.86
<u>Ephedra sp.</u>	3.1	0.35	2.6	0.32	0.5	0.11	1.9	0.24	2.0	0.25
<u>Gutierrezia sp.</u>	7.2	0.59	2.2	0.32	1.7	0.16	10.8	0.95	5.5	0.51
<u>Juniperus monosperma</u>	3.2	0.30	1.7	0.11	0.5	0.05	3.4	0.52	2.2	0.25
total browse	47.5	2.89	35.3	2.59	16.2	1.86	38.3	3.28	34.1	2.66
<u>Astragalus sp.</u>			0.5	0.05					0.1	0.01
<u>Euphorbia sp.</u>	0.5	0.06	1.7	0.11	2.7	0.21	1.0	0.14	1.5	0.13
<u>Salsola kali</u>			1.3	0.16	1.9	0.32			0.8	0.12
<u>Sphaeralcea sp.</u>			2.1	0.16	3.7	0.26	1.9	0.19	1.9	0.16
<u>Zinnia grandiflora</u>			1.1	0.11	1.4	0.16	0.5	0.05	0.8	0.08
total forbs	0.5	0.06	6.7	0.59	9.7	0.95	3.4	0.38	5.1	0.50
<u>Aristida fendleriana</u>	1.9	0.12	4.2	0.32	5.3	0.59	4.4	0.57	4.0	0.41
<u>Bouteloua curtipendula</u>					1.4	0.11	1.6	0.14	0.8	0.07
<u>Bouteloua eriopoda</u>	4.9	0.53	5.6	0.68	12.3	0.74	9.2	0.62	8.0	0.64
<u>Bouteloua gracilis</u>			1.2	0.11	3.7	0.26	1.5	0.19	1.6	0.14
<u>Hilaria jamesii</u>	8.2	0.94	14.2	1.00	2.9	0.42	4.6	0.76	7.5	0.78
<u>Oryzopsis hymenoides</u>	1.2	0.12	2.4	0.16	3.4	0.32	2.3	0.29	2.3	0.22
<u>Sporobolus flexuosus</u>			0.5	0.05					0.1	0.01
<u>Stipa neomexicana</u>	4.2	0.35	9.7	0.79	15.2	0.63	6.9	0.48	8.8	0.57
total grasses	20.4	2.06	37.8	3.11	44.2	3.07	30.5	3.05	33.1	2.84
unidentified components (%)	31.6		20.2		29.9		27.8		27.7	
total fecal samples	17		19		19		21		76	
total plant samples	11		17		16		15		18	
mean number of plant										
species per sample	5.01		6.29		5.88		6.71		6.00	

Table 9. Seasonal summary of food items by percent and frequency for mule deer/pronghorn in the Cold Desert Shrub Community.

	<u>Jan. - Mar.</u>		<u>Apr. - June</u>		<u>Oct. - Dec.</u>		<u>Annual</u>	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index
<u>Artemisia spp.</u>	14.1	0.67	5.8	0.50	21.3	0.50	13.7	0.55
<u>Atriplex spp.</u>	11.4	1.00	9.6	1.00	9.3	0.67	10.1	0.82
<u>Chrysothamnus sp.</u>	1.3	0.33			1.3	0.17	0.9	0.18
<u>Ephedra sp.</u>	2.7	0.67			2.0	0.33	1.6	0.36
<u>Fallugia paradoxa</u>	2.7	0.33	7.7	0.50	4.7	0.33	5.0	0.27
<u>Gutierrezia sp.</u>					0.7	0.17	0.2	0.09
<u>Juniperus monosperma</u>	10.7	1.00	5.8	1.00	10.0	0.67	8.8	0.82
total browse	42.9	4.00	28.9	3.00	49.3	2.84	40.3	3.09
<u>Astragalus sp.</u>			5.8	1.00			1.9	0.18
<u>Eriogonum sp.</u>	2.7	0.67	3.8	1.00	2.0	0.33	2.8	0.55
<u>Euphorbia sp.</u>	1.3	0.33	1.9	0.50	1.3	0.33	1.5	0.36
<u>Salsola kali</u>			3.8	1.00			1.3	0.18
<u>Sphaeralcea sp.</u>			1.9	0.50	2.0	0.50	1.3	0.36
total forbs	4.0	1.00	17.2	4.00	5.3	1.16	8.8	1.63

