

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

**FINAL REPORT
(PHASE II)**

FEBRUARY, 1978

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

**PREPARED BY MEMBERS OF THE
DEPARTMENT OF BIOLOGICAL SCIENCES
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FLAGSTAFF AREA NATIONAL MONUMENTS
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FLAGSTAFF, AZ 86004

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

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I

VEGETATION STUDIES OF SUNSET CRATER
AND
WUPATKI NATIONAL MONUMENTS

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February, 1978

INTRODUCTION

Wupatki and Sunset Crater National Monuments in northern Arizona have been studied for basic biological data for future management planning by the National Park Service. Wupatki National Monument is located northeast of Flagstaff, about 30 miles on U.S. Highway 89. Sunset Crater National Monument is located about 15 miles northeast of Flagstaff on U.S. Highway 89. Wupatki National Monument is about 14,577 hectares in area while Sunset Crater National Monument is much smaller, approximately 1230 hectares in area.

The basic biological survey has been conducted over the past two years, 1976-1977, by personnel of Northern Arizona University, under a grant from the National Park Service. This survey has been conducted to gather data and information to accomplish the following goals:

- 1) Preparation of an up-to-date species list of all vascular plants presently known to occur within the two Monuments.
- 2) Extensive vegetation measurements for identification and description of the major plant communities of both Monuments.
- 3) Preparation of a vegetation map outlining the major plant communities.
- 4) Preparation of a domestic livestock utilization map of the two affected communities of Wupatki National Monument.
- 5) Extensive vegetation measurements to determine any ecological damage that might be occurring as a result of domestic livestock grazing in Wupatki National Monument.
- 6) Preparation of a list of species collected during this study which are new records for the Monuments.

METHODS AND MATERIALS

Grazing Exclosures

Several modifications in the sampling procedure were made for this phase of the botanical survey of Wupatki and Sunset Crater National Monuments. For the four grazing exclosures, one 50 meter (m) base line was established inside the exclosure and one was established outside. In two cases, additional 50 m base lines were established as controls on the Coconino National Forest. Five 50 m transects were set up perpendicular to the base line at 10 m intervals, the first at 5 m and the last at 45 m, giving a total length of 250 m at each site. Permanent steel stakes were used to mark the beginning and end of the 50 m base line and additional steel stakes were set at the ends of the five transects running at right angles to the base line. At the beginning of the five perpendicular transects, on the inside of the exclosures, permanent wooden stakes were set. Outside the exclosures, stone cairns were built to mark the beginning points of the five 50 m perpendicular transects.

Vegetation cover for all plants, including annuals, was determined by measuring the intercept along the five transects (Canfield 1941). Frequency and density were determined for each perennial species by counting plants in a 1 m wide belt established along the left-hand side of each transect. The belts were divided into ten 1 x 5 segments, and counts were recorded separately in each segment. A total of 50 segments was measured at each 50 m base line.

Annual plant species were sampled in 1 m² plots by placing a plot frame at the beginning of each of the belt segments. Ten plots were measured along each transect, giving a total area sampled of 50 m² for

each 50 m base line.

The data from each of the five transects at each site were combined for analysis. The values for frequency, density, and cover generated for each species were converted to relative values (based on 100) for each parameter as follows (Mueller-Dombois and Ellenberg 1974):

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Sum frequency of all species}} \times 100$$

$$\text{Relative Density} = \frac{\text{No. of individuals of a species}}{\text{Total no. of individuals of all species}} \times 100$$

$$\text{Relative Cover} = \frac{\text{Intercept of a species}}{\text{Total intercept of all species}} \times 100$$

In addition to the above values, an absolute cover value was calculated to estimate the actual ground covered by vegetation. This absolute value was figured for individual species and for all vegetation intercepted. These values were calculated using the following formulae:

$$\text{Absolute Species Cover} = \frac{\text{Total intercept of a species}}{250 \text{ m}} \times 100$$

$$\text{Absolute Cover} = \frac{\text{Total intercept for all species}}{250 \text{ m}} \times 100$$

The Importance Value is defined as the sum of the relative values (Curtis 1959). This is converted to an "importance percentage" (based on 100 instead of 300) by dividing by 3 (Risser and Rice 1971). Importance Values given elsewhere in this report refer to the importance percentage obtained following division by 3. The importance value calculated for each species allows comparison of a given species between sampling areas.

To determine the similarities of the areas sampled by the grazing exclosures, coefficients of similarity were calculated based on species quantities as modified by Ellenberg (Mueller-Dombois and Ellenberg 1974, p. 215) using the Importance Values. The calculation of this value is

necessary in order to justify comparing the two, or in some cases three, areas sampled.

Livestock Utilization Studies

The method used to determine the utilization by domestic livestock was based on the Forest Service ocular weight estimate-by-plot method (F.S. Handbook 1970). Key areas representing the vegetation type found on Wupatki National Monument were selected on the adjacent Coconino National Forest. Within these areas, plots were established, clipped and weighed several times to train the observer to accurately estimate the amount of plant material that was removed by grazing. This results in $\pm 10\%$ accuracy of measurements and allows large areas to be surveyed without additional clipping. Because the utilization survey was conducted after the grazing season, accurate estimates of production could not be made.

Community Mapping

In addition to the transects established to sample the grazing exclosures, several transects were established to measure the vegetation for mapping purposes. The method used for these transects was a modification of the above described technique. A base line of 30 m was selected and three 30 m transects were set perpendicular to the base line, the first at 5 m and the last at 25 m, totaling 90 m transect length at each site. No permanent stakes were set for this type of transect.

Vegetation cover, frequency and density for perennials were determined in the same manner as previously described; a belt one meter wide, established on the left hand side and divided into 5 m lengths was used.

Again a 1 m^2 plot was set at the beginning of each 5 m segment to measure the annuals. A total of 90 m^2 was sampled for perennials and 18 m^2 for annuals at each site.

The data obtained from the three transects were again combined per site for analysis. The values for frequency, density and cover generated for each species were converted to relative values as previously described. Importance Values were calculated for each transect as described.

RESULTS

Grazing Exclosure I

Grazing Exclosure I is located in Hull's Canyon, a four-wing saltbush (Atriplex canescens) and galleta (Hilaria jamesii) dominated wash within the Juniper/Grassland Community. Three 50 m base line transects were established in this area. The one inside the exclosure was sampled on 11 August 1977, and another immediately adjacent and to the north of the exclosure was sampled on 29 June 1977. These two transects are located in the NW $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$ of Section 18, T25N, R9E, approximately 200 m north of the Monument boundary fence. The third 50 m base line transect, established in the same community type on the Coconino National Forest on 17 June 1977, is located approximately 350 m south of the boundary fence, towards Arrowhead Tank. This transect is located in the NE $\frac{1}{4}$, SW $\frac{1}{4}$, NW $\frac{1}{4}$, NW $\frac{1}{4}$ of Section 20, T25N, R9E. In all three transects, the 50 m base line is on a magnetic azimuth of 320° , with the five perpendicular transects on a magnetic azimuth of 230° .

The coefficient of similarity for Grazing Exclosure I was 98.85% between the transect inside the exclosure and the transect adjacent to the exclosure. There was a 92.59% similarity between the transect inside

the enclosure and the transect located on the National Forest. A 90.92% similarity coefficient was obtained for the transect outside the enclosure compared to the transect on the National Forest.

The results for the transect located inside the enclosure are presented in Table 1. Table 2 presents the results of the transect adjacent to the enclosure.

Galleta was highest in terms of Importance Value on both transects, having a 43.96% value inside the enclosure and a 40.62% value outside the enclosure. Dead galleta was second in Importance Value for the inside transect while four-wing saltbush was second in Importance Value outside the enclosure. A total of 3927 live galleta plants was counted inside the enclosure while a total of 1086 dead galleta plants was counted. For the transect outside the enclosure, a total of 4186 live galleta plants was counted and 697 dead galleta plants noted. There were 166 seedling/young four-wing saltbush plants inside the enclosure and 246 seedling/young four-wing saltbush plants outside the enclosure.

The total absolute ground cover value for the transect inside the enclosure was 14.44%, while the transect outside the enclosure measured 11.83% ground cover. No annuals were sampled in either of these transects on the Monument.

Table 3 presents the results of the transect established on the Coconino National Forest. Galleta ranked first with an Importance Value of 34.54% and four-wing saltbush second with 21.41%. A total of 1117 live galleta plants was counted but only 313 dead galleta plants were recorded. There were only 53 seedling/young four-wing saltbush plants recorded.

The total absolute ground cover value for the transect on the

National Forest was 29.55%. The majority of this total absolute ground cover value was attributable to the dead four-wing saltbush (14.80%) and the live four-wing saltbush (10.50%). No annuals were sampled on this transect.

Grazing Exclosure II

Grazing Exclosure II is located in the Juniper/Grassland Community approximately 250-300 m east of the cattleguard on Forest Service Road 545. Three 50 m base line transects were established in this area in the manner described for Grazing Exclosure I. The transect inside the exclosure was established on 12 August 1977, and the transect outside the exclosure was established on 29-30 June 1977. The transect on the Coconino National Forest was established on 11-12 August 1977. The two transects on the Monument are located in the SE $\frac{1}{4}$, SE $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$ of Section 17, T25N, R9E. The outside transect is approximately 30 m east of the southeast corner of the fenced grazing exclosure. The transect on the National Forest is located in the NW $\frac{1}{4}$, NE $\frac{1}{4}$, NW $\frac{1}{4}$, NE $\frac{1}{4}$ of Section 20, T25N, R9E. This transect is approximately 300-330 m east of the cattleguard on Forest Service Road 545, approximately 15-20 m due south of the boundary fence in an open area. In all three cases the 50 m base line is on a magnetic azimuth of 90⁰ or due east. The two transects are on a magnetic 0⁰ azimuth with the Forest Service perpendicular transects on a magnetic azimuth of 180⁰.

The coefficient of similarity was 88.91% between the inside and outside transects of Grazing Exclosure II. There was an 87.73% similarity between the transect inside the exclosure and the transect on the National Forest. An 88.97% coefficient of similarity was calculated for the outside-the-exclosure transect and the transect on the National Forest.

Table 4 contains the results for the transect inside Grazing Exclosure II and Table 5 shows the results for the outside-adjacent transect. Galleta ranked first with respect to Importance Value for both transects, 54.50% for the transect inside the exclosure and 46.57% for the outside transect. Dead galleta was second for both transects and one-seeded juniper (Juniperus monosperma) was third for both transects. Totals of 6864 live galleta plants and 2235 dead galleta plants were counted on the transect inside the exclosure. The transect outside the exclosure had 6711 live galleta plants and 1703 dead galleta plants.

The total absolute ground cover value for the transect inside the exclosure was 19.24% with the transect outside the exclosure measuring 13.59%. A spurge (Ephorbia sp.) was the dominant annual sampled on both transects on the Monument.

Table 6 presents the results of the transect established on the Coconino National Forest. Galleta had the highest Importance Value, 44.85% and dead galleta was second at 18.76%. Black grama (Bouteloua eriopoda) ranked third in Importance Value with 8.77%. There were 439 live galleta plants counted and 1725 dead galleta plants on the transect. The total absolute ground cover value of this transect was 21.09%.

Grazing Exclosure III

Grazing Exclosure III is located in Cedar Canyon, approximately 150 m west of the well-site near Magnetic Mesa, approximately 5 m west of the road. Only two base line transects were established due to the lack of a comparable site on the National Forest. The transect inside the exclosure was established on 9 August 1977, and the transect outside was established on 13 June 1977. These transects are located in the NW $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$ of Section 6, T25N, R9E. The transect outside

the exclosure is located approximately 17 m north of the fenced exclosure. Both transects have the 50 m base line on a magnetic 327° azimuth with the perpendicular transects on a magnetic 237° azimuth. The coefficient of similarity for these two transects was 78.62% (see discussion section for explanation of this value).

Table 7 presents the results for the transect inside Grazing Exclosure III and Table 8 shows the results for the transect outside the exclosure. Galleta ranked first in Importance Value for both these transects, with a value of 38.32% inside the exclosure and 39.97% outside the exclosure. Dead galleta ranked second in terms of Importance Value (15.00%) on the transect inside the exclosure and the transect outside the exclosure had rubber rabbitbrush (Chrysothamnus nauseosus) second (20.02%). Third in Importance Value for the inside transect was rubber rabbitbrush (10.07%) and third for the outside transect was one-seed juniper (7.56%). There were 3581 live galleta plants and 1263 dead galleta plants counted inside the exclosure. A total of 4567 live galleta plants was counted on the transect outside the exclosure.

The total absolute ground cover value for the transect inside the exclosure was 17.17% while that for the transect outside the exclosure was 13.02%. Galleta was first in absolute ground cover for the transect inside the exclosure (5.08%) and rubber rabbitbrush was first for the transect outside the exclosure (6.25%). Rubber rabbitbrush was second in absolute ground cover for the transect inside the exclosure (3.55%).

Grazing Exclosure IV

Grazing Exclosure IV is located in the Cold Desert Shrub Community,

approximately 1.5 kilometers from Forest Service Road 545 along the Wukoki Road. The enclosure is approximately 100 m south of the road. Only two 50 m base line transects were established, one inside the enclosure and the other outside and adjacent to the enclosure. Both of these transects were established on 3 December 1977, due to the difficulties of locating and building the enclosure. These two transects are located in the SE $\frac{1}{4}$, SE $\frac{1}{4}$, SW $\frac{1}{4}$, SW $\frac{1}{4}$ of Section 20, T25N, R10E. The transect outside the enclosure is approximately 10 m north of the fenced enclosure; the beginning stake for the 50 m base line is due north of the third perpendicular transect of the transect inside the enclosure. Both 50 m base lines are on a magnetic azimuth of 115°. The perpendicular transects for the transect inside the enclosure are on a magnetic azimuth of 205° while the perpendicular transects on the transect outside the enclosure are on a magnetic azimuth of 25°.

Tables 9 and 10 contain the results of the inside and outside transects respectively of Grazing Enclosure IV. Fringed sagebrush (Artemisia frigida) ranked first in Importance Value for both transects, 28.40% for the inside transect and 27.07% for the outside transect. Seedling/young fringed sagebrush was second for both transects. Tetradlea coulteri placed third for the inside transect (11.47%) while seedling/young four-wing saltbush was third for the outside transect (9.02%). There were 27 adult fringed sagebrush and 37 seedling/young fringed sagebrush counted on the transect inside the enclosure. A total of 28 adult fringed sagebrush and 39 seedling/young fringed sagebrush were located on the outside transect.

The total absolute ground cover value for the transect inside the enclosure was 14.24%; the transect outside the enclosure measured 14.92%.

Fringed sagebrush contributed most to absolute cover for both transects (7.40% for inside and 7.86% outside). Four-wing saltbush was second for the transect inside the enclosure (2.67%). Mormon tea (Ephedra torreyana) was second in absolute cover for the transect outside Enclosure IV (1.98%). Dead fringed sagebrush was third for both transects of Grazing Enclosure IV.

Livestock Utilization Studies

Livestock utilization studies in the Juniper/Grassland and Grassland Communities were conducted intermittently from 12 June to 21 June 1977, prior to the growing season. Based on examination of these areas, four general utilization patterns can be seen: 1) 100% to 80%, 2) 80% to 50%, 3) 50% to 30%, and 4) 30% to 0%.

Approximately 49% or 2110 ha of this total area is in the first category of 100 to 80% utilization. The majority of this heavy utilization is in the Grassland Community in the northern portion of Antelope Prairie. All of the Grassland Community along the edge of Antelope Wash, where it transects Antelope Prairie, is classified as having 100% utilization.

There are approximately 1425 ha, 23%, placed in the second category of 80% to 50% utilization. This includes the majority of the Juniper/Grassland Community. Approximately 16% or 1037 ha of area is in the 50 to 30% utilization category. The last utilization category of 30 to 0% comprises 12% (777 ha) of the total area. This area is mainly confined to the area between Antelope Wash and the Doney Cliffs. The rest of this utilization zone is in the southern one-third of the Grassland Community, primarily from Hull's Canyon west to the Monument boundary. The distance from an available water source appears to be the reason for this light use zone.

Community Map Transects

A total of 24 Community Map transects was established in various areas of both Wupatki and Sunset Crater National Monuments. Eighteen of the Community Map transects were established in the Cold Desert Shrub Community and three were established in the Grassland Community of Wupatki National Monument. No Community Map transects were established in the Juniper/Grassland Community of Wupatki National Monument due to a sufficient amount of data from transects established in this community during the previous year's study. A total of three Community Map transects was established in various areas of Sunset Crater National Monument.

Table 11 presents the combination of all 18 Community Map Transects established within the Cold Desert Shrub Community. Galleta ranks first in Importance Value with 27.82% and black grama is second with 7.87%. Third in Importance Value is four-wing saltbush (7.30%) and fourth is mesa dropseed (Sporobolus flexuosus) with 6.48%.

In all there are 42 species listed from the 18 transects. There is a total absolute ground cover value of 11.28% for the combined transects.

Table 12 presents the results for the three Community Map Transects established within the Grassland Community, again combining all three transects. From Importance Values, galleta and black grama constitute 34.92% and 13.72% respectively. Dead galleta is third (13.42%) and dead black grama is fourth (8.39%), with New Mexico feathergrass (Stipa neomexicana) fifth (6.59%). There were 5156 live galleta plants and 1671 dead galleta plants and 1593 live black grama plants and 603 dead black grama plants found on the three transects. There was a total absolute ground cover value of 19.09% for the three transects.

Table 13 contains the results for the three Community Map Transects

established in the Ponderosa Pine Community of Sunset Crater National Monument. Blue grama (Bouteloua gracilis) ranked first in Importance Value with 16.84% and sand bluestem (Andropogon hallii) was second with 12.25%. Seedling/young apache plume (Fallugia paradoxa) was third (10.05%) and ponderosa pine (Pinus ponderosa) was fourth with 8.04%. Dead apache plume was fifth in terms of Importance Value (7.14%). A total absolute ground cover of 24.17% was calculated for the combined three transects.

DISCUSSION

Grazing Effects

All three of the major plant communities represented at Wupatki National Monument are presently being grazed by domestic livestock. The Juniper/Grassland and Grassland Communities are utilized as winter range for cattle while the Cold Desert Shrub Community is grazed by both horses and sheep, with no established season of use. The cattle numbers are set at 600 head for five months, November 15th to April 15th (National Park Service 1976). The numbers of horses and sheep grazed within the Monument are not clearly outlined in the Statement for Management (National Park Service 1976).

Sunset Crater National Monument is not presently being grazed by any type of domestic livestock, but is grazed by some herbivorous wildlife species, primarily deer and elk. No detrimental effects on the vegetation, which might be a result of wildlife grazing, were noted during the two study periods of this survey.

The coefficient of similarity values, based on the Importance Values of the Grazing Exclosure transects, ranged from a high of 98.85% (the inside-outside transects of Exclosure I) to a low of 78.62% (the inside-

outside transects of Exclosure III). These values indicate that the transects established for their respective Grazing Exclosure can be compared in that "a similarity coefficient of approximately 0.7 (70%) or higher is considered an indication of virtual identity" (Vasek et al. 1975).

The data obtained from the transects for Grazing Exclosures I and II indicate several differences between Wupatki National Monument and the adjacent Coconino National Forest. Unfortunately, no similar vegetation of a non-grazed area could be located for Grazing Exclosures III and IV. However, data from Grazing Exclosure III generally supports the differences of Exclosures I and II.

The first difference between the Monument and the Forest Service lands can be seen in the total absolute ground cover values. Both transects established in Hull's Canyon (Exclosure I) had total absolute ground cover values of less than 15% (Tables 1 and 2). The transect established in the same community on Forest Service lands had a total absolute ground cover value of almost 30%. The transects established in the Juniper/Grassland Community (Exclosure II) are not as dramatic in difference; however, the Forest Service lands do have a higher total absolute ground cover value. The two transects on the Monument had less than 19% total absolute ground cover values, while the transect on Forest land had approximately a 21% total absolute ground cover value. The total absolute ground cover values for Grazing Exclosure III transects (13% and 17%) supports the trend of low cover values for the Monument (Tables 7 and 8).

Another difference between the Monument and the Forest becomes apparent when the density figures are reviewed. Galleta is the dominant plant for all three transects, according to Importance Values for Grazing

Exclosure I (Tables 1, 2, and 3). But galleta is by far more abundant on the Monument. There is an average of 4057 live galleta plants on the inside and outside transects on the Monument, but only 1117 live plants were counted on the Forest Service land transect. This is more than 3.5 times as many live galleta plants on the Monument as found on the Forest. There is an average of 891 dead galleta plants on the Monument transects and 313 on the Forest Service transect. This is more than 2.5 times as many dead galleta plants on the Monument as are on the National Forest.