Table 9. Seasonal summary of food items by percent and frequency for mule deer/pronghorn in the Cold Desert Shrub Community. (continued)

	<u>Jan. - Mar.</u>		<u>Apr. - June</u>		<u>Oct. - Dec.</u>		<u>Annual</u>	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index
<u>Andropogon hallii</u>	2.7	0.33					0.9	0.09
<u>Aristida fendleriana</u>	5.3	1.00	7.7	1.00	2.7	0.50	5.2	0.72
<u>Bouteloua eriopoda</u>	5.3	0.67			2.0	0.33	2.4	0.36
<u>Bouteloua gracilis</u>			1.9	0.50			0.6	0.09
<u>Hilaria jamesii</u>	12.0	1.00	3.8	0.50	4.7	0.67	6.8	0.72
<u>Oryzopsis hymenoides</u>	1.3	0.33			1.3	0.17	0.7	0.18
<u>Sitanion hystrix</u>			3.8	0.50			1.3	0.09
<u>Sporobolus airoides</u>			1.9	0.50	3.3	0.33	1.7	0.27
<u>Stipa neomexicana</u>								
total grasses	26.6	3.33	19.1	3.00	14.0	2.00	19.6	2.52
unidentified components (%)	26.5		34.8		31.4		31.3	
total fecal samples	3		2		6		11	
total plant species	13		14		15		20	
mean number of plant species per sample	8.33		10.00		6.00		6.97	

Table 10. Seasonal summary of food items by percent and frequency for muledeer/pronghorn in the Juniper/Grassland community.

	Jan. - Mar.		July - Sept.		Oct. - Dec.		Annual	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index
<u>Artemisia</u> spp.			6.7	0.33			2.2	0.08
<u>Atriplex</u> spp.	10.7	0.67	13.3	1.00	14.9	0.71	12.9	0.77
<u>Chrysothamnus</u> sp.	9.0	1.00	1.3	0.33	3.4	0.57	4.6	0.62
<u>Ephedra</u> sp.			1.3	0.33	2.3	0.43	1.2	0.31
<u>Fallugia paradoxa</u>					5.1	0.29	1.7	0.15
<u>Gutierrezia</u> sp.					1.1	0.29	0.4	0.15
<u>Juniperus monosperma</u>	34.7	1.00	10.6	1.00	26.4	1.00	23.9	1.00
total browse	54.4	2.67	33.2	2.99	53.2	3.29	46.9	3.08
<u>Astragalus</u> sp.			2.7	0.67			0.9	0.15
<u>Chenopodium</u> sp.			2.7	0.67	0.6	0.14	1.1	0.23
<u>Eriogonum</u> sp.	1.3	0.33	4.0	0.67	1.0	0.29	2.1	0.38
<u>Euphorbia</u> sp.	2.6	0.67					0.9	0.15
<u>Psilostrophe sparsiflora</u>			2.7	0.67	2.9	0.71	1.9	0.54
<u>Salsola kali</u>			1.3	0.33			0.4	0.08
<u>Sphaeralcea</u> sp.	1.3	0.33	2.7	0.33	3.4	0.57	2.5	0.46
total forbs	5.2	1.33	16.1	3.34	7.9	1.71	9.8	1.99
<u>Aristida fendleriana</u>	1.3	0.33	5.3	0.67	2.9	0.57	3.2	0.54
<u>Bouteloua eriopoda</u>	2.6	0.67	6.7	1.00	3.4	0.71	4.2	0.77
<u>Hilaria jamesii</u>	5.3	0.67	9.3	1.00	3.4	0.57	6.0	0.69
<u>Oryzopsis hymenoides</u>					2.3	0.43	0.8	0.23
total grasses	9.2	1.67	21.3	2.67	12.0	2.28	14.2	2.23
unidentified components (%)	31.2		29.4		26.9		29.1	
total fecal samples		3		3		7		13
total plant species		9		14		14		18
mean number of plant species per sample		5.67		9.00		7.28		7.30

Table 11. Seasonal summary of food items by percent and frequency for the cow in the Cold Desert Shrub community.