This same pattern of density difference in galleta can be seen when the figures for Grazing Exclosure II are reviewed (Tables 4, 5, and 6). There is an average of 6788 live galleta plants on the Monument and 4390 live galleta plants on the Forest, approximately 1.5 times as many plants on the Monument. There is an average of 1969 dead galleta plants on the Monument and only 1724 dead galleta plants on the Forest. This amounts to about 1.2 times as many dead galleta plants on the Monument.

Grazing Exclosure III, in Cedar Canyon, generally supports the results of this pattern on the Monument. There is an average of 4074 live galleta plants counted and 1263 dead galleta plants counted on the transect inside the exclosure.

It becomes obvious from the previously described general pattern that there is more galleta on Wupatki National Monument than there is on the Coconino National Forest. Galleta is classified as an increaser in all areas of Arizona and "increases in abundance as range condition deteriorates" (Utah Ag. Exp. Sta. Bulletin 487, 1972). The edaphic and climatic factors that might have affected the differences in densities are the same due to the close proximity of all the respective transects. Therefore, this general pattern of increased densities of galleta on the Monument appears to be the result of the domestic livestock grazing on the Monument, in that it is the only major difference between the

Monument and the Forest.

A similar but inverse pattern of density difference can be seen when the four-wing saltbush figures are reviewed for Grazing Exclosure I (Tables 1, 2, and 3). Four-wing saltbush is a palatable shrub species that is grazed by both wildlife and domestic livestock. There is an average of 83 live adult four-wing saltbush plants on the Monument and a total of 127 live adult four-wing saltbush plants on the Forest, approximately 1.5 times as many plants on the Forest, which is not presently being grazed. Another difference in four-wing saltbush can be seen in the seedling/young figures. There is an average of 206 seedling/young four-wing saltbush plants on the Monument and a total of only 53 seedling/young four-wing saltbush plants on the Forest. The last difference between the Monument and the Forest, in respect to four-wing saltbush, is in the absolute cover values. There is an average of only 4.77 m absolute cover for four-wing saltbush on the Monument, while there is 10.50 m absolute cover for the Forest, clearly indicating larger crown cover for the plants on the Forest.

Livestock Utilization Studies

All of the above differences can be attributed to the domestic livestock grazing on the Monument. Field observations clearly indicate that over 90% of the four-wing saltbush plants on the Monument have received 100% utilization. This consistent extreme utilization has reduced the vigor of the adult plants and has reduced the crown diameters of the plants on the Monument, explaining the major differences in absolute cover values. This same extreme utilization explains the differences in the number of live adult plants between the Monument and the Forest and the differences in numbers of seedling/young four-wing saltbush plants. Field observations during the two year study period

suggest that there is little replacement of adult four-wing saltbush plants taking place on the Monument, such is not the case on the Forest. The relative abundance of seedling/young plants on the Monument suggests sufficient reproduction to accomplish the replacement, but the continuous overgrazing seriously inhibits maturation of the seedling/young plants. This reproduction appears to be primarily in the vegetative form of shoots from presently overgrazed adult bushes. If this present pattern of extreme utilization of adult plants continues, it can be predicted that the four-wing saltbush element of the flora of Hull's Canyon will be eliminated.

The utilization study clearly supports the general concept that the Juniper/Grassland and Grassland Communities of Wupatki National Monument are being overgrazed. The Utah Agricultural Experiment Station Bulletin 487 (1972) dealing with galleta states "that proper use factors for this grass are in the neighborhood of 50 percent utilization by cattle." The utilization study conducted in the 1977 study period indicates that approximately 72% of the two communities (4535 ha) was grazed in excess of 50% during the 1976-1977 winter grazing season. What is very significant in this value is that when "galleta occurs with highly preferred species it may not be utilized until the preferred forages become scarce" (Utah Ag. Exp. Sta. 1972). Field observations during the utilization study indicate that this is the case on Wupatki National Monument.

In addition to galleta, grasses typical of the Juniper/Grassland and Grassland Community include: black grama, New Mexico feathergrass and Indian ricegrass. All three of these grasses are more palatable to livestock than is galleta. Field observations clearly indicate that

all three of these grasses had received over 90% utilization in all areas of both communities. Black grama had received 100% utilization in all areas, even in areas where galleta had received only 10-20% utilization. The continued heavy utilization of these more palatable grasses will eventually remove these grasses from the composition. This removal of competition will allow the continued increase in galleta density.

Community Description

As previously mentioned, the three basic vegetation community types found in Wupatki National Monument are 1) Juniper/Grasslands, 2) Grasslands, and 3) Cold Desert Shrub. The Juniper/Grassland and the Grassland Communities are homogeneous in their composition throughout the two respective areas with the Cold Desert Shrub being very complex in composition. The Cold Desert Shrub Community is the largest of the three communities.

Juniper/Grassland

This is the smallest of the three communities found on Wupatki National Monument, comprising only about 9% of the total area. This area is dominated by one-seed juniper and represents the lower limits of the tree's range. The two dominant shrubs found in this community are broom snakeweed (Gutierrezia sarothrae) and rubber rabbitbrush. One shrub is normally dominant over the other depending upon soil type and location within the community. Other shrubs found within the community in low densities are four-wing saltbush and apache plume.

The herb component of this community is quite varied, again dependent upon soil type and location within the community. Rocky Mountain Zinnia

(Zinnia grandiflora), globemallow (Sphaeralcea subhastata) and aster (Aster arenosus) are the most common herbs encountered. Rocky Mountain zinnia and aster can occur in very high density pockets in certain soil types, such as very little cinder cover with exposed sandstone.

The dominant grass throughout the community is galleta. This rhizomatous grass is very well adapted to this environment and appears to be "taking over" the grassland component of the Monument (see Grazing Impact section). Other grasses found in the community are black grama, mesa dropseed and Fendler threeawn (Aristida fendleriana).

Hull's Canyon, located approximately 2.8 kilometers south of Citadel Sink, was previously described as a four-wing saltbush and mesa dropseed community, based on visual observations without any transects. Transect data analysis reveals that this area is actually a four-wing saltbush and galleta area with scattered plants of mesa dropseed. Black grama is also present in very low densities. This area is heavily utilized by domestic livestock. This heavy utilization resulted in mesa dropseed being the visual dominant, with the galleta grazed down, causing the erroneous visual community description.

The dominant annuals found in this community are Russian thistle (Salsola kali) and spurge. The Russian thistle is primarily found in areas with exposed sandstone and little or no cinder cover, while the spurge is mainly found in open areas with deep cinders.

Grassland

This community is the second largest vegetation type of Wupatki National Monument, making up approximately 37% of the total area. The major portion of this community is represented by Antelope Prairie to the east and another large un-named prairie to the west.

One-seed juniper is present throughout the entire community, with the highest densities associated with the ecotone of the Juniper/Grassland. Only scattered, stunted, almost shrub-like one-seed junipers are present near the northern Monument boundary. Towards the center of the western un-named prairie, a canyon-like sink is found that is mapped out as a Juniper/Grassland Community. In association with this area, one-seed juniper is present within the Grassland Community.

The shrub component of this community is varied and in some areas has a high enough density to be mapped out separately. Rubber rabbitbrush is the dominant shrub throughout this community, with four-wing saltbush, threadleaf groundsel (Senecio longilobus) and broom snakeweed also present. Along the broken, cindery slopes surrounding the mesas of the Grassland Community, apache plume and squawbush (Rhus trilobata) are the dominant shrubs. Winterfat (Eurotia lanata) is present in very low densities, primarily in the western portion of the community, but appears to be decreasing in densities due to domestic livestock grazing.

The herb component of this community is dominated by globemallow, Rocky Mountain zinnia and aster. All three of these herbs, according to Community Map transects, make up less than 2% of the total ground cover. The dominance and density of these herbs varies considerably depending upon the soil type and location within the community. Also common, to occasional, throughout the community is wirelettuce (Stephanomeria pauciflora) and rushpea (Hoffmanseggia jamesii).

Galleta is the dominant grass in the Grassland Community, being found in high densities in all areas. Community Map transect analysis indicates that this grass has a relative cover value of almost 55%. The 90 square meters sampled by Community Map transect #16 contained

2440 galleta plants and 65.73% of the relative density was accounted for by this species. New Mexico feathergrass and black grama are the other major grasses found in the community, but both occur normally only in low densities. Certain areas in the western portions of the community are dominated by black grama but these areas are receiving heavy utilization by domestic livestock. Fendler threeawn and Indian ricegrass (Oryzopsis hymenoides) are also found within the community, the threeawn being more common than the rice grass.

Russian thistle is the most abundant and common annual in this community. It is found throughout the entire community and, in disturbed or overgrazed areas, is very abundant. The next most abundant annual is spurge, represented by several species. This annual is quite common within the community and is especially abundant in the open deep cinder areas. Buckwheat (Eriogonum sp.) is also found within the community in low densities.

A rather unique area occurs in the east central portion of Antelope Prairie. This is a pocket of deep black cinders about 2 hectares (5 acres) in area. It is unique in that normally deep cinders are only found on the slopes of mesas in this community, even though this area is in the open flat areas of the Grassland. Rubber rabbitbrush and threadleaf groundsel are quite common and form hummocks similar to those found in the Cold Desert Shrub Community. Mesa dropseed and New Mexico feathergrass are the common grasses in this area.

Cold Desert Shrub

This is the largest of the three communities represented in Wupatki National Monument, covering approximately 54% of the total area. This is a very complex community, primarily due to the variable soils. There are

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no dominant species that are common in all parts of the community as was the case with the Juniper/Grassland and the Grassland Communities. Certain shrub species are found in most areas of the community, but are dominant in some of these areas and sparsely represented in others, making it difficult to name any one species as dominant. The herb and grass components of the community follow the same pattern, with a few annuals the only element of composition that is the same throughout the community.

This complex community was divided into five general associations in the Phase I report, based on field observations. The Community Map transects that were established during Phase II have confirmed the accuracy of the five associations. The association boundaries will have to remain estimates due to the lack of aerial photographs.

The first association is the area north of Doney Mountain Wash up to the general area of Citadel Wash. This area is dominated by four-wing saltbush, apache plume, broom snakeweed and Mormon tea, forming randomly clumped shrub hummocks. The area between these shrub hummocks is characterized by very little vegetation in deep black cinders. These shrubs are the most important element of the composition of this association in that they create favorable micro-habitats for the other components in the association. Anders wolfberry (Lycium andersonii), Mohave brickellia (Brickellia oblongifolia) and squawbush are other shrubs commonly found throughout the association in low densities.

The herb component of this association is limited, due to the open, deep, black cinder interspaces. Tetradlea coulteri and a perennial buckwheat (Eriogonum corymbosum) are the two common herbs found in the deep black cinder interspaces in low densities. In some areas the cinder depth is reduced and the sandstone substrate is showing. In these areas,

prince's plume (Stanleya pinnata), globemallow, greenstem paperflower (Psilostrophe sparsiflora) and aster are commonly found in varying densities.

The grass component is dominated by galleta. Galleta normally occurs in high density pockets of small area. In the areas of shallow cinder cover, fluffgrass (Tridens pulchella) is the dominant grass. Commonly associated with both galleta and fluffgrass is Fendler threeawn in low densities. Bush muhly (Muhlenbergia porteri) is found in the association, normally growing within the shrub hummocks.

Spurge and buckwheat species are the two common annuals, growing in the open deep cinder interspaces. Stickleaf (Mentzelia albicaulis) and Russian thistle are also found within the association.

Analysis of three Community Map transects reveals that the absolute ground cover for this association is less than 10%. Four-wing saltbush was dominant in absolute cover value for all three transects, but had a value of less than 5%.

The second general association found in this community is probably better classified as a Cold Desert Shrub Grassland. This area is quite different in structure from the previously described association in two important ways. First, the shrub species diversity and density are greatly reduced and second, there is a distinct lack of sparsely-vegetated interspaces with open, deep cinder soils.

This association is dominated by rubber rabbitbrush and four-wing saltbush, with broom snakeweed and ephedra species also found in low densities. Analysis of the data from Community Map transect #5 indicates that rubber rabbitbrush appears to be increasing in density, based on the seedling/young rubber rabbitbrush in the area.

The herb component is dominated by aster, globemallow and greenstem paperflower. A perennial buckwheat is also present in low densities.

The main component of composition for this association is the grasses. Galleta is the dominant grass with New Mexico feathergrass and black grama also common. Bush muhly and Fendler threeawn are both present in varying densities. These grasses make up about 14% of the total 20% absolute ground cover for this association, emphasizing the importance of this component of the association.

No annuals were sampled by Community Map transect #5, but observations in the association indicate that spurge and buckwheat are the common annuals. Russian thistle was also observed in low densities.

The third association is similar to the first association in that randomly clumped shrub hummocks are dominant in a deep, black, cinder substrate. But unlike the first association, this area has fringed sagebrush as the dominant shrub component. The number of seedling and young fringed sagebrush counted in sample transects, established within the association, indicates that this plant is increasing in density and is a very important element in this association. Four-wing saltbush, ephedra species, rubber rabbitbrush and apache plume are all present in varied densities, depending upon the location within the association.

The major herb elements of this association are prince's plume, wirelettuce, white horsenettle (Solanum elaeagnifolium) and a milkvetch species (Astragalus sp.). Tetraclea coulteri is another important element of the herb stratum.

The major grass components of this association are fluffgrass, bush muhly, New Mexico feathergrass and galleta. Fendler's threeawn is also present. The grass component of this association is of low density and

is primarily confined to areas of shallow cinder cover.

Spurge and buckwheat are the two common annuals sampled within this community. The spurge is of greater density in the deep black cinder areas, while the buckwheat is commonly associated with the areas of exposed sandstone and shallow cinder.

The fourth association found in the Cold Desert Shrub Community is different from the other associations in that four-wing saltbush and broom snakeweed are the dominant shrubs, occurring in open sandstone substrate. Also found within the association are rubber rabbitbrush and species of ephedra. The sparse herb element is dominated by prince's plume, milkvetch and globemallow. The grass component is very sparse, and largely consists of alkali sacaton (Sporobolus airoides) and galleta. Fluffgrass and Fendler's threeawn are also present in very low densities. Buckwheat species is the common annual present, mostly in the open areas of the association.

Analysis of Community Map transects within this association indicates that the absolute ground cover value is less than 5%. The majority of this is accounted for by sparsely scattered shrubs.

The fifth association is dominated by shadscale (Atriplex confertifolia), ephedra species, broom snakeweed and four-wing saltbush. The herb composition is dominated by prince's plume, Coldenia hispidissima, and milkvetch species. Tetradlea coulteri and Chamaesarcha coronopus are additional herbs found in this association. The grasses are mainly composed of the dominants, alkali sacaton and galleta. Mesa dropseed, fluffgrass and Fendler's threeawn are also present. The grass component of this association is very limited in density, occurring normally in widely spaced, isolated clumps.

Analysis of the Community Map transects reveals that this association

generally has less than 5% absolute ground cover. One Community Map transect had less than 2% absolute ground cover, a situation not uncommon in many areas of this association.

Buckwheat species and spurge are the two common annuals. The buckwheat species are the dominant of these two annuals.

Ponderosa Pine

The Ponderosa Pine Community of Sunset Crater National Monument consists of approximately 712.6 hectares (1760 acres) and ranges in elevation from a low of about 2073 meters (6800 feet) to a high of 2438 meters (8000 feet) at the top of Sunset Crater. The average elevation of the Monument is approximately 2134 meters (7000 feet). The substrate consists mainly of very deep volcanic black cinders and basaltic lava rock. More than 50% of the Monument is the Bonito lava flow, an environment unfavorable for colonization by plants.

In areas of deep black cinders, ponderosa pine is the dominant tree. Analysis of data gathered by the point-quarter method indicates that there is an average distance between pines of approximately 13.34 m. There is an average crown cover per tree of 23.44 m^2 , with approximately 56 trees per hectare. One-seed juniper and pinyon pine (Pinus edulis) are also present within the community in low densities, one-seed juniper being the more common of the two.

According to analysis of Community Map transects established within the Monument, apache plume is the dominant shrub. Rubber rabbitbrush and Viguiera multiflora are other common shrubs associated with apache plume in the deep black cinder areas of the Monument. In the areas where basaltic outcrops occur, and throughout the Bonito lava flow, squawbush is the common shrub. Within the Bonito lava flow, the squawbush is normally

found in clumps of several plants in isolated pockets.

Herb composition of the Monument is quite variable and changes with the season. Twinpod (Physaria newberryi) is the first perennial to appear on the black cinder hills in April through May. Skyrocket (Gilia aggregata) and beardlip or scarlet beardtongue (Penstemon barbatus) appear next and are dominant throughout the rest of the summer. The densities of these two herbs are quite variable and are dependent on the rainfall of the area. Other herbs found on the Monument, in common to occasional densities throughout the summer, are stickleaf, skeleton plant (Lygodesmia spinosa), hiddenflower (Cryptantha sp.) and common mullein (Verbascum thapsus).

The grasses of Sunset Crater National Monument are mainly little bluestem (Andropogon scoparius), sand bluestem, and blue grama. The density and relative dominance of each species is dependent upon location within the Monument. This dependence is based on the soil type. In the deep black cinder areas little bluestem and sand bluestem, with stout rhizomes, are the dominant. The blue grama appears to be more restricted to areas where Ponderosa Pine stands have established the substrate, such as the slopes of Lenox Crater. Bottlebrush squirreltail (Sitanion hystrix) and Fendler's threeawn are also found within the Community.

Spurge is the common annual found in the Monument. Littleseed muhly (Muhlenbergia minutissima), an annual grass, is also found occasionally on the hills having deep black cinders.

Analysis of Community Map transects indicates an approximate absolute ground cover value of 20%. Most of this value consists of the shrub clumps common in this community.

Only three plant species new to Wupatki National Monument were

found in the 1977 field season. These are:

- 1) Celtis reticulata Hackberry. This was located, and appears to be restricted to Antelope Wash.
- 2) Bromus tectorum Cheatgrass. This annual grass was located at the southern entrance to the Monument along the road.
- 3) Yucca baccata Datil yucca. This was located in the bottom and on the edges of Antelope Wash.

MANAGEMENT RECOMMENDATIONS

This section of the report will deal with general management recommendations to aid in achieving Management Objectives as outlined in the Statement for Management, Wupatki-Sunset Crater National Monuments, February 1976. Ideally there should be no compromises in the preservation of the natural resources found in both Monuments, but it is realised that due to limited resources and manpower, alternatives may be necessary. These management recommendations are based on the accumulative data from two field seasons of botanical research. Because of the inclusiveness of the management recommendations in last year's report, there will be some repetition in this year's recommendations. This is necessary because recommendations made last year are still applicable to the preservation of the natural resources of both Monuments.

Wupatki National Monument

Grazing

From the data that has been gathered and from numerous field observations, this particular impact of grazing domestic livestock is by far the most detrimental activity on the Monument. This impact can be seen

in all three of the major plant communities of the Monument, with the most serious damage taking place in the Juniper/Grassland and Grassland Communities. With this in mind, the following recommendations are made:

1) All domestic livestock grazing within the Monument boundaries should be terminated.

2) Since it is unlikely that grazing will be terminated, all efforts should be conducted to stabilize the numbers and season of use of Navajo livestock that will graze the Cold Desert Shrub Community. In addition to the establishment of numbers and season of use, the following are recommended:

a) develop a long range (5 to 7 years) management plan that will allow utilization of the entire community. This will allow rotation and deferment of the various portions of the community that will prevent over-utilization of any one particular area. This management plan should include procedures for temporary water haul locations, salting locations and bedding locations.

b) special efforts should be made to prevent, or severely limit, the grazing and banding of sheep on the edges of the washes of the Community. These areas are especially susceptible to trampling and overgrazing, because many palatable plants occur here and therefore, use should be limited. Accelerated erosion will occur after grazing and trampling.

c) grazing and bedding of sheep should be away from archeological sites within the Community. Trampling may be detrimental to any such sites.