	Jan. - Mar.		Oct. - Dec.		Annual	
	mean % of diet	fre- quency index	mean % of diet	fre- quency index	mean % of diet	fre- quency index
<u>Artemisia</u> spp.	3.9	0.39	2.1	0.18	3.0	0.31
<u>Atriplex</u> spp.	17.4	1.00	18.1	1.00	17.8	1.00
<u>Ephedra</u> sp.	3.4	0.39	2.2	0.18	2.8	0.31
<u>Fallugia paradoxa</u>	3.7	0.32	2.9	0.24	3.3	0.29
<u>Gutierrezia</u> sp.			1.4	0.18	0.7	0.07
total browse	28.4	2.10	26.7	1.78	27.6	1.98
<u>Eriogonum</u> sp.	1.9	0.21	2.3	0.24	2.1	0.22
<u>Euphorbia</u> sp.			1.0	0.12	0.5	0.04
<u>Sphaeralcea</u> sp.	4.3	0.50	5.7	0.47	5.0	0.49
total forbs	6.2	0.71	9.0	0.83	7.6	0.75
<u>Aristida fendleriana</u>	7.4	0.64	7.9	0.82	7.7	0.71
<u>Bouteloua eriopoda</u>	4.1	0.29	4.8	0.47	4.5	0.36
<u>Hilaria jamesii</u>	19.1	1.00	16.4	1.00	17.8	1.00
<u>Sporobolus airoides</u>	6.1	0.54	5.3	0.53	5.7	0.53
<u>Sporobolus flexuosus</u>			3.1	0.29	1.6	0.10
total grasses	36.7	2.47	37.5	3.11	37.3	2.70
unidentified components (%)	28.7		26.8		27.5	
total fecal samples		28		17		45
total plant species		10		13		13
mean number of plant species per sample		5.28		5.72		5.43

Table 12. Seasonal summary of food items by percent and frequency for the cow in the Juniper/Grassland community.

	<u>Jan. - Mar.</u>		<u>Oct. - Dec.</u>		<u>Annual</u>	
	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index
<u>Atriplex spp.</u>	13.3	0.93	11.2	0.93	12.3	0.93
<u>Chrysothamnus sp.</u>	2.2	0.29	1.1	0.13	1.7	0.23
<u>Ephedra sp.</u>	1.4	0.18			0.7	0.12
<u>Gutierrezia sp.</u>	2.3	0.25			1.2	0.16
total browse	19.2	1.65	12.3	1.06	15.9	1.44
<u>Euphorbia sp.</u>	1.1	0.14	1.4	0.13	1.3	0.14
<u>Sphaeralcea sp.</u>	1.4	0.14	1.5	0.13	1.5	0.14
<u>Zinnia grandiflora</u>			0.5	0.07	0.3	0.02
total forbs	2.5	0.28	3.4	0.33	3.0	0.30
<u>Aristida fendleriana</u>	6.9	0.61	9.7	0.67	8.3	0.63
<u>Bouteloua curtipendula</u>	1.6	0.18			0.8	0.12
<u>Bouteloua eriopoda</u>	9.3	0.75	11.3	0.87	10.3	0.79
<u>Bouteloua gracilis</u>	3.3	0.39	4.2	0.40	3.8	0.40
<u>Hilaria jamesii</u>	16.7	1.00	14.3	1.00	15.5	1.00
<u>Oryzopsis hymenoides</u>	3.5	0.46	4.1	0.67	3.8	0.53
<u>Sporobolus flexuosus</u>	7.4	0.57	9.1	0.93	8.3	0.70
<u>Stipa neomexicana</u>	4.1	0.29	2.9	0.20	3.5	0.26
total grasses	52.8	4.25	55.6	4.74	54.3	4.43
unidentified components (%)	25.5		28.7		26.8	
total fecal samples		28		15		43
total plant species		14		12		15
mean number of plant species per sample		6.18		6.13		6.17

Table 13. Seasonal summary of food items by percent and frequency for the cow in the Grassland community.