3) Realizing that the domestic livestock grazing of the Juniper/Grassland and Grassland Communities are under permit and cannot

presently terminated, the following recommendations are made:

a) continue monitoring Grazing Enclosures established during the 1977 field season. Transects inside and outside the Grazing Enclosures should be re-read at least every two years to accumulate data that might reflect changes in the vegetation of grazed and un-grazed areas within the Monument boundaries.

b) in accordance with paragraph 12, page 2, of National Park Service Grazing Permit No. 14-10-0333-1273, determine by annual pre-season range condition inspections the allowable numbers of stock for that year. This determination should be followed up by one or two seasonal livestock counts that would establish permittee compliance with that season's numbers.

c) attempt to solicit permittee cooperation in obtaining voluntary reductions in numbers of livestock grazing the Monument in drought or otherwise unfavorable grazing condition years to reduce the grazing impact on the vegetation of the Monument. This could be aided by cooperative acknowledgement of certain overgrazed problem areas such as Hull's Canyon and Cedar Canyon and attempting to reduce grazing pressure in these and other areas through use of carefully designed riding, salting and watering practices.

d) consult with the permittee and discuss possible alternative grazing systems that would allow the Monument lands to receive some rest and/or deferment. This could be accomplished by developing a long range management plan for the remainder of the grazing permit period.

e) solicit permittee cooperation in re-establishment of "drift" fences in Antelope Wash to prevent cattle from "drifting" into the Cold Desert Shrub Community. Additional "drift" fences should be

established in areas to prevent the drifting of cattle to the Cold Desert Shrub by way of Doney Mountain.

4) All unfenced portions of the Monument boundary should be fenced. This could be accomplished economically by a "phase operation" in that a certain portion of the boundary could be surveyed and fenced in Phase I. Then continue the operation in Phases II, III, etc., until the entire boundary is fence. Fencing the boundary of the Monument is essential. No actual control of numbers and season of use will be possible in the Juniper/Grassland and Grassland Communities until this is accomplished. Trespass livestock grazing of any area of the Monument cannot be effectively controlled and/or prevented without a boundary fence.

5) With respect to establishing a stock driveway the following is recommended:

- a) the driveway should be located in Section 20, T26N, R10E.
- b) the driveway should be established to cross the slope, and not be directly up the slope, to prevent erosion.
- c) a minimum amount of grazing should be allowed along the driveway, especially on the slopes.
- d) drive schedules should be such that the animals are not bedded down in areas of wash slopes or on the slope leading up to White Mesa.

It is further recommended that this driveway receive minimum use in that the area involved for the driveway is a very fragile community. Any damage of this area would be detrimental and long lasting.

Human Impact

Human impact within Wupatki National Monument is limited and is not presently a threat to the botanical natural resources of the Monument.

Evidence of off road vehicle traffic was noted during the 1977 field season, primarily in the Juniper/Grassland Community. These tracks never were of high density but efforts should be made to terminate or restrict this activity because off road vehicle traffic disturbs the natural habitat.

Future Research

The main area for future research would be the Cold Desert Shrub Community. With the aid of air photographs, this very complex community could be mapped out more accurately and with much more detail. Additional work should be conducted to determine the grazing impact in the Community for both the permitted and trespass grazing.

Sunset Crater National Monument

Due to minimal environmental disturbances occurring on the Monument, there is little to recommend, other than to maintain the present policies regarding visitor use of the Monument.

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Table 1. Results of the inside transect of Grazing Exclosure I.

Species	Absolute			Relative %			Importance Value
	Cover %	Den.	Freq.	Cover	Den.	Freq.	
<u>Hilaria jamesii</u>	5.51	3927	50	38.16	73.48	20.24	43.96
Dead <u>Hilaria jamesii</u>	1.23	1086	50	8.53	20.32	20.24	16.36
<u>Atriplex canescens</u>	4.39	62	36	30.41	1.16	14.57	15.38
Dead <u>Atriplex canescens</u>	2.88	30	20	19.91	.56	8.10	9.52
SdIng/yng <u>Atriplex canescens</u>		166	45		3.11	18.22	7.11
Cowpie	.43	68	41	2.99	1.27	16.60	6.95
<u>Aster arenosus</u>		2	2		.04	.81	.28
<u>Sphaeralcea subhastata</u>		1	2		.02	.81	.28
<u>Bouteloua eriopoda</u>		2	1		.04	.40	.15

Table 2. Results of the outside transect of Grazing Exclosure I.

Species	Absolute			Relative %			Importance Value
	Cover%	Den.	Freq.	Cover	Den.	Freq.	
<u>Hilaria jamesii</u>	2.98	4186	50	25.15	78.11	18.59	40.62
<u>Atriplex canescens</u>	4.55	104	41	38.40	1.95	15.24	18.53
Dead <u>Atriplex canescens</u>	3.28	29	23	27.69	.54	8.55	12.26
Dead <u>Hilaria jamesii</u>	.44	697	50	3.68	13.01	18.59	11.76
Cowpie	.60	65	43	5.07	1.21	15.99	7.42
SdIng/yng <u>Atriplex canescens</u>		246	47		4.59	17.47	7.35
<u>Bouteloua eriopoda</u>		8	7		.15	2.60	.92
Dead <u>Bouteloua eriopoda</u>		22	6		.41	2.23	.88
<u>Sphaeralcea subhastata</u>		2	2		.04	.74	.26

Table 3. Results of the Forest Service transect of Grazing Exclosure I.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	3.56	1117	50	12.03	67.09	24.51	34.54
<u>Atriplex canescens</u>	10.50	127	43	35.53	7.63	21.08	21.41
Dead <u>Atriplex canescens</u>	14.80	55	32	50.09	3.30	15.69	23.03
Dead <u>Hilaria jamesii</u>	.67	313	49	2.26	18.80	24.02	15.03
SdIng/yng <u>Atriplex canescens</u>		53	30		3.18	14.71	5.96
<u>Muhlenbergia porteri</u>	.02			.08			.03

Table 4. Results of the inside transect of Grazing Exclosure II.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	13.49	6864	50	69.38	72.67	21.46	54.50
Dead <u>Hilaria jamesii</u>	2.56	2235	50	13.28	23.66	21.46	19.47
<u>Juniperus monosperma</u>	1.64	1	1	8.52	.01	.43	5.98
Cowpie	.32	39	32	1.66	.41	13.73	5.27
SdIng/yng <u>Gutierrezia sarothrae</u>		78	24		.83	10.30	3.71
Dead <u>Gutierrezia sarothrae</u>	.32	40	20	1.66	.42	8.58	3.55
<u>Aster arenosus</u>	.02	55	20	.08	.58	8.58	3.08
<u>Sphaeralcea subhastata</u>	.06	25	14	.31	.26	6.01	2.19
<u>Sporobolus flexuosus</u>	.48	69	2	2.52	.73	.86	1.37
<u>Stipa neomexicana</u>	.02	13	8	.08	.14	3.43	1.22
Dead <u>Sporobolus flexuosus</u>	.18	15	2	.94	.16	.86	.84
<u>Aristida fendleriana</u>		5	5		.05	2.15	.73
<u>Bouteloua eriopoda</u>	.04	4	4	.19	.04	1.72	.65
<u>Gutierrezia sarothrae</u>	.12	3	1	.62	.03	.43	.36

Table 5. Results of the outside transect of Grazing Exclosure II.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	6.68	6711	50	49.15	73.27	17.30	46.57
Dead <u>Hilaria jamesii</u>	1.50	1703	50	10.98	18.59	17.30	15.62
<u>Juniperus monosperma</u>	4.17	4	4	30.67	.04	1.38	10.70
<u>Bouteloua eriopoda</u>	.53	291	38	3.88	3.18	13.15	6.74
Dead <u>Bouteloua eriopoda</u>	.19	124	30	1.38	1.35	10.38	4.37
Cowpie	.32	35	24	2.32	.38	8.30	3.67
<u>Aster arenosus</u>	.02	149	26	.15	1.63	9.00	3.59
SdIng/yng <u>Gutierrezia sarothrae</u>	.10	28	17	.77	.31	5.88	2.32
Dead <u>Stipa neomexicana</u>	.04	17	7	.32	.19	2.42	1.85
<u>Stipa neomexicana</u>	.05	58	13	.38	.63	4.50	1.84
<u>Aristida fendleriana</u>		16	10		.17	3.46	1.21
<u>Sphaeralcea subhastata</u>		5	5		.05	1.73	.59
Dead <u>Sphaeralcea subhastata</u>		3	2		.03	.69	.24
<u>Zinnia grandiflora</u>		1	1		.01	.35	.12

Table 6. Results of the Forest Service transect of Grazing Exclosure II.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	11.28	4390	50	53.49	63.34	17.73	44.85
Dead <u>Hilaria jamesii</u>	2.88	1724	50	13.68	24.87	17.73	18.76
<u>Bouteloua eriopoda</u>	2.15	256	35	10.20	3.69	12.41	8.77
Dead <u>Gutierrezia sarothrae</u>	.88	116	32	4.19	1.67	11.35	5.74
Dead <u>Bouteloua eriopoda</u>	.56	154	29	2.64	2.22	10.28	5.05
<u>Aristida fendleriana</u>	.50	104	27	2.39	1.50	9.57	4.49
<u>Juniperus monosperma</u>	1.99	1	1	9.45	.01	.35	3.27
SdIng/yng <u>Gutierrezia sarothrae</u>		65	14		.94	4.96	1.97
Dead <u>Aristida fendleriana</u>	.33	16	10	1.56	.09	3.55	1.73
<u>Aster arenosus</u>	.04	52	12	.19	.75	4.26	1.73
<u>Gutierrezia sarothrae</u>	.23	13	4	1.10	.19	1.42	.90
<u>Zinnia grandiflora</u>	.05	22	5	.23	.32	1.77	.77
<u>Stipa neomexicana</u>		11	6		.16	2.13	.76
Dead <u>Opuntia whipplei</u>	.16			.78			.26
<u>Psilostrophe sparsiflora</u>		2	2		.03	.71	.25
Cowpie		2	2		.03	.71	.25
<u>Ephedra viridis</u>		2	2		.03	.71	.25
<u>Bouteloua gracilis</u>	.02	1	1	.11	.01	.35	.16

Table 7. Results of the inside transect of Grazing Exclosure III.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	5.08	3581	50	29.56	67.85	17.54	38.32
Dead <u>Hilaria jamesii</u>	.61	1263	50	3.54	23.93	17.54	15.00
<u>Chrysothamnus nauseosus</u>	3.55	40	25	20.68	.76	8.77	10.07
Dead <u>Chrysothamnus nauseosus</u>	2.66	21	17	15.49	.40	5.96	7.28
<u>Juniperus monosperma</u>	3.35	5	4	19.52	.09	1.40	7.00
Cowpie	.44	84	28	2.54	1.59	9.82	4.65
<u>Sphaeralcea subhastata</u>	.13	42	22	.75	.80	7.72	3.09
SdIng/yng <u>Chrysothamnus nauseosus</u>		54	18		1.02	6.32	2.45
<u>Bouteloua eriopoda</u>	.15	30	15	.89	.57	5.26	2.24
Dead <u>Bouteloua eriopoda</u>	.03	28	14	.19	.53	4.91	1.88
<u>Atriplex canescens</u>	.71	1	1	4.15	.02	.35	1.51
SdIng/yng <u>Gutierrezia sarothrae</u>		36	9		.68	3.16	1.28
<u>Aster arenosus</u>	.04	60	5	.26	1.14	1.75	1.05
<u>Hoffmanseggia jamesii</u>	.02	6	7	.09	.11	2.46	.89

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Table 7. Continued

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
Dead <u>Gutierrezia sarothrae</u>	.13	6	4	.77	.11	1.40	.76
<u>Gutierrezia sarothrae</u>	.12	4	3	.72	.08	1.05	.62
<u>Aristida fendleriana</u>		5	3		.09	1.05	.38
<u>Psilostrophe sparsiflora</u>		4	4		.08	1.40	.49
<u>Stipa neomexicana</u>	.04	2	2	.23	.04	.70	.32
<u>Muhlenbergia porteri</u>	.11	4	2	.63	.08	.70	.47
<u>Zinnia grandiflora</u>		2	2		.04	.70	.25

Table 8. Results of the outside transect of Grazing Enclosure III.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	2.63	4567	49	20.22	82.86	16.84	39.97
<u>Chrysothamnus nauseosus</u>	6.25	59	32	47.99	1.07	11.00	20.02
<u>Juniperus monosperma</u>	2.72	5	5	20.86	.09	1.72	7.56
<u>Bouteloua eriopoda</u>	.36	335	39	2.80	6.08	13.40	7.43
Dead <u>Bouteloua eriopoda</u>		288	39		5.22	13.40	6.21
Cowpie	.40	61	26	3.07	1.12	8.93	4.37
SdIng/yng <u>Chrysothamnus nauseosus</u>		50	23		.91	7.90	2.94
<u>Psilostrophe sparsiflora</u>	.06	22	16	.52	.40	5.54	2.14
<u>Sphaeralcea subhastata</u>	.08	28	15	.68	.51	5.15	2.11
<u>Atriplex canescens</u>	.41	11	7	3.13	.20	2.41	1.91
<u>Aster arenosus</u>		39	11		.71	3.78	1.50
<u>Hoffmanseggia jamesii</u>	.02	12	11	.12	.22	3.78	1.37
<u>Gutierrezia sarothrae</u>	.08	19	6	.71	.34	2.06	1.04

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Table 8. Continued

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Stipa neomexicana</u>	.01	9	5	.09	.16	1.72	.66
<u>Muhlenbergia porteri</u>		2	2		.04	.68	.24
Sdlng/yng <u>Atriplex canescens</u>		1	1		.02	.34	.12
Sdlng/yng <u>Gutierrezia sarothrae</u>		1	1		.02	.34	.12
<u>Stephanomeria pauciflora</u>		1	1		.02	.34	.12
<u>Tridens pulchella</u>		1	1		.02	.34	.12
<u>Aristida fendleriana</u>		1	1		.02	.34	.12

Table 9. Results of the inside transect of Grazing Exclosure IV.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Artemisia frigida</u> <i>Ar</i>	7.40	27	23	53.15	14.36	17.69	28.40
SdIng/yng <u>Artemisia frigida</u> <i>Ar</i>		37	23		19.68	17.69	12.46
<u>Tetradlea coulteri</u> <i>Tec</i>	.36	41	13	2.59	21.81	10.00	11.47
<u>Atriplex canescens</u> <i>Ar</i>	2.67	9	9	19.20	4.79	6.92	10.30
SdIng/yng <u>Atriplex canescens</u>		26	19		13.83	14.62	9.48
Dead <u>Artemisia frigida</u>	1.90	10	8	5.46	5.32	6.15	5.64
<u>Astragalus</u> spp.	.32	11	8	2.27	5.85	6.15	4.76
<u>Muhlenbergia porteri</u>	.32	8	8	2.27	4.26	6.15	4.23
<u>Chrysothamnus nauseosus</u>	.51	5	5	3.68	2.66	3.85	3.40
<u>Ephedra torreyana</u>	.49	2	3	3.51	1.06	2.31	2.29
SdIng/yng <u>Ephedra torreyana</u>		5	4		2.66	3.08	1.91
<i>DA</i> Dead <u>Atriplex canescens</u>	.27	9	1	1.93	.53	.77	1.08
SdIng/yng <u>Chrysothamnus nauseosus</u>		2	2		1.06	1.54	.87
<u>Stephanomeria pauciflora</u>		2	2		1.06	1.54	.87
<u>Tridens pulchella</u>		1	1		.53	.77	.43
<u>Stipa neomexicana</u>		1	1		.53	.77	.43

Table 10. Results of the outside transect of Grazing Exclosure IV.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Artemisia frigida</u>	7.86	28	22	52.64	11.91	16.67	27.07
SdIng/ yng <u>Artemisia frigida</u>		39	22		16.60	16.67	11.09
SdIng/ yng <u>Atriplex canescens</u>		28	20		11.91	15.15	9.02
<u>Hilaria jamesii</u>		50	3		21.28	2.27	7.85
<u>Ephedra torreyana</u>	1.98	9	6	13.29	3.83	4.55	7.22
<u>Tetradlea coulteri</u>	.15	28	10	1.02	11.91	7.58	6.84
Dead <u>Artemisia frigida</u>	1.89	4	6	12.68	1.70	4.55	6.31
<u>Muhlenbergia porteri</u>	.43	9	10	2.89	3.83	7.58	4.77
<u>Atriplex canescens</u>	.89	6	5	5.95	2.55	3.79	4.10
Dead <u>Atriplex canescens</u>	.91	4	4	6.11	1.70	3.03	3.61
<u>Astragalus</u> spp.	.16	8	7	1.07	3.40	5.30	3.26
<u>Chrysothamnus nauseosus</u>	.25	6	6	1.69	2.55	4.55	2.93
<u>Tridens pulchella</u>		5	4		2.13	3.03	1.72
<u>Fallugia paradoxa</u>	.31	1	1	2.06	.43	.76	1.08

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Table 10. Continued

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
SdIng/yng <u>Fallugia paradoxa</u>		5	1		2.13	.76	.96
SdIng/yng <u>Chrysothamnus nauseosus</u>		2	2		.85	1.51	.79
SdIng/yng <u>Ephedra torreyana</u>		1	1		.43	.76	.40
<u>Stephanomeria pauciflora</u>		1	1		.43	.76	.40
<u>Stipa neomexicana</u>		1	1		.43	.76	.40
Dead <u>Muhlenbergia porteri</u>	.09			.59			.20

Table 11. Results of 18 Community Mapping Transects of the Cold Desert Shrub.

Species	Absolute			Relative %			Importance Value
	Cover%	Den.	Freq.	Cover	Den.	Freq.	
<u>Hilaria jamesii</u>	1.90	3608	93	16.99	54.91	11.57	27.82
<u>Bouteloua eriopoda</u>	.55	708	63	4.99	10.77	7.84	7.87
<u>Atriplex canescens</u>	1.97	55	43	15.72	.84	5.35	7.30
<u>Sporobolus flexuosus</u>	.85	396	46	7.68	6.03	5.72	6.48
<u>Fallugia paradoxa</u>	.97	54	34	8.72	.82	4.23	4.59
<u>Gutierrezia sarothrae</u>	.52	150	47	5.01	2.28	5.85	4.38
Dead <u>Bouteloua eriopoda</u>	.26	358	41	2.50	5.45	5.10	4.35
<u>Ephedra torreyana</u>	.78	30	24	7.04	.46	2.99	3.50
<u>Coldenia gregii</u>	.31	215	32	2.88	3.27	3.98	3.38
<u>Atriplex confertifolia</u>	.69	41	24	6.22	.62	2.99	3.28
<u>Chrysothamnus nauseosus</u>	.37	40	20	6.03	.61	2.49	3.04
Dead <u>Muhlenbergia porteri</u>	.17	204	24	1.69	3.10	2.99	2.59
<u>Ephedra viridis</u>	.47	19	17	4.32	.29	2.11	2.24
Cowpie/Horsepie	.62	47	29	.71	.72	3.61	1.68
<u>Stipa neomexicana</u>	.09	93	20	.97	1.42	2.49	1.63
<u>Tertraclea coulteri</u>	.01	61	29	.23	.93	3.61	1.59

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Table 11. Continued

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Muhlenbergia porteri</u>	.10	23	17	1.01	.35	2.11	1.16
<u>Brickellia oblongifolia</u>	.05	36	18	.63	.55	2.24	1.14
Dead <u>Hilaria jamesii</u>	.04	52	14	.52	.79	1.74	1.02
<u>Aristida fendleriana</u>	.03	41	16	.42	.62	1.99	1.01
Dead <u>Coldenia gregii</u>	.02	31	17	.45	.47	2.11	1.01
<u>Tridens pulchella</u>	.01	29	19	.17	.44	2.36	.99
<u>Aster arenosus</u>	.01	91	9	.26	1.38	1.12	.92
<u>Eriogonum corymbosus</u>	.01	23	13	.65	.35	1.62	.87
<u>Artemisia dracunculoides</u>	.07	27	11	.74	.41	1.37	.84
<u>Stanleya pinnata</u>	.02	21	11	.34	.32	1.37	.68
<u>Lycium andersonii</u>	.15	3	3	1.41	.05	.37	.61
SdIng/yng <u>Atriplex canescens</u>		12	13		.18	1.62	.60
<u>Sphaeralcea subhastata</u>	.01	11	11	.22	.17	1.37	.59
SdIng/yng <u>Fallugia paradoxa</u>		19	11		.29	1.37	.55
<u>Stephanomeria pauciflora</u>		16	10		.21	1.23	.46
SdIng/yng <u>Chrysothamnus nauseosus</u>		3	9		.05	1.12	.39

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Table 11. Continued

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Gaura coccinea</u>	.02	29	2	.33	.44	.25	.34
<u>Tragia stylaris</u>	.01	13	4	.20	.20	.50	.30
Dead <u>Ephedra viridis</u>	.07	1	1	.75	.02	.12	.30
<u>Echinocactus polycephalus</u>	.02	1	1	.20	.02	.12	.11
<u>Yucca angustissima</u>		3	2		.05	.25	.10
<u>Chrysothamnus depressus</u>		2	2		.03	.25	.09
<u>Opuntia whipplei</u>		1	1		.02	.12	.05
<u>Zinnia grandiflora</u>		2	1		.03	.12	.05
<u>Sporobolus airoides</u>		1	1		.02	.12	.05
<u>Solanum elaeagnifolium</u>		1	1		.02	.12	.05

Table 12. Results of 3 Community Map Transects of the Grassland Community.

Species	Absolute			Relative %			Importance Value
	Cover%	Den.	Freq.	Cover	Den.	Freq.	
<u>Hilaria jamesii</u>	8.26	5156	43	43.25	51.52	10.00	34.92
<u>Bouteloua eriopoda</u>	2.64	1593	49	13.83	15.92	11.40	13.72
Dead <u>Hilaria jamesii</u>	2.59	1671	43	13.56	16.70	10.00	13.42
Dead <u>Bouteloua eriopoda</u>	1.83	603	41	9.60	6.03	9.53	8.39
<u>Stipa neomexicana</u>	.71	443	50	3.70	4.43	11.63	6.59
Dead <u>Stipa neomexicana</u>	.12	174	41	.64	1.74	9.53	3.97
Cowpie	.53	66	36	2.75	.66	8.37	3.93
<u>Chrysothamnus nauseosus</u>	1.00	14	9	5.26	.14	2.09	2.50
<u>Aristida fendleriana</u>	.12	31	19	.62	.31	4.42	1.78
Dead <u>Chrysothamnus nauseosus</u>	.64	2	7	3.36	.02	1.63	1.67
<u>Ephedra viridis</u>	.06	15	16	.33	.15	3.72	1.40
<u>Zinnia grandiflora</u>	.08	106	11	.43	1.06	2.56	1.35
<u>Aster arenosus</u>	.01	63	13	.06	.63	3.02	1.24
Dead <u>Senecio longilobus</u>	.09	19	12	.49	.19	2.79	1.16
Dead <u>Gutierrezia sarothrae</u>	.26	8	7	1.36	.08	1.63	1.01
SdIng/yng <u>Chrysothamnus nauseosus</u>		19	11		.19	2.56	.92
<u>Senecio longilobus</u>	.02	6	6	.12	.06	1.40	.53

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Table 12. Continued

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Psilostrophe sparsiflora</u>	.01	7	5	.04	.07	1.16	.42
<u>Gutierrezia sarothrae</u>	.12	1	1	.62	.01	.23	.29
<u>Opuntia erinacea</u>		4	3		.04	.70	.25
<u>Sphaeralcea subhastata</u>		3	3		.03	.70	.24
<u>Stephanomeria pauciflora</u>		3	3		.03	.70	.24
<u>Hoffmanseggia jamesii</u>		1	1		.01	.23	.08

Table 13. Results of 3 Community Map Transects of Sunset Crater National Monument.

Species	Absolute			Relative %			Importance Value
	Cover%	Den.	Freq.	Cover	Den.	Freq.	
<u>Bouteloua gracilis</u>	1.39	514	29	5.75	31.59	13.18	16.84
<u>Andropogon hallii</u>	2.23	315	18	9.21	19.36	8.18	12.25
Sd lng/ yng <u>Fallugia paradoxa</u>		276	29		16.96	13.18	10.05
<u>Pinus ponderosa</u>	8.77	2	2	23.10	.12	.91	8.04
Dead <u>Fallugia paradoxa</u>	1.60	78	22	6.63	4.79	10.00	7.14
<u>Fallugia paradoxa</u>	3.60	29	8	14.88	1.78	3.64	6.77
<u>Andropogon scoparius</u>	1.69	104	15	6.99	6.39	6.82	6.73
Dead <u>Bouteloua gracilis</u>	.75	116	15	3.11	7.13	6.82	5.69
Dead <u>Andropogon hallii</u>	.20	62	13	.84	3.81	5.91	3.52
<u>Viguiera multiflora</u>	1.28	9	6	5.30	.55	2.73	2.86
<u>Sitanion hystrix</u>	.13	23	12	.55	1.41	5.45	2.47
<u>Aristida divaricata</u>	.13	25	10	.54	1.54	4.55	2.21
<u>Chrysothamnus nauseosus</u>	.53	8	6	2.21	.49	2.73	1.81
<u>Yucca angustifolia</u>	.51	3	3	2.10	.18	1.36	1.21
Dead <u>Andropogon scoparius</u>	.25	12	4	1.04	.74	1.82	1.20
<u>Phacelia serrata</u>		9	5		.55	2.27	.94

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Table 13. Continued.

Species	Cover%	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Oenothera caespitosa</u>	.08	10	3	.32	.61	1.36	.76
Dead <u>Chrysothamnus nauseosus</u>	.42	1	1	1.75	.06	.45	.75
<u>Juniperus monosperma</u>	.30	1	1	1.24	.06	.45	.58
<u>Cryptantha</u> sp.	.02	4	3	.09	.25	1.36	.57
<u>Gilia aggregata</u>	.01	3	3	.05	.18	1.36	.53
<u>Physaria newberryi</u>	.03	5	2	.12	.31	.91	.45
Dead <u>Viguiera multiflora</u>	1.28	1	1	.83	.06	.45	.45
<u>Penstemon barbata</u>		5	2		.31	.91	.41
<u>Erodium cicutarium</u>		5	2		.31	.91	.41
<u>Sporobolus flexuosus</u>		3	2		.18	.91	.36
<u>Hymenoxys acaulis</u>	.04	1	1	.18	.06	.45	.28
SdIng/yng <u>Chrysothamnus nauseosus</u>		1	1		.18	.45	.21
<u>Stipa comata</u>		2	1		.12	.45	.19

II

SURVEY OF ARTHROPOD COMMUNITIES OF
SUNSET CRATER AND WUPATKI NATIONAL MONUMENTS

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February, 1978

INTRODUCTION

There are major differences in the diversity of biota between Sunset Crater and Wupatki National Monuments. These differences are due to a number of factors. The eruption of Sunset Crater in A.D. 1065 spread ash and cinders over hundreds of square miles of the two monuments, drastically changing not only geologic features but also the biota of the area. With new soil and environmental conditions, novel forms of vegetation and animals became established. Elevation gradients exist in the monuments, ranging from 8000 feet in Sunset Crater National Monument to 4280 feet in Wupatki National Monument. Thus, the contrasting combinations of elevation, rainfall, soil, and vegetation produce major differences in the diversity of biota between areas of the monument.

. Because of the diversity of the vegetation in the area, our study included a survey of the insect fauna and a study of the diversity of insects in the two monuments. To accomplish this over 46,000 insects were collected and identified in the four months from July 1977 to October 1977.

METHODS AND MATERIALS

Six sites were established in the monuments in July 1977. Two of these sites were located at the visitor centers and are designated Visitor Center-Wupatki (VCW) and Visitor Center-Sunset Crater (VCS). At each of these sites a black-light trap was operated. 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 and is located at an elevation of 4870 feet.

Four other sites, designated S1, S2, S3, and S4, are located throughout

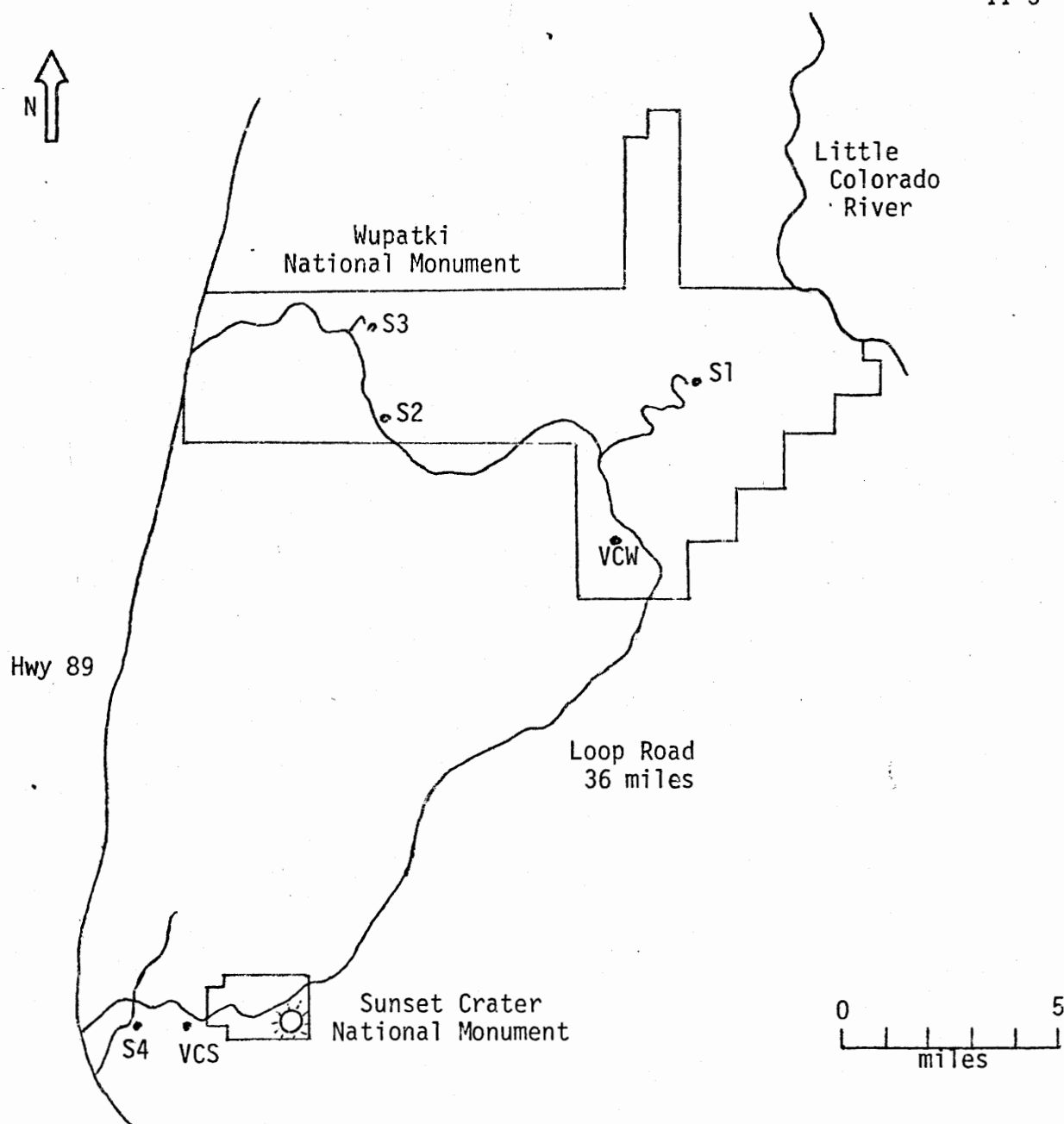
the monuments in the four major vegetation types. Site 1 is located in Cold-Desert Shrub at 4410 feet, Site 2 in Juniper/Grassland at 5430 feet, Site 3 in Grassland at 5360 feet, and Site 4 in Ponderosa Pine at 7005 feet. Locations of all six sites in the monuments are shown in Figure 1.

At each of the four sites located at the visitor centers, a transect approximately 125 yards in length was established. Each transect consisted of 25 pitfall traps. Pitfall traps were made by setting a 7 inch deep by 5 inch diameter plastic bucket in the ground. A 12 inch x 12 inch particle-board lid supported by three stones provided rain protection and a more effective trap.

Insects were sampled along the four transects each week. At this weekly visit, any insects caught in traps were collected. Also, 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 sampling.

The insects were removed from the black-light traps twice per week until September 17th; then they were emptied once per week until October 29th. Insects were separated by site, date, quantity, and sample method. Borror et al. (1976) was employed for identification of insects to family.

Black-light traps catch insects because the high illumination of the trap relative to the surroundings interferes with the normal photic orientation, which results in the insects moving towards the light source (Verheijen 1960). Anything that reduces this contrast, such as street lights or other buildings, will subsequently reduce the number of insects caught. It is generally conceded the larger the catch, the more acceptable the figures will be for statistical work. Williams et al. (1955) has shown that the previous night's trapping has little effect on the success of the following



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

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

night's catch.

Pitfall traps rely on random movements of ground dwelling insects for capture. Briggs (1961) concluded that "the size of the population at most plays a minor role in determining the numbers trapped" by pitfall methods. Therefore, pitfall traps probably should not be employed to compare the numbers of one species in different habitats (Greensdale 1964). However, pitfall trapping can be useful in the study of daily rhythm of activity, seasonal incidence and the dispersion of a single species in one type of vegetation (Southwood 1971).

The main limitation of using the sweep net is that only those individuals on top of the vegetation that do not fall off or fly away on the approach of the collector are caught. This can partially be overcome by sweeping close to the ground and moving the net more rapidly through the vegetation. It should be noted that weather conditions, availability of food, and variations in insect activity profoundly affect catch diversity and quantity of insects in all three sampling methods used in this survey. For example, Hughes (1955) showed that weather factors affected the vertical distribution and hence availability of insects to the sweep net.

The starting dates of the different sampling methods at each site are shown in Table 1.

Table 1. Starting Dates of Sites by Sampling Methods

Site	Black-light	Pitfall	Sweep
VCS	6-30-77	-	-
YCW	6-30-77	-	-
S1	-	7-9-77	7-21-77
S2	-	7-8-77	7-21-77
S3	-	7-8-77	7-21-77
S4	-	8-4-77	7-28-77

The last sampling day for all sites was 10-29-77.

RESULTS

The total number of insects captured and identified at each site by all sample methods is shown in Table 2.

Table 2. Number of Insects Captured and Identified
By All Sample Methods At Each Site

VCS: 18,277	S2 : 721
VCW: 22,776	S3 : 1,105
S1 : 255	S4 : 2,975
Total = 46,108	

Table 3 and Table 4 list the numbers of insects caught at the visitor center-Sunset Crater and visitor center-Wupatki, respectively, by date and family. Sites 1-4, which were not located at the visitor centers, have combined data for sweeping and pitfall traps (Tables 5-8). All insects and selected arthropods caught at Wupatki and Sunset Crater National Monuments during 1977 are listed in Table 9.

An outbreak of the Noctuid moth, Tridepia nova (Sm.), also referred to as Trichodea antica (Sm.), occurred in the Cold Desert Shrub from 8-24-77 to 8-30-77. The area encompassed Site 1 and the area around the visitor center of Wupatki. Upon emerging, the moth larvae were seen only to attack and feed upon the four-wing saltbush (Atriplex canescens), causing considerable damage to the plants. At Site 1, few saltbush remained intact by 8-30-77,

as most were stripped of nearly all their leaves. No birds were observed to feed on the moth larvae. I. nova was captured in the black-light trap at Wupatki around 9-13-77, which corresponds to the emergence date 9-12-77 to 9-15-77 of I. nova reared in the laboratory.

DISCUSSION

Black-light trapping (Tables 3 and 4) shows that the relative abundance and diversity of insects between the Cold Desert Shrub and Ponderosa Pine is similar. Whereas 18,277 insects were caught and 66 families identified at Sunset Crater, 22,776 insects and 63 families were captured and classified at Wupatki.

The Wupatki light trap data are probably artificially high because of two sewage ponds located near the trap that harbor many aquatic insects that normally would not be in great abundance in the Cold Desert Shrub vegetation. The outbreak of 1,215 Dytiscidae (Coleoptera) on 7-7-77 and the continued influx of Corixidae (Hemiptera) undoubtedly came from the sewage ponds. Twenty-six different families of beetles, similar to the 28 different families caught at Wupatki, were collected in the black-light at Sunset Crater. However, abundance was quite varied between the sites. Sunset Crater showed 59 total Alleculidae caught whereas Wupatki totaled 1313. More dramatically, 2670 Dytiscidae were recorded at Wupatki while 83 were recorded from Sunset Crater for the four month study period. Some families that appeared at both sites, however, were similar in abundance: Pyralidae moths totaled 9,545 at Wupatki and 9,917 at Sunset Crater.

Although the two sites were fairly similar in number of families, many families of insects that appeared at one site were not collected at the other.

For example, beetle families Lampyridae, Lucanidae, Lycidae and Phengodidae were recorded in the black-light at Sunset Crater but not at Wupatki. Conversely, the bug families Notonectidae and Pentatomidae appeared at Wupatki but not at Sunset Crater.

The families of insects that consistently appeared at both sites throughout the study included Scarabaeidae, Miridae, Geometridae, Noctuidae, Pyralidae, and Sphingidae. Although Hymenopterous insects were abundant at the Wupatki black-light throughout the study, Tiphids and Mutillids were not seen at Sunset Crater after 8-30-77 with one exception on 9-9-77.

Of the four other sites, Site 4 in the Ponderosa Pine had by far the greatest diversity and abundance of insects (Table 8), with 2,974 insects and 39 different families recorded. This occurred even though sampling was started for this site later than the other sites. Site 3 followed with 1,105 insects and 27 families. The remaining sites trailed behind dramatically, with Site 1, Cold Desert Shrub, having the least number of insects captured, 255 (Table 5).

Tenebrionid or darkling beetles were the most abundant ground dwelling insects caught at Sites 1-4. Both mimics and defense-secreting tenebrionid beetles were captured abundantly at all sites. The most common insect family caught by sweeping at most sites were leafhoppers (Cicadellidae: Homoptera). Parasitic wasps were also caught at all sites. It would seem that insect numbers vary with rainfall, although studies next year should quantify this observation.

Ground meat was dropped into two pitfall traps on 9-3-77 at each site in order to attract insects that had not been recorded previously. The meat was left in for 3 weeks and two new families of Coleoptera, Histeridae and

Dermestidae, were found in the traps. At Site 4, a scavenger, probably a skunk, found the meat the first night and so negated this part of the experiment in the Ponderosa Pine. It should be noted that the skunk(s) checked most of the transect at Site 4 throughout September and into October. Whether insects were taken from the pitfall traps and what effect, if any, this had on the data is not known.

The outbreak of Tripedia nova on the four-wing saltbush Atriplex canescens in the Cold Desert Shrub demonstrates some aspects of insect-plant interactions. Although no predator of the larvae was seen, this may have been due to the brief outbreak (one week) and the few observations made.

The larvae were cryptically colored to blend with the light green color of the saltbush leaves. Also, when touched, the larvae demonstrated two behavioral defense mechanisms. One was to drop immediately to the ground under the saltbush where they were extremely hard to find. The second occurred if the larvae were handled with forceps, whereby a brown liquid was secreted. Certainly, the larvae must have predators or these defense mechanisms would not exist.

How Atriplex canescens prevents the larvae at normal levels from destroying them or how they recover from the attacks of the larvae is not known. Data gathered during the second study period in 1978 should help to answer these questions. It was noted that some saltbush were not attacked by these larvae, but it is not known why.

Insect abundance and diversity is affected by vegetation, rainfall, predators, and parasites. If overgrazing is allowed to occur, insect populations will become unstable and fluctuate more than under natural conditions. Since insects form the basic food chain for many birds, rodents, and mammals,

this can have devastating effects on the ecology of the area affected. Environmental factors such as heavy rain or drought may tend to amplify stress situations that man has already put upon a certain area. Thus, overgrazing for example, may represent more of a potential for harmful effects than it is producing at the present time.

SUMMARY AND CONCLUSIONS

1. Ponderosa Pine vegetation showed the most diversity of insect families with 66.
2. Cold Desert Shrub vegetation had the most abundance of insects with 22,776.
3. Sewage ponds located near the Wupatki Visitor Center probably accounted for many aquatic insects that would normally not be found in great abundance in the Cold Desert Shrub.
4. Site 4, in Ponderosa Pine, had the most diversity and abundance of insects of all sites not at the visitor centers.
5. 107 families and 46,108 insects were identified during the four months of collecting.
6. A noctuid moth outbreak of Tridepia nova on the four-wing saltbush Atriplex canescens occurred in August, defoliating much of the Atriplex.

Insect fauna contributes dramatically to the complexity and stability of a given ecosystem. Certain checks, such as predators and parasites, keep levels of insects at stable levels. Availability of food (plants) is a major factor limiting insect diversity and abundance. Since insects are an important food source of many other animals, disturbance of ecosystems by

building or grazing may dramatically alter the biology of a given area. These effects can be amplified by environmental factors.

It would seem to us that the best course of action is to leave the monuments as free as possible of human interference. Further study of the insects of Wupatki and Sunset Crater National Monuments would lead to a better understanding of insect-plant and insect-animal interactions. In addition, more quantitative conclusions could be drawn about differences between the four major vegetation types in the monument, which would produce a better understanding of how management decisions affect insect abundance and diversity.