	<u>Jan. - Mar.</u>		<u>Oct. - Dec.</u>		<u>Annual</u>	
	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index
<u>Atriplex</u> spp.	10.2	0.79	9.7	0.81	10.0	0.80
<u>Chrysothamnus</u> sp.	3.1	0.29	2.1	0.25	2.6	0.27
<u>Ephedra</u> sp.			1.5	0.13	0.8	0.05
total browse	13.3	1.08	13.3	1.19	13.4	1.12
<u>Sphaeralcea</u> sp.			1.9	0.19	1.0	0.07
total forbs			1.9	0.19	1.0	0.07
<u>Aristida fendleriana</u>	7.3	0.61	8.6	0.69	8.0	0.64
<u>Bouteloua curtipendula</u>	2.1	0.18			1.1	0.11
<u>Bouteloua eriopoda</u>	12.2	0.86	11.9	0.94	12.1	0.89
<u>Hilaria jamesii</u>	17.2	1.00	14.1	1.00	15.7	1.00
<u>Oryzopsis hymenoides</u>	4.7	0.43	4.2	0.38	4.5	0.41
<u>Sporobolus flexuosus</u>	4.1	0.32			2.1	0.20
<u>Stipa neomexicana</u>	15.6	1.00	18.3	1.00	17.0	1.00
total grasses	63.2	4.40	57.1	4.01	60.5	4.25
unidentified components (%)	23.5		27.7		25.1	
total fecal samples		28		16		44
total plant species		9		9		11
mean number of plant species per sample		5.48		5.39		5.44

Table 14. Seasonal summary of food items by percent and frequency for the horse in the Cold Desert Shrub community.

	<u>Jan. - Mar.</u>		<u>Apr. - June</u>		<u>July - Sept.</u>		<u>Annual</u>	
	mean	fre-	mean	fre-	mean	fre-	mean	fre-
	% of	quency	% of	quency	% of	quency	% of	quency
	diet	index	diet	index	diet	index	diet	index
<u>Atriplex</u> spp.	12.1	1.00	10.0	0.50	11.3	0.89	11.1	0.86
<u>Chrysothamnus</u> sp.	3.0	0.33	2.0	0.50			1.7	0.14
<u>Ephedra</u> sp.			4.0	0.50			1.3	0.07
total browse	15.1	1.33	16.0	1.50	11.3	0.89	14.1	1.07
<u>Eriogonum</u> sp.					2.1	0.22	0.7	0.14
<u>Salsola kali</u>			8.0	1.00	5.3	0.44	4.4	0.43
<u>Sphaeralcea</u> sp.			2.0	0.50	2.9	0.33	1.6	0.29
total forbs			10.0	1.50	10.3	0.99	6.7	0.86
<u>Aristida fendleriana</u>	7.4	0.67	14.0	1.00	8.4	0.78	9.9	0.79
<u>Bouteloua curtipendula</u>					3.1	0.22	1.0	0.14
<u>Bouteloua eriopoda</u>	13.2	0.67	8.0	1.00	11.7	0.89	11.0	0.86
<u>Hilaria jamesii</u>	20.7	1.00	18.0	1.00	15.4	1.00	18.0	1.00
<u>Sporobolus airoides</u>	11.4	1.00	4.0	0.50	9.2	0.56	8.2	0.64
total grasses	52.7	3.34	44.0	3.50	47.8	3.45	48.1	3.43
unidentified components (%)	32.2		30.0		30.6		31.1	
total fecal samples	3		2		9		14	
total plant species	6		9		9		11	
mean number of plant species per sample	4.67		6.50		5.34		5.36	

Table 15. Ranking of plant species in order of importance as food for the cottontail based on total annual percent consumption.

	<u>Cold Desert Shrub</u>	<u>Juniper/ Grassland</u>	<u>Grassland</u>
browse			
<u>Artemisia</u> spp.	13		
<u>Atriplex</u> spp.	1	1	4
<u>Chrysothamnus</u> sp.	4	5	2
<u>Ephedra</u> sp.	10	13	16
<u>Fallugia paradoxa</u>	15	19	
<u>Gutierrezia</u> sp.	5	10	8
<u>Juniperus monosperma</u>	11	11	13
forbs			
<u>Astragalus</u> sp.	12	22	17
<u>Chenopodium</u> sp.	19	9	
<u>Eriogonum</u> sp.	8	16	19
<u>Euphorbia</u> sp.	7	4	6
<u>Psilostrophe sparsiflora</u>		21	
<u>Salsola kali</u>	9	17	12
<u>Sphaeralcea</u> sp.	3	8	1
<u>Zinnia grandiflora</u>	20	7	10
grasses			
<u>Andropogon hallii</u>	21		
<u>Aristida fendleriana</u>	6	6	9
<u>Bouteloua curtipendula</u>	17	20	18
<u>Bouteloua eriopoda</u>	18	3	7
<u>Bouteloua gracilis</u>		14	14
<u>Hilaria jamesii</u>	2	2	5
<u>Oryzopsis hymenoides</u>	16	15	11
<u>Sitanion hystrix</u>		23	
<u>Sporobolus airoides</u>	14		
<u>Sporobolus flexuosus</u>		12	15
<u>Stipa neomexicana</u>		18	3

Table 16. Ranking of plant species in order of importance as food for the jackrabbit, based on total annual percent consumption.