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TABLE 3. VCS: Summarized Data for the Black-Light Trap at Sunset Crater Visitor Center

7/5 7/7 7/12 7/15 7/19 7/21 7/25 7/28 8/1 8/4 8/8 8/11 8/15 8/18 8/22 8/24 8/30 9/3 9/6 9/9 * * 9/13 9/17 9/24 10/1 10/8 10/15 10/22 10/29 * Total

Coleoptera

1	Alleculidae	3		11	4	10	1	3	7	7	3	3			4	3												59
2	Anthicidae							1	1																			2
3	Bostrichidae	1	1		1	1				1						1									1			7
4	Buprestidae							1				1																2
5	Cantharidae	3	5	22	4	3			2	2	7	5			1	1												55
6	Carabidae			1		2			5	7	1	2			5	5												28
7	Cerambycidae	9	2	13	9	11	2	4	6	2	5	10		2	1	2		2	1									81
8	Chrysomelidae										1	2			3			1										7
9	Cleridae									5	3	2		1	2	1												14
10	Cicindelidae										1																	1
11	Coccinellidae	2	2	4	1	2		1				3		3	3	2												23
12	Dytiscidae					1	1	1	3	53	4			1	1	15		1	2									83
13	Elateridae	1		2	2	5	2	3	10	8	4	3	2		1	1		1	1	1								47
14	Histeridae										1																	1
15	Hydrophilidae								1							1												2
16	Lampyridae					1												2						1				4
17	Lucanidae					1						2																3
18	Lycidae					1	2	2	1	3		1		2	1	1												14

Table 3 continued

	7/5	7/7	7/12	7/15	7/19	7/21	7/25	7/28	8/1	8/4	8/8	8/11	8/15	8/18	8/22	8/24	8/30	9/3	9/6	9/9	9/13	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Total
19 Melandryidae									1																				1
20 Melyridae				1			1	3											1										6
21 Mordellidae		1																											1
22 Nitidulidae									13	3	5	2	3	9	5	1	1				4					1			47
23 Phengodidae							2		3	2	3	4	1	2	1	1													19
24 Scarabaecidae	4	1	6	16	26	11	10	41	21	10	9	8	19	15	14	4	4	9	9	6			2						245
25 Scolytidae							5																						5
26 Silphidae	1	1	1	1	3					2	3		1		1	1	2	6	3	1			3			1			31
27 Staphylinidae	1												2	1															4
28 Tenebrionidae			5		6	1	5	3	2				2					1							1				26
<u>Diptera</u>																													
29 Calliphoridae			4							1																			5
30 Muscidae										4																			4
31 Mycetophilidae														3						53									56
32 Rhagionidae						1																							1
33 Sarcophagidae										2																			2
34 Syrphidae							2						1																3
35 Tipulidae			1																										1
<u>Hemiptera</u>																													
36 Coreidae				2																									2

Table 3 continued

	7/5	7/7	7/12	7/15	7/19	7/21	7/25	7/28	8/1	8/4	8/8	8/11	8/15	8/18	8/22	8/24	8/30	9/3	9/6	9/9	9/13	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Total
37 Corixidae								15	295			3					2	1		2									321
38 Cycladinae																	1												1
39 Lygaeidae					1	1	1		1	4	4	2	1	3									1						19
40 Miridae			5			1	1	2	2	3		8	48	46	48	2	2	10	6	18					2	12			216
41 Nabidae			1																										1
42 Reduviidae	1																												1
<u>Homoptera</u>																													
43 Cercopidae										1	1																		2
44 Cicadellidae			3													3													6
<u>Hymenoptera</u>																													
45 Formicidae	3					6		2		3	2	1	1		26			2											46
46 Ichneumonidae			1	2				3	2				3	3	2	1	7	4	1	1			2						32
47 Mutillidae			1		1		1	4			1		1		1		2			1									13
48 Tiphidae	7	2	13	6	68	11	3	6	129	5	3	1				2													256
<u>Lepidoptera</u>																													
49 Acrtiidae	12	7	10	23	51	21	33	25	29	23	64	17	23	21	3		4	1											372
50 Drepanidae	22	48	102	130	62	53	48	34	4	2	1	2	6				2												516
51 Ethniidae														3														1	4
52 Gelechiidae																22													22
53 Geometridae	8	3	4	17	3	25	155	17	10	19	48	9	9	29	10	23	7	4	6	9				1		3	1		420

Table 3 continued

	7/5	7/7	7/12	7/15	7/19	7/21	7/25	7/28	8/1	8/4	8/8	8/11	8/15	8/18	8/22	8/24	8/30	9/3	9/6	9/9	9/13	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Total
54 Lasiocampidae	1		4	3	9				2	3	60	42	58	23	20	3	12	17	23	17			15	17	16	1			346
55 Noctuidae	75	168	241	138	186	153	42	191	86	197	382	62	170	298	176	102	272	565	242	302	1		210	188	23	65	107		4643
56 Pterophoridae	1		1		1											2													5
57 Pyralidae	756	2	1240	1488	1267	487	559	295	571	704	825	217	352	299	224	34	47	211	162	136	2		13	13	9	2	2		9917
58 Saturniidae			1	2	1		2		3				9	4	5	3		1											31
59 Sphingidae	3		8	25	30		4	22	24	9	5	2	4	1	2		4	1	1	1									146
<u>Neuroptera</u>																													
60 Chrysopidae					1			1	4	1			6	10	1			2											26
61 Hemerobiidae			2											1															3
62 Myrmeleontidae	2			1	1																								4
63 Raphidiidae									1																				1
<u>Odonta</u>																													
64 Coenagrionidae				1																									1
<u>Orthoptera</u>																													
65 Gryllacrididae																			1										1
66 Gryllidae													2																2
67 Tettigoniidae														1															1
<u>Trichoptera</u>																													
68 Limnephilidae															1	1	1	2	2				2		1				10
Total	917	243	1709	1882	1755	779	890	700	1287	1031	1451	382	731	791	581	202	375	840	460	553	3	0	248	224	63	71	110	1	13,277

*Black-light not working for week

TABLE 4. VCW: Summarized Data for the Black-Light Trap at Wupatki Visitor Center

*

7/5 7/7 7/12 7/15 7/19 7/21 7/25 7/28 8/1 8/4 8/8 8/11 8/15 8/18 8/22 8/24 8/30 9/3 9/6 9/9 9/13 9/17 9/24 10/1 10/8 10/15 10/22 10/29 Total

Coleoptera

1 Alleculidae	11	8	336		232	1	96	205	134	165	5	48	54	14		2	1	1									1313
2 Anobiidae			2		1			1																			4
3 Anthicidae	1		13		3		2	3			1		8														31
4 Bostrichidae	1																						1				2
5 Buprestidae																	1					1					2
6 Cantharidae			1																								1
7 Carabidae	1	19	1	110	38	2	31	26	7	9		7	19	11	2	7	15	4	1	1		1	2		1		315
8 Cerambycidae		1		3	3		3	2	4	2		1		1													19
9 Chrysomelidae													1					5				6	2				14
10 Cicindelidae					2							1															3
11 Cleridae								1	2	1	2					1	2				2						11
12 Coccinellidae			1	23	6			1								1											32
13 Curculionidae	1		3		3		1		5			1	1														15
14 Dermestidae								7					1														8
15 Dytiscidae	1215		4	348	18	2	175	408	17	114	4	49	21	39	68	30	75	56	6	2		9	10				2670
16 Elateridae		1	1	27	10		16	7	2	2			1	1													68
17 Histeridae								1													1	1				1	4

Table 4 continued

	7/5	7/7	7/12	7/15	7/19	7/21	7/25	7/28	8/1	8/4	8/8	8/11	8/15	8/18	8/22	8/24	8/30	9/3	9/6	9/9	9/13	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Total
18 Hydrophilidae		3		2				4	1																				10
19 Melyridae								17					1	1															19
20 Mordellidae				4																									4
21 Nitidulidae												2		1															3
22 Pedilidae				9				5																					14
23 Scarabaeidae	9	8	49	129		188	143	245	101	55	127	8	166	121	63	2	21	25	7	6	5	1		1		1			1481
24 Scolytidae			2																										2
25 Silphidae									1													2	5			5	2	5	20
26 Staphylinidae		2		5		1			1																				9
27 Tenebrionidae				3							2															1			6
28 Trogositidae									9																				9
<u>Diptera</u>																													
29 Acroceridae																	1												1
30 Asilidae																									1				1
31 Dolichopodidae		79																											79
32 Muscidae																	1			10									11
33 Mycetophilidae																						1							1
34 Sarcophagidae			1																										1
35 Syrphidae																										1			1

List continued

7/5 7/7 7/12 7/15 7/19 7/21 7/25 7/28 8/1 8/4 8/8 8/11 8/15 8/18 8/22 8/24 8/30 9/3 9/6 9/9 9/13 9/17 9/24 10/1 10/8 10/15 10/22 10/29 Total

Hemiptera

36 Coreidae					1			4																				5
37 Corixidae	842	3	29		5		73	441		30	2	2	13	5	1	7	39	1	5		3	6				2	4	1513
38 Lygaeidae	2		61		274		42	20	4	14	2	12	4	1		9	3	4	6	2	1		4				465	
39 Miridae	2	1	1	8	20	1	1		5		2	7	1			2		4	3	1	1	23	17	3	9	23	135	
40 Notonectidae	6																										6	
41 Pentatomidae			1	4	1		3	7	5	7	3	24	18	30	5	7	7	11	10	9	2		1				155	
42 Reduviidae	1			6	1	2							1				1										12	

Homoptera

43 Acanaloniidae																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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Hymenoptera

45 Apidae							1						1		1	1											4
46 Formicidae	1		1	81	10	5	24	13	4	97		3	345														584
47 Ichneumonidae			4		3		1					3	1		1		1		3	1			1	2			21
48 Mutillidae		1	1	63	42	3	58	47	19	18		11	16	4	1	2	16		5	2	1		3	2			315
49 Tiphidae	19	19	22	46	34	1	57	74	19	22		9	10	6	1	9	11	4	12	3	1				2	14	395

Lepidoptera

50 Arctiidae			62	2		6	6	29	24	4	8	21	29	5	4	5	1	5	22	12	1		1	2			249
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List continued

	7/5	7/7	7/12	7/15	7/19	7/21	7/25	7/28	8/1	8/4	8/8	8/11	8/15	8/18	8/22	8/24	8/30	9/3	9/6	9/9	9/13	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Total
51 Ctenuchidae	1															1	4	26	29	46	24		1	1					133
52 Geometridae				18					3	8	2	8		3	3	1	1	1	2		1						11	13	75
53 Lasiocampidae							5	2							3		4	1											15
54 Noctuidae	67	58	58	23	37	47	10	71	34	26	45	61	32	81	26	35	11	13	58	35	96	109	126	83	306	280	319	61	2208
55 Pyralidae				3051	23	414		343	555	72	97	38	46	56	37	21	42	2013	968	890	720	41	22	30	49	6	3	8	9545
56 Saturnidae																		7	3	7	4		1						22
57 Sphingidae	5	2	1	50	13	31	24	24	32	7	24	27	66	69	26	2	22	11	13	13	31	3	9	3					508
<u>Neuroptera</u>																													
58 Chrysopidae					1								3	9															13
59 Myrmeleontidae	3	2		15	6	20	3				1			1				1		1									53
<u>Orthoptera</u>																													
60 Acrididae		1		72		5	1		1		2		1						1										84
61 Blattellidae	1														2														3
62 Blattidae						2		2	1	1	1			1		1			1										10
63 Gryllidae				1			2						1	2															6
Total	115	2280	155	4638	81	1437	211	1298	2030	413	804	168	514	892	283	146	188	2274	1168	1074	928	160	171	174	395	300	351	129	22,776

*Black-light found blown over

TABLE 5. Combined Data for Site 1, Cold Desert Shrub: Pitfall Traps and Sweeping. (# per Pitfall Traps/# per Sweeps)

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Pittraps	Sweeps	Total
<u>Coleoptera</u>																			
1 Chrysomelidae					/1													1	1
2 Curculionidae					/1	/1	2/1		1/		/1						3	4	7
3 Dermestidae									7/						2/		9		9
4 Histeridae									8/		2/	1/			2/		13		13
5 Tenebrionidae	1/	1/	3/	4/	4/	1/	12/		10/		6/	4/	7/	12/			65		65
<u>Diptera</u>																			
6 Phoridae													/1					1	1
7 Sepsidae													/1					1	1
8 Tephritidae													/3					3	3
<u>Hemiptera</u>																			
9 Lygaeidae										1/	1/	/4					2	4	6
10 Miridae										/1	/2		/1					5	5
11 Tingidae		/1							1/	/1		/1		/12			1	15	16
<u>Homoptera</u>																			
12 Acanaloniidae						/1												1	1
13 Aphidae											/1	/1	/5		/1			8	8
14 Cicadellidae		/1		/1	/1	/1		/1	/1		/1	/1	/1	/1	/4	/1		14	14

List continued.

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Pittraps	Sweeps	Total
15 Psyllidae										/1		/60						61	61
<u>Hymenoptera</u>																			
16 Braconidae									1/					/1			1	1	2
17 Chalcididae			/1															1	1
18 Eulophidae										/1								1	1
19 Evanidae								/1										1	1
20 Formicidae	6/				/3	/1								/3			6	7	13
21 Mutillidae		1/						1/	1/	1/	1/			2/			7		7
22 Pteromalidae											/2							2	2
23 Pteromalidae											/1	/2	/3	/1				7	7
24 Sphecidae										1/							1		1
<u>Neuroptera</u>																			
25 Chrysopidae													/2					2	2
<u>Orthoptera</u>																			
26 Acrididae												1/					1		1
27 Blattidae													1/				1		1
28 Gryllacrididae					1/						1/				2/		4		4
29 Mantidae		/1																1	1
Pitfall Traps	7	1	4	0	5	4	1	15	4	27	3	10	6	9	18	0	114		
Sweeps	-	2	2	1	6	4	0	3	0	4	4	68	16	24	4	3		141	
Total	7	3	6	1	11	8	1	18	3	32	7	78	22	33	22	3			255

About half into 2 pitfall traps

TABLE 6. Combined Data for Site 2, Juniper/Grassland: Pitfall Traps and Sweeping. (# per Pitfall Traps/# per Sweeps)

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3*	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Pittraps	Sweeps	Total
<u>Coleoptera</u>																			
1 Chrysomelidae		/3	/1				/1					/1						6	6
2 Curculionidae					1/		/2								1/	/1	2	3	5
3 Elateridae	6/																6		6
4 Histeridae							3/		2/								5		5
5 Melyridae		/4				/1		/35	/3									43	43
6 Scarabaeidae			2/			2/	2/	2/										8	8
7 Tenebrionidae	7/	4/	4/	1/	14/	5/	11/	4/	11/	5/	6/	8/	2/	8/	8/			98	98
<u>Diptera</u>																			
8 Pipunculidae															/1			1	1
9 Tephritidae											/2	/1						3	3
<u>Homoptera</u>																			
10 Cicadellidae	3/				/1	/1	/1	/11	/5	/79	/84	/14	/78	/46	/166			489	489
11 Membracidae										/1								1	1
<u>Hymenoptera</u>																			
12 Braconidae													/1					1	1
13 Figitidae													/1					1	1
14 Formicidae	2/																2		2

List continued

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Pittraps	Sweeps	Total
15 Mutillidae							1/				1/	2/			1/		5		5
16 Pompilidae																1/	1		1
17 Pteromalidae											/1	/3			/22			26	26
<u>Neuroptera</u>																			
18 Chrysopidae												/2						2	2
<u>Orthoptera</u>																			
19 Acrididae	1/		/1		/1	/1				/1	/1	/4		1/	/1		12		12
20 Gryllacrididae	1/					1/									1/		3		3
21 Gryllidae										1/							1		1
22 Mantidae	1/																1		1
<u>Thysanura</u>																			
23 Lepismatidae			1/														1		1
Pitfall Traps	11	7	7	4	2	17	11	13	6	12	6	8	8	2	11	9	134		
Sweeps	-	10	2	0	2	3	4	46	0	9	82	96	17	79	70	167		587	
Total	11	17	9	4	4	20	15	59	6	21	88	104	25	81	81	176			721

*meat put into 2 pitfall traps

TABLE 7. Combined Data for Site 3, Grassland: Pitfall Traps and Sweeping. (# per Pitfall Traps/# per Sweeps)

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Pittraps	Sweeps	Total
<u>Coleoptera</u>																			
1 Curculionidae				1/				1/	/1								2	1	3
2 Dermestidae								4/	3/								7		7
3 Histeridae								8/	5/				1/				14		14
4 Nitidulidae													/1					1	1
5 Scarabaeidae		1/	1/		5/	1/	1/	1/			2/						12		12
6 Tenebrionidae	56/	43/	61/	57/	101/	63/	55/	72/	51/	47/	50/	33/	37/	14/	15/	11/	766		766
<u>Diptera</u>																			
7 Muscidae															/4	/7		11	11
8 Pipunculidae										/1	/1	/8	/1			/1		12	12
<u>Hemiptera</u>																			
9 Lygaeidae										/2			/1					3	3
10 Miridae							/1											1	1
<u>Homoptera</u>																			
11 Acanaloniidae			/17	/9	/2			/1		/2		/2	/1					34	34
12 Cicadellidae			/1	/3	/18	/4	/2	/2			/22	/14	/18	/1	/4	/26		115	115
13 Psyllidae										/1								1	1
<u>Hymenoptera</u>																			
14 Braconidae											/1	/1				/1		3	3

List continued

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Pittraps	Sweeps	Total
15 Eupelmidae														/2				2	2
16 Formicidae	1/	3/		1/	/1		1/	3/					/8	/1			9	10	19
17 Ichneumonidae			/1															1	1
18 Mutillidae		3/	3/	1/	1/	2/			4/	2/	11/	4/	12/	11/	3/	2/	59		59
19 Pteromalidae													/2					2	2
<u>Lepidoptera</u>																			
20 Pyralidae												1/					1		1
<u>Neuroptera</u>																			
21 Myrmeleontidae								/1										1	1
<u>Orthoptera</u>																			
22 Acrididae				/1	/1	1/2				/2	/1		/1	/1			1	9	10
23 Gryllacrididae		3/	1/		2/	1/	1/	2/	1/		2/	2/	1/	1/	1/	1/	19		19
24 Gryllidae						1/											1		1
25 Mantidae		1/						1/				1/					3		3
<u>Thysanura</u>																			
26 Lepismatidae			3/														3		3
27 Machilidae								1/											
Pitfall Traps	57	54	69	60	109	69	58	80	69	57	65	40	51	26	19	14	897		
Sweeps	-	0	19	13	22	6	3	4	0	9	25	26	33	3	10	35		208	
Total	47	54	88	73	131	75	61	84	69	66	90	66	84	31	27	49			1105

*meat put into 2 pitfall traps

TABLE 8. Combined Data for Site 4, Ponderosa Pine: Pitfall Traps and Sweeping. (# per Pitfall Traps/# per Sweeps)

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3*	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Pittraps	Sweeps	Total
<u>Coleoptera</u>																			
1 Carabidae					115/	158/	75/	130/	25/	16/	29/	20/	14/	3/	5/	3/	593		393
2 Cerambycidae				1/	/1												1	1	2
3 Chrysomelidae			/2	/6		/2						/1						11	11
4 Cleridae				/1			/1	/1										3	3
5 Coccinellidae													/1					1	1
6 Curculionidae			/5	/2	/5	/18	/4	/1	/1		/1	/1						38	38
7 Histeridae											1/						1		1
8 Melyridae			/3	/10	/15	/46	/44	/4	/2	/1	/5	/1				1/	1	131	132
9 Silphidae								4/		2/		3/					9		9
10 Tenebrionidae					46/	72/	33/	52/	16/1	21/	6/	2/	6/	3/	1/	3/	261	1	262
<u>Diptera</u>																			
11 Asilidae						/1												1	1
12 Bombyliidae								/1										1	1
13 Pipunculidae												/10						10	10
14 Tephritidae											/3	/1		/1	/1			6	6
<u>Hemiptera</u>																			
15 Lygaeidae										/13			/23					36	36

List continued

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3*	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/29	Pittraps	Sweeps	Total
16 Miridae			/19	/6	/3		/3	/2	/10	/4	/74	/18	/16	/2	/6	/1		164	164
17 Scutelleridae							/1				/1	/3	/1					6	6
<u>Homoptera</u>																			
18 Acanaloniidae					/2	/2												4	4
19 Aphidae			/3									/3				/1		7	7
20 Cicadellidae			/63	/188	/93	/124	/107	/296	/103	/25	/46	/45	/47	/176	/26	/3		1342	1342
21 Membracidae				/1				/1	/1									3	3
22 Psyllidae										/16			/28					44	44
<u>Hymenoptera</u>																			
23 Apidae								1/					/2				1	2	3
24 Braconidae									/1	/1	/1		1/			/1	1	4	5
25 Eurytomidae										/5								5	5
26 Formicidae			/6	/35	/5	/14	/22		/9	/3	/8							100	100
27 Ichneumonidae							/2	/2			/8		/3			/1	2	14	16
28 Mutillidae										1/							1		1
29 Pteromalidae								/1		/7	/2	/6	/3	/2				21	21
30 Sphecidae			/1				/1											2	2
31 Tiphiidae											/5		/1					6	6
<u>Lepidoptera</u>																			
32 Noctuidae																1/	1		1