	<u>Cold Desert Shrub</u>	<u>Juniper/ Grassland</u>	<u>Grassland</u>
browse			
<u>Artemisia</u> spp.	2	21	
<u>Atriplex</u> spp.	1	2	2
<u>Chrysothamnus</u> sp.	3	1	1
<u>Ephedra</u> sp.	5	8	10
<u>Fallugia paradoxa</u>	8	12	
<u>Gutierrezia</u> sp.	6	4	6
<u>Juniperus monosperma</u>	7	6	9
forbs			
<u>Astragalus</u> sp.	16	18	17
<u>Chenopodium</u> sp.	11	15	
<u>Eriogonum</u> sp.	15	24	
<u>Euphorbia</u> sp.		20	
<u>Psilostrophe sparsiflora</u>	18	25	13
<u>Salsola kali</u>	14	19	14
<u>Sphaeralcea</u> sp.	12	16	11
<u>Zinnia grandiflora</u>		23	15
grasses			
<u>Andropogon hallii</u>	20	22	
<u>Aristida fendleriana</u>	4	7	7
<u>Bouteloua curtipendula</u>	19	14	16
<u>Bouteloua eriopoda</u>	10	3	4
<u>Bouteloua gracilis</u>		13	12
<u>Hilaria jamesii</u>	9	5	5
<u>Oryzopsis hymenoides</u>	17	11	8
<u>Sitanion hystrix</u>		17	
<u>Sporobolus airoides</u>	13		
<u>Sporobolus flexuosus</u>		9	18
<u>Stipa neomexicana</u>		10	3

Table 17. Ranking of plant species in order of importance as food for mule deer/pronghorn, based on total annual percent consumption.

	<u>Cold Desert Shrub</u>	<u>Juniper/ Grassland</u>
browse		
<u>Artemisia</u> spp.	1	8
<u>Atriplex</u> spp.	2	2
<u>Chrysothamnus</u> sp.	17	4
<u>Ephedra</u> sp.	11	12
<u>Fallugia paradoxa</u>	6	11
<u>Gutierrezia</u> sp.	20	17
<u>Juniperus monosperma</u>	3	1
forbs		
<u>Astragalus</u> sp.	9	15
<u>Chenopodium</u> sp.		13
<u>Eriogonum</u> sp.	7	9
<u>Euphorbia</u> sp.	12	14
<u>Psilostrophe sparsiflora</u>		10
<u>Salsola kali</u>	14	18
<u>Sphaeralcea</u> sp.	13	7
grasses		
<u>Andropogon hallii</u>	16	
<u>Aristida fendleriana</u>	5	6
<u>Bouteloua eriopoda</u>	8	5
<u>Bouteloua gracilis</u>	19	
<u>Hilaria jamesii</u>	4	3
<u>Oryzopsis hymenoides</u>	18	16
<u>Sitanion hystrix</u>	15	
<u>Sporobolus airoides</u>	10	

Table 18. Ranking of plant species in order of importance as food for the cow, based on total annual percent consumption.

	<u>Cold Desert Shrub</u>	<u>Juniper/ Grassland</u>	<u>Grassland</u>
browse			
<u>Artemisia</u> spp.	8		
<u>Atriplex</u> spp.	2	2	4
<u>Chrysothamnus</u> sp.		9	7
<u>Ephedra</u> sp.	9	14	11
<u>Fallugia paradoxa</u>	7		
<u>Gutierrezia</u> sp.	12	12	
forbs			
<u>Eriogonum</u> sp.	10		
<u>Euphorbia</u> sp.	13	11	
<u>Salsola kali</u>		10	
<u>Sphaeralcea</u> sp.	5	15	10
grasses			
<u>Aristida fendleriana</u>	3	4	5
<u>Bouteloua curtipendula</u>		13	9
<u>Bouteloua eriopoda</u>	6	3	3
<u>Bouteloua gracilis</u>		7	
<u>Hilaria jamesii</u>	1	1	2
<u>Oryzopsis hymenoides</u>		6	6
<u>Sporobolus airoides</u>	4		
<u>Sporobolus flexuosus</u>	11	5	8
<u>Stipa neomexicana</u>		8	1

Table 19. Ranking of plant species in order of importance as food for the horse, based on total annual percent consumption.