List continued

	7/15	7/21	7/28	8/4	8/11	8/18	8/24	9/3*	9/9	9/17	9/24	10/1	10/8	10/15	10/22	10/27	Pittraps	Sweeps	Total
<u>Neuroptera</u>																			
33 Raphidiidae								/1										1	1
<u>Orthoptera</u>																			
34 Acrididae			/5	/3		1/6	/5	3/4	/1	1/4	/1	/2		/1	/1		5	37	38
35 Gryllacrididae					15/	20/	24/	6/		5/	1/	2/	2/	1/	2/	1/	79		79
36 Mantidae												1/					1		1
37 Tettigoniidae			/1				1/1										1	2	3
<u>Thysanura</u>																			
38 Machilidae					16/												16		16
<u>Trichoptera</u>																			
39 Limnephilidae										/1								1	1
Pitfall Traps	-	-	-	-	193	251	133	198	41	46	37	28	23	7	9	8	974		
Sweeps	-	-	108	251	123	214	190	312	129	79	155	91	125	182	35	6		2000	
Total	-	-	108	251	316	464	324	510	170	125	192	119	148	189	44	14			2974

*meat put into 2 pitfall traps

TABLE 9. List of Arthropods collected at Wupatki and Sunset Crater
National Monuments during 1977

	Order	Family	Common name
1	Coleoptera	Alleculidae	Comb-clawed beetles
2	Coleoptera	Anobiidae	Anobiid beetles
3	Coleoptera	Anthicidae	Antlike flower beetles
4	Coleoptera	Bostrichidae	Branch, twig borers
5	Coleoptera	Buprestidae	Metallic wood-boring beetles
6	Coleoptera	Cantharidae	Soldier beetles
7	Coleoptera	Carabidae	Ground beetles
8	Coleoptera	Cerambycidae	Long-horned beetles
9	Coleoptera	Chrysomelidae	Leaf beetles
10	Coleoptera	Cicindelidae	Tiger beetles
11	Coleoptera	Cleridae	Checkered beetles
12	Coleoptera	Coccinellidae	Ladybird beetles
13	Coleoptera	Curculionidae	Snout beetles, weevils
14	Coleoptera	Dermestidae	Dermestid, skin beetles
15	Coleoptera	Dystiscidae	Predaceous diving beetles
16	Coleoptera	Elateridae	Click beetles
17	Coleoptera	Histeridae	Hister beetles
18	Coleoptera	Hydrophilidae	Water scavenger beetles
19	Coleoptera	Lampyridae	Fireflies, lightningbugs
20	Coleoptera	Lucanidae	Stag beetles
21	Coleoptera	Lycidae	Net-winged beetles
22	Coleoptera	Melandryidae	False darkling beetles
23	Coleoptera	Melyridae	Soft-winged flower beetles
24	Coleoptera	Mordellidae	Tumbling flower beetles

List continued

	Order	Family	Common name
25	Coleoptera	Nitidulidae	Sap beetles
26	Coleoptera	Pedilidae	Pedilid beetles
27	Coleoptera	Phengodidae	Glow-worms
28	Coleoptera	Scarabaeidae	Scarab, June beetles
29	Coleoptera	Scolytidae	Bark beetles
30	Coleoptera	Silphidae	Carrion beetles
31	Coleoptera	Staphylinidae	Rove beetles
32	Coleoptera	Tenebrionidae	Darkling beetles
33	Coleoptera	Trogostidae	Bark-gnawing beetles
34	Diptera	Acroceridae	Small-headed flies
35	Diptera	Asilidae	Robber flies
36	Diptera	Bombyliidae	Bee flies
37	Diptera	Calliphoridae	Blow flies
38	Diptera	Dolichopodidae	Long-legged flies
39	Diptera	Muscidae	House, stable fly
40	Diptera	Mycetophilidae	Fungus gnats
41	Diptera	Phoridae	Humpbacked flies
42	Diptera	Pipunculidae	Big-headed flies
43	Diptera	Rhagionidae	Snipe flies
44	Diptera	Sarcophagidae	Flesh flies
45	Diptera	Sepsidae	Black scavenger flies
46	Diptera	Syrphidae	Syrphid, flower flies
47	Diptera	Tephritidae	Fruit flies
48	Diptera	Tipulidae	Crane flies
49	Hemiptera	Coreidae	Leaf-footed bugs
50	Hemiptera	Corixidae	Water boatmen

	Order	Family	Common name
51	Hemiptera	Cydnidae	Burrower bugs
52	Hemiptera	Lygaeidae	Seed bugs
53	Hemiptera	Miridae	Plant bugs
54	Hemiptera	Nabidae	Damselflags
55	Hemiptera	Notonectidae	Backswimmers
56	Hemiptera	Pentatomidae	Stink bugs
57	Hemiptera	Reduviidae	Assassin bugs
58	Hemiptera	Scutelleridae	Shield-backed bugs
59	Hemiptera	Tingidae	Lace bugs
60	Homoptera	Acanaloniidae	Acanaloniid planthoppers
61	Homoptera	Aphididae	Aphids
62	Homoptera	Cercopidae	Froghoppers, spittlebugs
63	Homoptera	Cicadellidae	Leafhoppers
64	Homoptera	Membracidae	Treehoppers
65	Homoptera	Psyllidae	Jumping plantlice
66	Hymenoptera	Apidae	Bees
67	Hymenoptera	Braconidae	Braconid wasps
68	Hymenoptera	Chalcididae	Chalcidid wasps
69	Hymenoptera	Eulophidae	Eulophid wasps
70	Hymenoptera	Evaniidae	Ensign wasps
71	Hymenoptera	Figitidae	Figitid wasps
72	Hymenoptera	Formicidae	Ants
73	Hymenoptera	Ichneumonidae	Ichneumonid wasps
74	Hymenoptera	Mutillidae	Velvet ants
75	Hymenoptera	Perilampidae	Perilampid wasps
76	Hymenoptera	Pompilidae	Spider wasps
77	Hymenoptera	Pteromalidae	Pteromalid wasps

	Order	Family	Common name
78	Hymenoptera	Sphecidae	Sphecid wasps
79	Hymenoptera	Tiphiidae	Tiphiid wasps
80	Lepidoptera	Arctiidae	Tiger moths
81	Lepidoptera	Ctenuchidae	Wasp moths, day-flying moths
82	Lepidoptera	Drepanidae	Hook-tip moths
83	Lepidoptera	Ethmiidae	Ethmiid moths
84	Lepidoptera	Gelechiidae	Gelechiid moths
85	Lepidoptera	Geometridae	Measuring worms, geometers
86	Lepidoptera	Lasiocampidae	Tent caterpillars, lappet moths
87	Lepidoptera	Noctuidae	Noctuid moths
88	Lepidoptera	Nymphalidae	Brush-footed butterflies
89	Lepidoptera	Pterophoridae	Plume moths
90	Lepidoptera	Pyrallidae	Snout moths
91	Lepidoptera	Saturniidae	Giant silkworm moths
92	Lepidoptera	Sphingidae	Sphinx moths
93	Neuroptera	Chrysopidae	Green lacewings
94	Neuroptera	Hemerobiidae	Brown lacewings
95	Neuroptera	Myrmeleontidae	Antlions
96	Neuroptera	Raphidiidae	Raphidiid snakeflies
97	Odonta	Coenagrionidae	Narrow-winged damselflies
98	Orthoptera	Acrididae	Short-horned grasshoppers
99	Orthoptera	Blattellidae	German cockroaches
100	Orthoptera	Blattidae	American cockroaches
101	Orthoptera	Gryllacrididae	Camel, cave crickets
102	Orthoptera	Gryllidae	Crickets
103	Orthoptera	Mantidae	Praying mantid
104	Orthoptera	Tettigoniidae	Long-horned grasshoppers

	Order	Family	Common name
105	Trichoptera	Limnephilidae	Northern caddisflies
106	Thysanura	Lepismatidae	Silverfish
107	Thysanura	Machilidae	Jumping bristletails

Non-Insecta Arthropods

	Class	Order	Family	Common name
1	Chilopoda	Scolopendromorpha		Centipedes
2	Arachnida	Solpugidae	Eremobatella	Sun Scorpions
3	Arachnida	Pseudoscorpionidae		Pseudoscorpions
4	Arachnida	Acari		Mites and Ticks
5	Arachnida	Scorpionida		Scorpions
6	Arachnida	Araneida	Filastatidae	Filastid Spiders
7	Arachnida	Araneida	Lycosidae	Wolf Spiders
8	Arachnida	Araneida	Salticidae	Jumping Spiders
9	Arachnida	Arandida	Theridiidae	Cobweb Weavers
10	Arachnida	Arandida	Thomisidae	Crab Spiders

III

STUDIES OF AVIAN COMMUNITIES

Lynn Beatty, Research Assistant
February, 1978

INTRODUCTION

Sunset Crater and Wupatki National Monuments offer an opportunity to study birds in rather unique habitats. The inconsistencies in vegetation type, geological formations, and the presence of cinders as ground cover in most of the area characterize these monuments. The proximity of the southernmost edge of the cold desert to the monuments may increase the uniqueness of the areas, as may the presence of the Little Colorado River. Although the riparian habitat along the Little Colorado River contributes a very small fraction to the overall area of Wupatki National Monument, it may be an important north-south leading line for migratory birds. These attributes of the overall environment may contribute to unique assemblages of avian communities when compared to similar vegetation types in other areas.

Birds have been particularly lacking in formal ecological investigations at the monuments in the past. Apparently sometime in the 1930's Z. Bradley and L. Hargrave did an extensive study of the birds of Wupatki National Monument. The manuscript is apparently at the Museum of Northern Arizona, but has yet to be found. The only information concerning birds at the two monuments comes from species lists compiled by various park rangers, and from study skins at the Museum of Northern Arizona.

The present study was initiated in the spring of 1976, and has been continued through the fall of 1977. The results reported herein describe comparisons in the avian communities between years, and their relationship to relative insect densities in each study area. Relative insect densities for each area are discussed, as are species composition, species diversity, and habitat utilization. A more complete statistical analysis of the avian ecology of Sunset Crater and Wupatki National Monuments will be

forthcoming in the form of a Master of Science thesis. When the thesis is completed, the National Park Service will receive a copy.

METHODS AND MATERIALS

Three of the four study areas, the juniper-grassland, grassland, and cold desert shrub, are the same as those described in section II. The fourth study area is the ponderosa pine community at Sunset Crater National Monument, and is discussed in the following section. Methodology for censusing birds, insect collection, habitat utilization, and statistical analysis is described beyond.

Ponderosa Pine Study Area

The ponderosa pine community at an elevation of 2300 m is composed of four major vegetative strata: the tree, shrub, herb and grass layers. The dominant plant species in each stratum are the ponderosa pine (Pinus ponderosa); apache plume (Fallugia paradoxa); beardtongue (Penstemon barbatus) and scarlet gilia (Gilia aggregata); and bluestem (Andropogon scoparius and A. hallii) and blue grama grass (Bouteloua gracilis). Visually the ponderosa pine community can be characterized by a hilly terrain with the density of vegetation varying throughout, and the most extensive and deepest cinder groundcover of all the study sites.

Censusing Methods

In each of the four study areas, birds were censused by traversing a 1.61 km (1 mile) transect on consecutive days throughout the breeding season following Emlen's census methods (1971). The transects were established in each habitat type by placing stakes at 31 m intervals. A distance of 125 m on either side of the transect line yields a total area of 40 ha

(100 acres) sampled in each of the study areas. Foraging location, foraging stance, foliage position, distance from the transect, vocalizations, and where detectable, sex of the birds, were recorded during the breeding seasons of 1976 and 1977. The ponderosa pine community was sampled from 15 May to 22 July, 1976, and 29 April to 25 June, 1977 for a total of 13 and 8 census days, respectively. Birds in the juniper-grassland were censused from 26 May to 6 July, 1976, and from 1 May to 2 July, 1977 on 10 and 8 days. The grassland study area was sampled for 10 and 7 days between 5 May and 24 June, 1976, and 25 May through 24 June, 1977. The cold desert scrub was censused for 9 days and 8 days in 1976 and 1977 from 14 May to 26 June and 15 April through 29 June.

The riparian habitat of the Little Colorado River was censused on five days between 14 August and 29 September, 1977. On these days, the investigator walked for one hour immediately after sunrise along the river bank counting all the birds either seen or heard. These data give a quantitative measure of the birds seen along the river from which frequency and relative density measurements can be obtained.

Insect Collection

Because most nesting birds on the monuments feed insects to their young (Welty 1975), relative densities of insect populations have been determined at each study site. Three techniques were used to insure adequate sample coverage.

During the 1977 breeding seasons, five 0.1 m boards covered on both sides with a commercial product (Tanglefoot) used to kill insect pests were placed in each foliage layer (trees, shrubs and herbs) in each study site. These sticky boards were left in place for one week intervals during the breeding season. At the end of this time, the insects were taken from the boards and placed in 70% ethyl alcohol.

The boards were covered again with Tanglefoot, and moved to different locations in the same stratum to insure broad sampling coverage.

Ground dwelling insects were sampled during the 1977 breeding season with can traps submerged in the soil. The can traps contained glycerol so all insects captured were killed. The total surface area sampled was approximately 1 m^2 in each of the ground, shrub, and tree strata. After each 24 hour sampling period, the insects were removed from the cans and placed in alcohol. There were four weekly samples taken in each study area.

Insects in the juniper-grassland also were sampled by using a fumigation procedure at weekly intervals. This technique entails placing large plastic garbage bags over branches of trees at heights of three and six feet, closing the opening and cutting off the branch. Insects were killed with cotton balls saturated with carbon tetrachloride and placed inside the bags. After the branch was fumigated, the dead insects and larvae were collected, identified and counted.

Nesting and Feeding Guilds

In each study area birds were subdivided into four feeding and four nesting guilds. The feeding guilds were determined by observing birds foraging. Some nests were found which helped place species in nesting guilds. The remaining species were placed in their respective guilds by consulting The Birds of Arizona (Phillips et al. 1964).

Indices

Frequency and relative density measurements are used in several instances to obtain a quantitative measure of data. Frequency is determined by dividing the number of points at which a species occurs by the total number of transect intervals. Relative density is calculated by dividing the total number of individuals in a species by the total number of individuals of all species (Smith 1974).

Species diversity indices were calculated by finding the relative densities of each species in relation to the total number of breeding pairs. The formula, $H' = \sum p_i \log_2 p_i$ (MacArthur and MacArthur 1961), was used to calculate the diversity indices. Habitat evenness, J' , values were calculated by dividing the H' value by the logarithm of the number of breeding species per community (H'_{Max}).

RESULTS

A tentative bird species list was compiled in February, 1976, from species lists compiled by various park rangers at the monuments, and from study skins at the Museum of Northern Arizona. This list contains 113 species in 34 families, plus an addendum with 20 species in 11 families which appears at the end of the report.

Ponderosa Pine Birds

The ponderosa pine community had 12 species of birds breeding along the transect line in 1976 (Table 1). The Mourning Dove and Violet-green Swallow contributed a total of 30 breeding pairs per 40 ha or 48 per cent of all breeding pairs. Four additional species were seen in the area, but did not breed there.

In the 1977 breeding season, 11 species of birds bred along the ponderosa pine transect and seven additional species were seen in the area, but did not breed there (Table 1). The Western Bluebird and Pygmy Nuthatch contributed a total of 32 breeding pairs per 40 ha or 51 per cent of all breeding pairs.

The diversity index for the ponderosa pine study area in 1976 was 3.0256, and the J' value was 0.844. These values were determined from a population of 62.7 breeding pairs (Table 5). The diversity index for the 1977 breeding season is 2.8963, and the J' value is 0.837.

These indices were determined from a total breeding population of 62.3 pairs per 40 ha (Table 5).

Each species in both breeding seasons was placed into appropriate feeding and nesting guilds (Table 1), and the relative proportions of species and pairs were calculated (Table 3). In 1976, there was a relatively equal distribution of pairs represented in the four feeding guilds, while 53 per cent of the pairs were cavity and depression nesters. The 1977 breeding population shows that 53 per cent of the pairs were hawkers, hoverers or aerial feeders, while 75 per cent of the breeding pairs were cavity and depression nesters.

Juniper-Grassland Birds

Twelve breeding species and seven additional species were observed in the juniper-grassland community in 1976 (Table 2). The Mourning Dove and Black-throated Sparrow contributed 16 breeding pairs per 40 ha or 40 per cent of all breeding pairs. In 1977, 11 species bred along the transect, and six additional species were seen in the area (Table 5). A more equitable distribution of species is shown in 1977. The Black-throated Sparrow stands out with 8.5 pairs or 24.2 per cent of the breeding pairs, while the Common Nighthawk, Mockingbird, and Loggerhead Shrike have 4.9, 4.6, and 4.3 breeding pairs respectively (Table 2). These four species comprise 22 breeding pairs per 40 ha or 64 per cent of all pairs breeding along the transect.

In 1976, a diversity index of 3.2371 and a J' value of 0.903 were calculated from 39.8 breeding pairs in the juniper-grassland (Table 5). The diversity index and J' value for the 1977 breeding season are 3.4594 and 0.912 respectively, and were calculated from a total for 35.2 breeding pairs per 40 ha (Table 5).

The number of species and number of pairs per 40 ha, and their respective

proportions in each of the four feeding and four nesting guilds were calculated for both breeding seasons (Table 4). In 1976, 63 per cent of the breeding pairs were ground feeders, while 54 per cent nested in foliage. During the 1977 breeding season, 43 per cent were ground feeders, and 42 per cent were hawkers, hoverers, or aerial feeders. Eight per cent of the breeding pairs were parasitic nesters in 1976, while 54 per cent nested in foliage, and 39 per cent were ground nesters. There were no parasitic nesters in 1977, 56 per cent of the pairs nested in foliage, and the remaining birds nested on the ground.

Grassland Birds

In the grassland study site, the Horned Lark was found to be the only species that bred along the transect line during both breeding seasons (Table 6). Five additional species were observed in 1976, and four in the 1977 breeding season, but their numbers were not sufficient to be included in the "bred along transect" category.

Diversity indices for 1976 and 1977 are 0.0144 for both years. Since diversity is calculated from the per cent that each species contributes to the whole community, and the Horned Lark contributes 100 per cent, the diversity indices are the same. Similarly, no J' values can be calculated with only one breeding species representing the community. The Horned Lark is placed in the ground feeding and ground nesting guilds which represent the entire study area.

Cold Desert Shrub Birds

The cold desert shrub community had seven species breeding along the transect in 1976, and six species in 1977 (Table 7). The Black-throated Sparrow contributed 16 breeding pairs per 40 ha or 56 per cent of all breeding pairs in the community, and 19.8 breeding pairs or 48.5 per cent of the breeding pairs in 1977. There were five additional species seen in 1976, and seven in 1977 (Table 5).

From a total of 28.5 breeding pairs in 1976, a diversity index of 2.09 and a J' value of 0.744 were calculated (Table 5). In 1977, a diversity index of 2.1326 and J' value of 0.825 were calculated from a total population of 40.8 breeding pairs (Table 5).

Two feeding and four nesting guilds were represented in this community in 1976, and their respective proportions were calculated (Table 8). Ninety-two per cent of the breeding pairs were ground feeders, and 64 per cent were ground nesters. In 1977, 77 per cent of the breeding birds were ground feeders, and 61 per cent were ground nesters. There were two guilds represented in each category (Table 8).

Little Colorado River Birds

Twenty species of birds in 11 families were seen between 14 August and 29 September, 1977, on five census days at the Little Colorado River. The most common birds seen were the Yellow-headed Blackbird with a frequency of 14.2 birds seen per hour, and the Rough-winged Swallow with a frequency of 8.6 birds per hour (Table 9). The relative densities show these two birds to be the most common migrants with the Yellow-headed Blackbird representing 33 per cent of the total, and the Rough-winged Swallow comprising 20 per cent of the total.

Insects

In the ponderosa pine community, insects were collected throughout the breeding season, although data for the third week are missing for the tree and shrub strata, because the national forest was inaccessible at this time. There were a total of 384 insects collected from the tree, shrub, and ground strata. The family Formicidae represents 43 per cent of the total, while the Muscidae, Psyllidae, and Chalcidoidea comprise 4.2, 4.7, and 4.4 per cent respectively. These four families contribute a total of 56 per cent of all insects collected (Table 10). The tree stratum contributed

21 per cent of the total, the shrub 24 per cent, and the ground represented 54 per cent of all insects collected in the ponderosa pine study site (Table 10).