<u>Cold Desert Shrub</u>	
browse	
<u>Atriplex</u> spp.	2
<u>Chrysothamnus</u> sp.	7
<u>Ephedra</u> sp.	9
forbs	
<u>Eriogonum</u> sp.	11
<u>Salsola</u> <u>kali</u>	6
<u>Sphaeralcea</u> sp.	8
grasses	
<u>Aristida</u> <u>fendleriana</u>	4
<u>Bouteloua</u> <u>curtipendula</u>	10
<u>Bouteloua</u> <u>eriopoda</u>	3
<u>Hilaria</u> <u>jamesii</u>	1
<u>Sitanion</u> <u>hystrix</u>	5

Table 20. Annual preference indices and preference rankings of selected plant species in the diet of the cottontail.

	Cold Desert Shrub		Juniper/Grassland		Grassland	
	Prefer- ence Index	Prefer- ence Rank	Prefer- ence Index	Prefer- ence Rank	Prefer- ence Index	Prefer- ence Rank
<u>Artemisia</u> spp.	0.02	8				
<u>Atriplex</u> spp.	1.22	4	3.88	2		
<u>Chrysothamnus</u> sp.	1.85	3	0.20	6	0.10	6
<u>Ephedra</u> sp.	0.22	7				
<u>Fallugia paradoxa</u>	0.33	6				
<u>Gutierrezia</u> sp.			3.50	3		
total browse	0.39		1.33		.59	
<u>Astragalus</u> sp.	2.00	2				
<u>Eriogonum</u> sp.	1.05	5				
<u>Euphorbia</u> sp.					53.00	1
<u>Psilostrophe sparsiflora</u>			1.33	4		
<u>Salsola kali</u>	12.00	1				
<u>Sphaeralcea</u> sp.			19.50	1		
total forbs	4.18		1.00		10.80	
<u>Bouteloua eriopoda</u>			1.24	5	49.00	2
<u>Hilaria jamesii</u>			0.13	7	1.86	5
<u>Oryzopsis hymenoides</u>					30.00	3
<u>Stipa neomexicana</u>					4.47	4
total grasses	0.61		0.40		0.47	

Table 21. Annual preference indices and preferences rankings of selected plant species in the diet of the jackrabbit.

	Cold Desert Shrub		Juniper/ Grassland		Grassland	
	Prefer- ence Index	Prefer- ence Rank	Prefer- ence Index	Prefer- ence Rank	Prefer- ence Index	Prefer- ence Rank
<u>Artemisia</u> spp.	0.12	8				
<u>Atriplex</u> spp.	1.29	4	5.29	2		
<u>Chrysothamnus</u> sp.	3.00	2	0.50	5	0.15	9
<u>Ephedra</u> sp.	0.57	7				
<u>Fallugia paradoxa</u>	2.33	3				
<u>Gutierrezia</u> sp.			6.80	1		
total browse	0.65		2.28		0.95	
<u>Astragalus</u> sp.	1.17	5				
<u>Eriogonum</u> sp.	0.60	6				
<u>Euphorbia</u> sp.					15.00	3
<u>Psilostrophe sparsiflora</u>			0.11	7		
<u>Salsola kali</u>	5.00	1			0.32	8
<u>Sphaeralcea</u> sp.			4.00	3	0.44	7
<u>Zinnia grandiflora</u>					8.00	4
total forbs	1.44		0.19		2.55	
<u>Bouteloua eriopoda</u>			1.57	4	80.00	1
<u>Hilaria jamesii</u>			0.14	6	2.14	6
<u>Oryzopsis hymenoides</u>					23.00	2
<u>Stipa neomexicana</u>					5.18	5
total grasses	0.54		0.46		0.53	

Table 22. Annual preference indices and preference rankings of selected plant species in the diet of mule deer/pronghorn.