The juniper-grassland had the same three vegetative strata in which insects were collected four times for a total of 879 insects. The family Melyridae contributed 52 per cent of all those insects collected, and the family Formicidae represented 19 per cent (Table 10). These two families represent 71 per cent of all insects collected in the juniper-grassland during the breeding season. The tree, shrub, and ground contributed 11, 48 and 41 per cent respectively.

The grassland study area, comprised of only the shrub and ground layers, had insects collected on four days for the largest total population of 1425 insects. The family Melyridae contained over one half of all the insects collected (56.5 per cent), while the Formicidae contributed 24 per cent to the overall population (Table 10). The shrub stratum represented 60 per cent, and the ground 40 per cent of the total.

The cold desert shrub community represents the most equitable distribution of insect families. The Formicidae contributed 28 per cent, and the Melyridae contributed 26 per cent of the total. The family Lygaeidae contained 8 per cent of the total, while the order Araneida contained 7 per cent. The shrub and ground strata were censused on four days yielding a total of 585 insects. The shrub layer comprised 42 per cent of all insects collected, and the ground stratum contained 58 per cent of the total.

Fumigation procedure in the juniper-grassland was done on four days at weekly intervals between 7 June and 1 July, 1977. No more than three insects were found on any tree on any one day. These numbers are not large enough to warrant analysis.

DISCUSSION

The avian populations in the four communities at Sunset Crater and Wupatki National Monuments vary tremendously in composition, diversity, and habitat utilization.

Comparisons Among Avian Communities

In 1976, the populations of breeding pairs were greatest in the ponderosa pine community (62.7 pairs per 40 ha), followed by the juniper-grassland and grassland with 40 breeding pairs, and the cold desert shrub with 28.5 breeding pairs per 40 ha (Table 5). A somewhat different level of abundance occurred in 1977. The ponderosa pine study site remained near its 1976 level with 62.3 breeding pairs, but the grassland had an increase of 19.3 breeding pairs, the cold desert shrub increased 12.3 pairs, and the juniper-grassland remained nearly constant with a total of 35.2 breeding pairs per 40 ha (Table 5). The difference in a sequence of avian populations between years may reflect the change in climatic conditions during the two breeding seasons.

Ponderosa Pine

In the ponderosa pine community, the Brown-headed Cowbird was the only species that did not breed along the transect in both years (Table 1). Although the distribution of numbers of pairs per species changed significantly, it appears that this community is at its carrying capacity. Since the total number of breeding pairs in each year remained constant (62.7 and

62.3 prs./40 ha), it may be assumed that this reflects a natural limit that the habitat can support.

This ponderosa pine community appears to be able to maintain approximately 63 pairs of birds per 40 ha. This is considerably fewer breeding pairs encompassing fewer species than have been recorded in similar habitats. Carothers et al. (1973) found a total of 232 breeding pairs encompassing 23 species in the Pearson Natural Area north of Flagstaff, Arizona. Balda (1967) found 31 species and 336 pairs per 40 ha in the ponderosa pine forest of the Chiricahua Mountains of southeastern Arizona. The general trend of populations of breeding pairs in Northern Arizona is intermediate between those from northern Colorado and southern Arizona (Carothers et al. 1973). The Sunset Crater ponderosa pine forest appears to be an island in the midst of this trend where populations are extremely reduced to points lower than those recorded in northern Colorado (Snyder 1950).

Juniper-Grassland

The juniper-grassland had four species of birds that bred in the area in 1976, but did not breed there in 1977, and they represent 11.7 breeding pairs. There were three species that bred in 1977, and did not breed in 1976, and they contributed a population of 11.0 pairs per 40 ha to the total (Table 2). This suggests that although there was some variation in species composition between years, these changes did not drastically affect the overall breeding bird numbers. It appears that the absence of the Mourning Dove as a major breeding species in 1977 explains the small variation in total numbers of pairs between years. The diversity indices and J' values for the juniper-grassland reflect this similarity in numbers between years in that they are nearly equal (Table 5).

When compared to similar habitats in other areas, the juniper-grassland community might be thought of as an intermediate between the pinyon-juniper

woodland and the grassland communities. Although the juniper-grassland is not an ecotone of these two communities, it shares some of the major vegetative features of each. Laudenslayer and Balda (1976) found five species of breeding birds and 46 breeding pairs per 40 ha. Although these data are from a pinyon-juniper-ponderosa pine ecotone, these results were found to coincide with those of other pinyon-juniper areas studied.

Grassland habitats have been found to contain from three to five species and 40 to 95.6 breeding pairs per 40 ha (Wiens 1974). The juniper-grassland community studied here consisted of 12 breeding species with 39.8 and 35.2 breeding pairs of 11 species in 1976 and 1977 respectively. The greater number of species in the juniper-grassland may be due to increased height diversity of the vegetation. The average number of pairs in 1976, and the even lower number of pairs in 1977 may be explained by the moderate amount of precipitation that the area receives which in turn may influence primary productivity (Wiens 1974b), and thereby affect the densities of birds that can survive in the area.

Grassland

The grassland community in Wupatki National Monument showed the largest increase in breeding pairs from 40 pairs in 1976 to 59.3 pairs per 40 ha in 1977. This increase was not due to an increase in numbers of species, because the Horned Lark was the only breeding species in either year. As mentioned above, grassland communities of breeding birds can vary tremendously from 3-5 species and 40-95.6 breeding pairs per 40 ha. The unique nature of the grassland community investigated here may be explained by unpredictable variations in climate, causing subsequent variations in productivity between years (Wiens 1974b). Also, the amount of grazing in the area may have varied between years, which could influence the amount of food (seeds and insects) that would

be available to the birds.

Cold Desert Shrub

In the cold desert shrub community, the Rock Wren and Brown-headed Cowbird bred along the transect in 1976 contributing a population of 4.5 pairs to the total, and they did not breed there in 1977. The Mockingbird was the only new breeding species in 1977, and contributed 4.3 breeding pairs per 40 ha to the total population (Table 7). All species that bred along the transect in both years increased their total number of pairs in 1977. This suggests that the ability of this environment to provide food to support the bird populations increased from one year to the next, and that perhaps there was a change in weather that enhanced this increase (Smith 1974).

Even with the increase in numbers of pairs in 1977, the cold desert shrub study area still has a relatively low number of breeding pairs when compared to other similar habitats. Raitt and Maze (1968) summarized values recorded from several desert communities, and found that they ranged from 10 to 109 pairs per 40 ha. Raitt and Maze explain that these differences are related to variations in rainfall, complexity of vegetation, and probably increasing productivity. Comparisons to other specifically cold desert shrub communities are not possible at this time.

Diversity Indices

All diversity indices and J' values were remarkably similar within study areas between years (Table 5). The juniper-grassland has the greatest diversity indices of the four communities for both years. The number of species in each area has great importance to the diversity index. The grassland community readily exemplifies this point. It has a similar number of breeding pairs to the juniper-grassland in 1976, and to the ponderosa pine study area in 1977, but in contrast has only one

species representing the community. This drastically lowers the diversity to the point where calculations of diversity are meaningless. This is not to say, however, that the grassland habitat is not productive. Productivity is a relative measure, and it is difficult to compare it among different habitats.

Comparisons within habitat types show that in one ponderosa pine community, species diversity was 2.28 (Balda 1969), compared to 3.03 calculated for the community in this study. Szaro and Balda (1976) found diversities ranging from 1.02 to 2.89 on several disturbed ponderosa pine forests in northern Arizona. The high diversity found here compared to other areas suggests that this is a more stable community, because the higher the diversity, the more mature and stable a community is thought to be (Smith 1974). Similarly, the absence of fluctuations in the indices between years suggests that this ponderosa pine community is at a plateau of maturity, because the diversity did not increase significantly.

Diversities in comparable grassland habitats are decidedly higher than those found for the breeding species in this community (0.0144). This is explained by only one breeding species being present on the study area. If, as Wiens (1974b) suggests, climatic irregularity imposes limits on the number of species that can inhabit a grassland community, then this grassland is probably severely limited by these irregularities. In contrast to the ponderosa pine community, the low diversity in the grassland is an indication of an immature community that is at a plateau, because stratification and diversity are low, and they did not increase between years (Smith 1974).

Specific values for diversity comparisons in the juniper-grassland and cold desert shrub are not available. However, Raitt and Maze (1968) suggest that to increase densities in desert scrub avifaunas, addition

of species is needed. This depends on densities and productivity of vegetation which in turn results from increased available moisture.

The communities of Sunset Crater and Wupatki National Monuments appear to be limited by available moisture, and this limitation is heightened by the presence of cinders as ground cover. A layer of cinders may reduce the available moisture by its inability to retain moisture, and thereby influence vegetative structure.

Habitat Utilization and Insect Densities

Subdividing species and pairs of birds into proportions of feeding guilds offers an alternative means of understanding communities. Comparisons within and between years will be made for each study area, and any correlations to insects will be discussed.

The ponderosa pine community had a relatively stable equitable distribution of pairs in the feeding guilds in 1976, and in 1977 had more than 50 per cent of breeding pairs feeding as peckers, hammerers, or tearers. The juniper-grassland and cold desert shrub have a majority of the species and pairs in the ground feeding guild. This is probably correlated with the vegetational diversity of the areas. Szaro and Balda (1976) found that certain guilds exhibit a positive correlation to increasing foliage volumes. The number of seeds in each area will vary with the type and amount of vegetation. Similarly, insect densities will vary with different heights and composition of vegetation.

In the ponderosa pine community, insect densities were lowest in the tree layer, and most of these insects caught were flying insects. Since insects living on the trees were not adequately sampled, and the majority of birds are those that eat insects under the bark, the insect densities and birds in various insect-feeding guilds would not necessarily be expected to correlate.

In the juniper-grassland study area, the shrub and ground strata

contained relatively equal percentages of insects (Table 9). There was a majority of birds in the ground feeders guild followed closely by the hawking, hovering, and aerial feeding guild. The latter guild utilizes flying insects which are readily caught by the tanglefoot, but it is difficult to state a correlation here. In contrast, the ground stratum alone has almost half of all insects collected, which infers a correlation between ground insect densities and percentages of ground feeding birds.

In the cold desert shrub, insect densities and feeding guilds have the greatest correlation. Insects were found most frequently along the ground stratum, and the highest percentage of birds were feeding on the ground. Data from this study area gives the best indication that insect densities may influence the degree to which birds can feed in a particular stratum.

Closely related to the feeding guilds, the nesting guilds also show a probable correlation with the amount and type of vegetation. The ponderosa pine habitat is unique in having over 50 per cent of both species and pairs nesting in cavities and depressions in both years (Table 3). The juniper-grassland has 54 per cent of the breeding pairs, and 67 per cent of the species nesting in foliage in 1976, 73 per cent of the species and 56 per cent of the pairs nesting there in 1977 (Table 4). Both the cold desert shrub and the grassland have bird species that consistently nest on the ground (Table 6, 8). As height of vegetation decreases, the height of nests also decreases which may explain the variation in nest site selection in each study area.

The techniques used in sampling insects may reflect a bias in the insect families and numbers of insects collected. Using tanglefoot, insects adhere to the board only if they fly or crawl into it, which excludes larvae, and those insects that are large enough to break away from the sticky material. The glycerol used in ground traps is a sugar, so that insects which are instinctively attracted to nectar (ants, bees) would

also be attracted to the traps. All things considered, it is still valid to compare insect data among these study areas and among the same strata in the different study areas. However, a comparison of insect families collected in these study areas to insect families collected in other areas would be less valid, because of possible variations in sampling techniques.

CONCLUSIONS

The avian communities of Sunset Crater and Wupatki National Monuments appear to be limited in varying degrees by the presence of cinders as ground cover and by the proximity of the monuments to the southernmost edge of the cold desert. Available moisture may be the most severe limiting factor to the breeding birds in that moisture is scarce throughout most of the year, and this tends to keep the limit of birds that the environment can support at a plateau. Diversity indices are quite high in all but the grassland community where climatic irregularities and grazing pressure may adversely influence the success of many avian populations.

There are numerous species of waterfowl, shorebirds, and other migrants that use the waterway of the Little Colorado River in late summer and fall. Although this area is a small portion of the total area of Wupatki National Monument, it serves as an important migration route, and may play an important role as an access corridor for new bird species that may invade the monuments in the future.

RECOMMENDATIONS

The recommendations made in the 1976 report are still regarded as being beneficial to the monuments. Although there are no additions to these recommendations for management of avian communities, the investigator would like to stress one point. Even though the monuments are supposed to be preserved in a natural state, the expansion of the sewage ponds or the development of natural springs as a water source for wildlife would not necessarily contradict this principle. It is highly conceivable that the Little Colorado River had much more water flowing through it during the past few centuries than at present, so that expanding a water source at the monuments may not be altering the natural habitat. The large numbers of cattle grazing in the monument has most probably reduced the amount of water at natural watering holes that is presently available to the natural inhabitants of the area, and obviously has changed the natural vegetative structure of the area, so that extending the water sources may in fact be bringing the monuments closer to their natural state.

Because of its unique biogeographic position (southern-most edge), the cold desert shrub area of Wupatki National Monument should be preserved for public enjoyment and future study. Wupatki National Monument and the Painted Desert are the only representatives of this community in the state of Arizona presently afforded protection. Thus, it is part of Arizona's heritage that deserves protection for future generations. Grazing of this habitat could alter the composition and densities of the grasses and forbs. Grasses and forbs now serve as the principal producers of seeds for 33 per cent of the breeding species and 53 per cent of all the breeding pairs as the avian community is presently structured. Thus, an increase in grazing intensity could seriously alter the contemporary avian community.

The ponderosa pine forest at Sunset Crater deserves special consideration from a scientific point of view. It is very difficult to find ecological communities that show the ends of a natural biological spectrum. The bird community in this habitat is a depauperate one due to natural circumstances. If we are to ever unravel the ecological constraints placed on breeding birds it will be necessary to have areas such as this available for study. Although one can make this point an abstraction, it should be pointed out that most ponderosa pine forests in the southwest are being altered drastically for timber and pulp. At the same time, elements of the U.S. Forest Service are questioning their policies in light of non-game bird habitat management. Thus, this area has distinct value.

The sewage ponds at Wupatki National Monument serve as a reliable source of water for thousands of resident and migratory birds. With proper management and landscaping, a small area around these ponds could be developed into an attractive resting and drinking area for the birds. Because water is no problem, a modest landscaping plan, utilizing native plants could enhance the value of the area for birds. The planting of a few cottonwoods along the edges would be beneficial to the birds. This pond could be made the focal point of visitors interested in natural history but unwilling to venture off the main roads of the monuments.

A word of caution is in order about the sewage ponds. During the past year we have determined that the ponds contain high amounts of $O-PO_4$ and NO_3 . The values are well above those recommended by the Environmental Protection Agency for water safe for human consumption. At the present time no data are available indicating this water is unsafe for birds.

ADDENDUM (February 1978) - to the Checklist of Birds of Sunset Crater and Wupatki National Monuments (appendix C) of the Final Report submitted in December 1976 to the Office of Natural Resources Management, Southwest Region, National Park Service, (Lynn Beatty).

PODICIPEDIFORMES

PODICIPEDIDAE - Grebes

Eared Grebe

Podiceps nigricollis

ANSERIFORMES

ANATIDAE - Waterfowl

Blue-winged Teal

Anas discors

Canvasback

Aythya valisineria

FALCONIFORMES

FALCONIDAE - Falcons

Merlin (=Pigeon Hawk)

Falco columbarius

GALLIFORMES

PHASIANIDAE - Quails, Pheasants

Montezuma Quail*

Cyrtonyx montezumae

CUCULIFORMES

CUCULIDAE - Cuckoos, Anis, Roadrunners

Roadrunner

Geococcyx californianus

PASSERIFORMES

HIRUNDINIDAE - Swallows

Tree Swallow

Iridoprocne bicolor

FRINGILLIDAE - Grosbeaks, Finches,
Sparrows, Buntings

Rose-breasted Grosbeak

Pheucticus ludovicianus

Blue Grosbeak

Guiraca caerulea

Lazuli Bunting

Passerina amoena

* The Montezuma Quail (Cyrtonyx montezumae) was reported verbally to the investigator by park service officials, but habitat requirements for this species do not support its presence at the monuments.

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Table 1. Ponderosa Pine Habitat, 15 May - 22 July 1976 and 29 April - 25 June 1977. A dash indicates absence in this category. The feeding guilds are: ground feeders (GF); hoverers, hawkers or aerial feeders (HHA); peckers, hammerers, tearers (PHT); pickers and gleaners (PG). The nesting guilds are: foliage nesters (FN); cavity and depression nesters (CD); ground nesters (GN); parasitic (P).

Species	Bred along tran- sect 76/77	Breeding spp. but not along transect line 76/77	Tran- sient 76/77	Span be- tween 1st and last days of detection 76/77	Popula- tions (prs./ 40 ha) 76/77	Feed- ing Guild	Nest- ing Guild
Sparrow Hawk (<u>Falco sparverius</u>)		-/X		-/1	-	-	-
Mourning Dove (<u>Zenaidura macroura</u>)	X/X			69/58	13.6/5.1	GF	FN
Common Nighthawk (<u>Chordeiles minor</u>)			-/X	-/1	-/-	-	-
Broad-tailed Hummingbird (<u>Selasphorus platycercus</u>)	X/X			66/50	3.7/4.9	HHA	FN
Common Flicker (<u>Colaptes auratus</u>)	X/X			69/58	.9/1.9	PHT	CD
Williamson's Sapsucker (<u>Sphyrapicus thyroideus</u>)			X/-	20/-	-	-	-
Hairy Woodpecker (<u>Picoides villosus</u>)	X/X			38/46	1.9/1.2	PHT	CD
Violet-green Swallow (<u>Tachycineta thalassina</u>)	X/X			69/58	16.4/8.5	HHA	CD
Steller's Jay (<u>Cyanocitta stelleri</u>)	X/X			69/58	1.2/1.4	PHT	FN
Common Crow (<u>Corvus brachyrhynchos</u>)		-/X		-/1	-/-	-	-
Mountain Chickadee (<u>Parus gambeli</u>)		X/-		1/-	-/-	-	-
White-breasted Nuthatch (<u>Sitta carolinensis</u>)	X/X			35/13	4.9/3.1	PHT	CD
Pygmy Nuthatch (<u>Sitta pygmaea</u>)	X/X			69/58	5.9/12.1	PHT	CD
Western Bluebird (<u>Sialia mexicana</u>)	X/X			19/30	3.5/19.8	HHA	CD
Blue-gray Gnatcatcher (<u>Poliophtila caerulea</u>)			X/-	1/-	-/-	-	-
Grace's Warbler (<u>Dendroica graciae</u>)	X/X			51/58	1.9/3.1	PG	FN
Brown-headed Cowbird (<u>Molothrus ater</u>)	X/-	-/X		57/42	8.0/-	GF	P
Western Tanager (<u>Piranga ludoviciana</u>)	X/X			38/26	0.8/1.2	PG	FN
Rose-breasted Grosbeak (<u>Pheucticus ludovicianus</u>)			-/X	-/1	-/-	-	-
Red Crossbill (<u>Loxia curvirostra</u>)			-/X	-/1	-/-	-	-
Dark-eyed Junco (<u>Junco hyemalis</u>)			X/-	1/-	-/-	-	-

Table 2. Juniper-Grassland Habitat, 26 May - 6 July 1976, and 1 May - 2 July 1977.