	Cold Desert Shrub		Juniper/ Grassland	
	Prefer- ence Index	Prefer- ence Rank	Prefer- ence Index	Prefer- ence Rank
<u>Artemisia</u> spp.	0.21	7		
<u>Atriplex</u> spp.	1.06	4	7.59	2
<u>Chrysothamnus</u> sp.	0.33	6	0.21	6
<u>Ephedra</u> sp.	0.16	8		
<u>Fallugia paradoxa</u>	3.33	2		
<u>Gutierrezia</u> sp.			0.40	5
total browse	0.57		2.93	
<u>Astragalus</u> sp.	3.17	3		
<u>Eriogonum</u> sp.	0.67	5		
<u>Euphorbia</u> sp.				
<u>Psilostrophe sparsiflora</u>			2.11	3
<u>Salsola kali</u>	6.50	1		
<u>Sphaeralcea</u> sp.			12.5	1
<u>Zinnia grandiflora</u>				
total forbs	1.76		0.44	
<u>Bouteloua eriopoda</u>			0.91	4
<u>Hilaria jamesii</u>			0.14	7
<u>Oryzopsis hymenoides</u>				
<u>Stipa neomexicana</u>				
total grasses	0.83		0.23	

Table 23. Annual preference indices and preference rankings of selected plant species in the diet of the cow.

	Cold Desert Shrub		Juniper/ Grassland		Grassland	
	Prefer- ence Index	Prefer- ence Rank	Prefer- ence Index	Prefer- ence Rank	Prefer- ence Index	Prefer- ence Rank
<u>Artemisia spp.</u>	0.05	5				
<u>Atriplex spp.</u>	1.87	2	7.24	2		
<u>Chrysothamnus sp.</u>			0.08	6	0.01	6
<u>Ephedra sp.</u>	0.27	3				
<u>Fallugia paradoxa</u>	2.20	1				
<u>Gutierrezia sp.</u>			1.20	4		
total browse	0.39		0.99		0.37	
<u>Eriogonum sp.</u>	0.12	4				
<u>Sphaeralcea sp.</u>			7.50	1	0.23	5
total forbs	1.52		0.14		0.50	
<u>Bouteloua eriopoda</u>			2.24	3	121.00	1
<u>Hilaria jamesii</u>			0.36	5	4.49	4
<u>Oryzopsis hymenoides</u>					45.00	2
<u>Stipa neomexicana</u>					10.00	3
total grasses	1.55		0.87		0.97	

Table 24. Annual preference indices and preference rankings of selected plant species in the diet of the horse.

	Cold Desert Shrub	
	Prefer- ence Index	Prefer- ence Rank
<u>Atriplex</u> spp.	1.17	2
<u>Chrysothamnus</u> sp.	0.63	3
<u>Ephedra</u> sp.	0.13	5
total browse	0.20	
<u>Eriogonum</u> sp.	0.17	4
<u>Salsola kali</u>	22.00	1
total forbs	1.36	
total grasses	2.01	

Table 25. Percent similarity of diet between domestic and native herbivores on Wupatki National Monument as determined by Gauch's (1972) similarity index. Reported seasonally by community.

Cow vs Desert Cottontail

	Jan.-Mar.	Oct.-Dec.
Cold Desert Shrub	56.2	64.1
Juniper/Grassland	52.9	51.0
Grassland	50.1	53.3

Cow vs Black-tailed Jackrabbit

	Jan.-Mar.	Oct.-Dec.
Cold Desert Shrub	41.1	52.7
Juniper/Grassland	40.2	46.3
Grassland	46.5	59.0

Cow vs Mule Deer/Pronghorn

	Jan.-Mar.	Oct.-Dec.
Cold Desert Shrub	60.8	48.9
Juniper/Grassland	32.7	37.7

Cow vs Horse

	Jan.-Mar.
Cold Desert Shrub	74.1

Horse vs Desert Cottontail

	Jan.-Mar.	Apr.-June	July-Sept.
Cold Desert Shrub	40.6	48.1	47.5

Horse vs Black-tailed Jackrabbit

	Jan.-Mar.	Apr.-June	July-Sept.
Cold Desert Shrub	26.1	51.3	54.7

Horse vs Mule Deer/Pronghorn

	Jan.-Mar.	Apr.-June
	50.1	42.5