Species	Bred along tran- sect 76/77	Breeding spp. but not along transect line 76/77	Tran- sient 76/77	Span be- tween 1st and last days of detection 76/77	Popula- tions (prs./ 40 ha) 76/77	FG	NG
Sharp-shinned Hawk (<i>Accipiter striatus</i>)			X/-	1/-	-	-	-
Mourning Dove (<i>Zenaida macroura</i>)	X/X			42/63	9.4/2.2	GF	FN
Common Nighthawk (<i>Chordeiles minor</i>)	X/X			42/28	5.1/4.9	HHA	GN
Broad-tailed Hummingbird (<i>Selasphorus platycercus</i>)			-/X	-/1	-/-	-	-
Cassin's Kingbird (<i>Tyrannus vociferans</i>)	X/X			37/63	1.5/1.1	HHA	FN
Ash-throated Flycatcher (<i>Myiarchus cinerascens</i>)	X/-			19/-	2.5/-	HHA	FN
Gray Flycatcher (<i>Empidonax wrightii</i>)	X/-	-/X		22/10	2.5/-	HHA	FN
Horned Lark (<i>Eremophila alpestris</i>)	X/-	-/X		31/53	3.7/-	GF	GN
Rough-winged Swallow (<i>Stelgidopteryx ruficollis</i>)			X/-	1/-	-/-	-	-
Common Raven (<i>Corvus corax</i>)		X/-		13/-	-/-	-	-
Common Crow (<i>Corvus brachyrhynchos</i>)		X/X		6/52	-/-	-	-
Plain Titmouse (<i>Parus inornatus</i>)	X/X			30/63	1.2/3.2	PHT	FN
Mockingbird (<i>Mimus polyglottos</i>)	-/X			-/24	-/4.6	HHA	FN
Bendire's Thrasher (<i>Toxostoma bendirei</i>)	X/X			24/52	1.0/.6	GP	FN
Loggerhead Shrike (<i>Lanius ludovicianus</i>)	-/X	X/-		16/22	-/4.3	HHA	FN
Gray Vireo (<i>Vireo vicinior</i>)	X/X			42/63	2.0/1.9	PG	FN
Wilson's Warbler (<i>Wilsonia pusilla</i>)			X/-	1/-	-	-	-
Scott's Oriole (<i>Icterus parisorum</i>)	X/X			42/63	1.2/1.9	GF	FN
Brown-headed Cowbird (<i>Molothrus ater</i>)	X/-	-/X		20/1	3.0/-	GF	P
Lark Sparrow (<i>Chondestes grammacus</i>)	-/X			-/25	-/2.1	GF	GN
Black-throated Sparrow (<i>Amphispiza bilineata</i>)	X/X			42/63	6.7/8.5	GF	GN
Chipping Sparrow (<i>Spizella passerina</i>)			-/X	-/1	-/-	-	-
Brewer's Sparrow (<i>Spizella breweri</i>)			X/-	1/-	-/-	-	-

Table 3. Number and Per Cent of Breeding Species and Breeding Pairs in the Ponderosa Pine Community in each Guild 1976/1977.

	Number of Species	Number of prs./ 40 ha	Per Cent of Species	Per Cent of prs./40 ha
Guilds*	1976/1977	1976/1977	1976/1977	1976/1977
<u>Feeding</u>				
GF	2/1	21.6/ 5.1	17/9	34/8
HHA	3/3	23.6/33.2	25/27	38/53
PHT	5/5	14.8/19.7	42/45	24/32
PG	2/2	2.7/4.3	17/18	4/7
<u>Nesting</u>				
FN	5/5	21.2/15.7	42/45	34/25
CD	6/6	33.5/46.6	50/54	53/75
GN	-/-	-/-	-/-	-/-
P	1/-	8.0/-	8/-	13/-

*Guild abbreviations:

Ground Feeders (GF)
 Hoverers, Hawkers, Aerial Feeders (HHA)
 Peckers, Hammerers, Tearers (PHT)
 Pickers and Gleaners (PG)

Foliage Nesters (FN)
 Cavity and Depression Nesters (CD)
 Ground Nesters (GN)
 Parasitic (P)

Table 4. Number and Per Cent of Breeding Species and Breeding Pairs in the Juniper-Grassland Community in each Guild Between Years.

Guilds	Number of Species 1976/1977	Number of prs./40 ha 1976/1977	Per Cent of Species 1976/1977	Per Cent of prs./40 ha 1976/1977
<u>Feeding</u>				
GF	6/5	25.0/15.3	50/45	63/43
HHA	4/4	11.6/14.9	33/36	29/42
PHT	1/1	1.2/3.2	8/9	3/9
PG	1/1	2.0/1.9	8/9	5/5
<u>Nesting</u>				
FN	8/8	21.3/19.8	67/73	54/56
CD	-/-	-/-	-/-	-/-
GN	3/3	15.5/15.5	25/27	39/44
P	1/-	3.0/-	8/-	8/-

Table 5. Comparisons Among Communities and Between Years.

Data	Ponderosa Pine 1976/1977	Juniper- Grassland 1976/1977	Grassland 1976/1977	Cold Desert Shrub 1976/1977
Total number of species	16/17	19/17	6/5	12/13
Total number of breeding species (N)	12/11	12/11	1/1	7/6
Number of days censused	13/8	10/8	10/7	9/8
Populations of breeding birds (prs./40 ha)	62.7/62.3	39.8/35.2	40/59.3	28.5/40.8
Diversity indices (H')	3.0256/ 2.8963	3.2371/ 3.1560	0.0144/ 0.0144	2.0900/ 2.1326
H' max values	3.5849/ 3.4594	3.5849/ 3.4594	-/ -	2.8073/ 2.5850
J' values	0.844/ 0.837	0.903/ 0.912	-/ -	0.744/ 0.825

Table 6. Grassland Habitat, 5 May-24 June 1976 and 25 May-24 June 1977.

	Bred along transect 1976/1977	Breeding spp. but not along transect line 1976/1977	Trans- ient 76/77	Span be- tween 1st and last days of detection 76/77	Popula- tions (prs./ 40 ha) 76/77	Feed- ing Guild	Nest- ing Guild
Mourning Dove (<u>Zenaida macroura</u>)		X/-		1/-	-	-	-
Common Nighthawk (<u>Chordeiles minor</u>)		X/X		1/19	-	-	-
Cassin's Kingbird (<u>Tyrannus vociferans</u>)		-/X		-/1	-	-	-
Horned Lark (<u>Eremophila alpestris</u>)	X/X			50/31	40/59.3	GF	GN
Common Raven (<u>Corvus corax</u>)		X/-		40/-	-	-	-
Common Crow (<u>Corvus brachyrhynchos</u>)		X/X		31/31	-	-	-
Mockingbird (<u>Mimus polyglottos</u>)		-/X		-/1	-	-	-
Loggerhead Shrike (<u>Lanius ludovicianus</u>)		X/-		1/-	-	-	-

Table 7. Cold Desert Shrub Habitat, 14 May-26 June 1976 and 15 April-29 June 1977.

Species	Bred along transect 76/77	Breeding spp. but not along transect line 76/77	Trans- ient 76/77	Span be- tween 1st and last days of detection 76/77	Popu- lations (prs./ 40 ha) 76/77	FG	NG
Mourning Dove (<u>Zenaida macroura</u>)	X/X			33/25	2.1/6.6	GF	FN
Common Nighthawk (<u>Chordeiles minor</u>)	X/X			20/11	2.3/4.9	HHA	GN
Broad-tailed Hummingbird (<u>Selasphorus platycercus</u>)			X/X	1/21	-	-	-
Say's Phoebe (<u>Sayornis saya</u>)			X/-	8/-	-	-	-
Cliff Swallow (<u>Petrochelidon pyrrhonota</u>)			X/-	1/-	-	-	-
Violet-green Swallow (<u>Tachycineta thalassina</u>)			-/X	-/1	-	-	-
Common Raven (<u>Corvus corax</u>)		X/-		28/-	-	-	-
Common Crow (<u>Corvus brachyrhynchos</u>)		-/X		-/1	-	-	-
Rock Wren (<u>Salpinctes obsoletus</u>)	X/-			21/-	1.1/-	GF	CD
Mockingbird (<u>Mimus polyglottos</u>)	-/X			-/30	-/4.3	HHA	FN
Bendire's Thrasher (<u>Toxostoma bendirei</u>)	X/X			22/34	1.5/1.7	GF	FN
Ruby-crowned Kinglet (<u>Regulus calendula</u>)			-/X	-/1	-	-	-
Phainopepla (<u>Phainopepla nitens</u>)		-/X		-/1	-	-	-

Table 7. (continued)

Species	Bred along transect 76/77	Breeding spp. but not along transect line 76/77	Trans- sient 76/77	Span be- tween 1st and last days of detection 76/77	Popu- lations (prs./ 40 ha) 76/77	FG	NG
Brown-headed Cowbird (<u>Molothrus ater</u>)	X/-	-/X		44/55	3.4/-	-	-
House Finch (<u>Carpodacus mexicanus</u>)	X/X			33/55	2.1/3.5	GF	FN
Black-throated Sparrow (<u>Amphispiza bilineata</u>)	X/X			44/77	16/19.8	GF	GN
Brewer's Sparrow (<u>Spizella breweri</u>)			X/X	8/1	-	-	-

Table 8. Number and Per Cent of Breeding Species and Breeding Pairs in the Cold Desert Shrub Community in each Guild Between Years.

Guilds	Number of Species 1976/1977	Number of prs./40 ha 1976/1977	Per Cent of Species 1976/1977	Per Cent of prs./40 ha 1976/1977
<u>Feeding</u>				
GF	6/4	26.2/31.6	86/67	92/77
HHA	1/2	2.3/9.2	14/33	8/23
PHT	-/-	-/-	-/-	-/-
PG	-/-	-/-	-/-	-/-
<u>Nesting</u>				
FN	3/4	5.7/16.1	43/67	20/39
CD	1/-	1.1/-	14/-	4/-
GN	2/2	18.3/24.7	29/33	64/61
P	1/-	3.4/-	14/-	12/-

Table 9. Number of Insects Collected in Each Study Area in Each Stratum Per Week.

Area Strata	Ponderosa Pine	Juniper- Grassland	Grassland	Cold Desert Shrub
Week				
1	36	34		
2	27	37		
3	--	14		
4	19	15		
TOTAL	82	100		
1	46	263	581	138
2	16	100	197	51
3	--	36	44	27
4	31	19	30	27
TOTAL	93	418	852	243
1	60	206	139	161
2	25	75	200	28
3	106	69	178	63
4	18	11	56	90
TOTAL	209	361	573	342
Totals	384	879	1425	585

Table 10. Number of Individuals and Percentages of the Major Insect Families Collected In Each of The Study Areas.

Study Area	Families	Individuals	Percentages	Total Percent
Ponderosa Pine	Formicidae	165	43.0	56
	Psyllidae	18	4.7	
	Chalcidoidea	17	4.4	
	Muscidae	16	4.2	
Juniper-Grassland	Melyridae	461	52.0	71
	Formicidae	166	19.0	
Grassland	Melyridae	805	56.5	81
	Formicidae	348	24.0	
Cold Desert Shrub	Formicidae	164	28.0	62
	Melyridae	149	26.0	
	Lygaeidae	44	8.0	

IV

STUDIES OF SELECTED MAMMALIAN POPULATIONS

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February, 1978

INTRODUCTION

Sunset Crater and Wupatki National Monuments encompass a wide variety of habitat types. In response to variations in soil type and plant communities, these areas are characterized by a high level of rodent species diversity. Sub-specific variation is also evident. Several unique rodent subspecies were described by early collectors from the Biological Survey and Museum of Vertebrate Zoology, University of California, Berkeley, (Cockrum 1960).

A number of more recent studies regarding mammals have been conducted on the monuments. During the 1960's several studies were carried out, including 1) the study of a Peromyscus population in a volcanic region by R. P. Maynard Jr.; 2) the bats of Wupatki National Monument by T. A. Gustafson; and 3) the Antelope of Wupatki National Monument by James A. Mack.

During the 1970's, faculty and graduate students at Northern Arizona University have become increasingly interested in the mammals of these monuments. J. O. Wolff and G. C. Bateman studied torpor in the silky pocket mouse (Perognathus flavus) using specimens and field observations from Wupatki National Monument in 1972, and B. H. Campbell and G. C. Bateman studied population dynamics as well as habitat and dietary requirements of the same species in and around Cedar Canyon in Wupatki. An investigation of the relationship between air temperature and nocturnal foraging behavior in several Peromyscus and Perognathus species was begun in 1976 by J. L. Fisher and is being continued at present.

As is the case in many temperate and boreal localities, the most important components of the mammalian communities at Wupatki and Sunset Crater monuments, in terms of energy conversion, are generally the rodent populations. These rodent populations represent an integral part of ecosystem functioning within

the monuments, and studies investigating the ecology and behavior of these animals are of value not only to the National Park Service but to the scientific community as well.

The objective of this study was to conduct an examination of existing rodent communities in what were determined to be the three major plant communities at Wupatki National Monument. Within this examination an attempt was made to determine: 1) the species composition of the rodent community at each area; 2) the relative abundances of the species in each community; 3) the relative importance to ecosystem functioning of each component species of the community; 4) seasonal changes in abundance and patterns of activity of these species; and finally, 5) the probable ecological stability of each community with an eye toward management implications.

METHODS AND MATERIALS

Live-trapping grids

Three live-trapping grids, or quadrats, were established within fairly homogeneous stands of vegetation designated as representative of one of the three general plant communities occurring at Wupatki National Monument. These communities were: 1) Grassland; 2) Juniper/Grassland and 3) Cold Desert Shrub. On these three grids trapping data regarding the populations of important rodent species were obtained.

An alidade and 50 meter (m) tapes were used to survey the trapping quadrats. Since topographic complexity was nearly absent, horizontal distances were used in measuring. Each grid consisted of 12 rows, each having 12 trap stations spaced at 15 m intervals. A quadrat, therefore, was 165 m on a side and included 2.723 hectares (ha) or 6.727 acres (ac). Each row of traps was assigned a letter and columns were numbered. Hence, any trap site was designated by a specific combination of a letter and number. Trap sites were marked by wooden stakes having

this designation indicated on them. The locations of the three mammal trapping grids are indicated on the vegetation map provided with this report.

The area sampled by each quadrat was estimated to include a boundary strip equal to one half the distance between traps. This boundary strip was added to the perimeter of the grid. Thus, the area sampled by a grid was roughly 3.240 ha (8.006 ac).

More sophisticated means of determining sampling area have been designed. These techniques, however, involve determining more about patterns of rodent movements than our trapping regime permitted. Such patterns are known to vary interspecifically as well as intraspecifically on age, sex and seasonal bases.

Trapping Program

During the summer months, each grid was trapped every two weeks. Fall sampling was reduced to approximately one sampling period per month. Each sampling period involved two nights of trapping. The summer samplings were carried out by running the Juniper and Juniper/Grassland grids simultaneously and the Cold Desert Shrub grid on different nights. In the fall sampling periods, all three grids were often run simultaneously, as two researchers, rather than one, were available to conduct the trapping, and cooler temperatures decreased the possibility of rodent mortality in traps due to hyperthermia after sunrise. Sheet metal, non-folding live traps were used, having dimensions of 7.6 x 7.6 x 25.4 centimeters (cm). One trap was placed at each trap site. Traps were set in late afternoon and baited with a small amount of rolled milo. A bit of milo was scattered in front of the trap door to increase the attractiveness of the trap.

Traps were checked in the morning as soon as it was possible to see clearly. Unsprung traps were closed and left in place. Captured animals were removed from the trap into a soft cloth bag to facilitate handling. Each individual was examined and species, sex, and approximate age (by pelage characteristics) were determined. Each animal, if not previously marked, was given a distinctive

toe-clip number, which allowed positive identification of the individual animal in subsequent captures. Conspicuous marks, reproductive features (e.g. lactation, position of testes) and general behavior were also noted at this time. The animals were then released at the place of capture. All these data were recorded on a standard trapping form, punched on to computer cards and analyzed on a Xerox Sigma 6 Computer using programs written by Dr. W. S. Gaud.

Population Densities

Two different methods were used to determine population density.

1) A minimum population estimate per sampling period was provided by the computer printout which listed the numbers of different individuals of each species trapped during a single trapping period. An individual caught during any one sampling period was considered a single sampling occurrence whether captured one night or both.

2) The Lincoln Index was also used. Population estimates are arrived at by marking a number of individuals and releasing them. The population is then sampled again. An estimate of total population is then computed from the ratio of marked to unmarked individuals using the following formula:

$$N = nT/t$$

where

T = number marked in the precensus period

t = number of marked animals trapped in the census period

n = total number animals trapped in the census period

N = population estimate

The standard error of the estimate is given by:

$$S.E. = T^2 n(n-t)/t^3$$

In general, the 95% confidence interval may be determined by adding or subtracting two standard errors from the estimate.

Rodent Activity

Per cent trapping success is a rough index to rodent activity and is determined by dividing the total number of captures during a period by the number of trap - nights during that period. A trap - night is one trap set for one night. A total of 288 trap nights of effort was expended on each quadrat during each sampling period.

Rodent Diversity

The diversity of the community of nocturnal rodents in each of the major plant communities was determined using data gathered following the above procedures. Additionally, rodent diversity was determined on a seasonal basis considering the first three sampling periods to represent late spring and early summer, prior to normal summer monsoons. The second three sampling periods made up the late summer census, and the final three samples represented the autumn census. The formula used to compute the diversity index is:

$$H' = \sum p_i \log_2 p_i,$$

where

p_i is the proportion of the total rodents in the community contributed by the i th species.

RESULTS

Species Present

As represented in Table 1, the nocturnal rodent populations of each of the three major plant communities were sampled nine times in 1977. Tables 2, 3 and 4 provide information regarding species composition and numbers of individuals present at each of the three quadrats. The grassland community was dominated by the silky pocket mouse (Perognathus flavus), but also supported a significant number of deer mice (Peromyscus maniculatus). Also occurring on the grid were a single Stephens' Woodrat (Neotoma stephensi) and a single western harvest mouse (Reithrodontomys megalotis). Although these species must be considered rare, their

presence does indicate the support of greater rodent diversity by the grassland habitat than was evident from the 1976 sample. In addition to these nocturnal rodents, the spotted ground squirrel and the valley pocket gopher are also known to occur in this area (G.C.B. pers. obs.).

The 1976 mammal survey indicated that the Juniper/Grassland community provided a base for greater rodent density and diversity than did the Grassland. The 1977 sample contrasts significantly with the previous year, however. The main change in rodent numbers appears to be due to a sharp decrease in the number of members of the genus Peromyscus on the Juniper/Grassland grid, particularly in the pinyon mouse (Peromyscus truei). The average number of pinyon mice captured per sampling period dropped from 12.4 in 1976 to 3.0 in 1977. As a result of this decrease, a reverse situation is apparent, with Grassland supporting greater numbers of individual rodents per hectare than the Juniper/Grassland (table 10). The silky pocket mouse was the dominant species in the habitat, as it was in the Grassland. Also present in low numbers were Peromyscus maniculatus, as well as rarely occurring Neotoma stephensi (4 captures). The Juniper/Grassland community should be considered marginal habitat for the Stephen's woodrat, providing few rock outcrops or lava escarpments for densites and a relatively low abundance of the shrubby plants shown by Kuch (1969) to be necessary food items.

As in 1976, the Cold Desert Shrub community was found to be inhabited by the greatest diversity and density of rodents. An extremely high total of nine species of rodent were captured, including the diurnal white-tailed antelope ground squirrel (Ammospermophilus leucurus).

A number of species were found to be exclusive to this habitat. Perognathus amplus (Arizona pocket mouse) was the dominant rodent, as it was last year, comprising a large majority of the total captures.

Next to the Arizona pocket mouse, the species most often captured was Peromyscus truei, which also occurred in the Juniper/Grassland grid. Also occurring rarely was Peromyscus maniculatus, apparently the most ubiquitous of the Wupatki rodents, as well as a single cactus mouse (Peromyscus eremicus) which is a new record for the monument.

Other heteromyid rodents found on the grid were Ord's kangaroo rat (Dipodomys ordii) and the rock pocket mouse (Perognathus intermedius). Both of these species are exclusive to the Cold Desert Shrub grid. Dipodomys ordii occurred in low numbers throughout most of the sampling periods, being absent only in early August and September. The rock pocket mouse was caught consistently, also in low numbers, and was restricted in all captures to a small segment of the S.E. corner of the grid where a wide canyon of Antelope Wash is sampled by the grid. As indicated by its common name, this species requires rocky terrain as suitable habitat.

A single Stephens' woodrat was captured on several occasions. Each capture was either in or just outside the small side canyon in the S.E. corner which provides the only suitable densites available within the quadrat. Along with P. maniculatus, the Stephens' woodrat is the only other species found on all three grids.

As in 1976, a few individuals of the species Reithrodontomys megalotis were found in the Cold Desert Shrub. Normally a grassland species, this shrubby, dry habitat must be considered sub-optimal for the western harvest mouse. In all the sampling periods, there was a total of only five captures, involving three individuals. The Northern grasshopper mouse (Onychomys leucogaster), present in low numbers in the 1976 sample, was totally absent from the 1977 trapping records.

Population Densities

In most cases where samples were of sufficient size, the Lincoln index estimates of population densities of individual species (tables 5,6,7) corresponded closely with the actual number of animals caught per sampling period. Generally, the estimated total population inhabiting the grid area was only a few individuals greater than the number actually captured. This would indicate that the species involved were quite susceptible to capture by the live-trapping methods used, and that a large segment of the resident population was being successfully trapped. As previously mentioned, Lincoln index population estimates arrived at from very small sample sizes are often unreliable since proportions change rapidly when small numbers are involved. Since this high probability of error exists, estimates were not given when the sample size was very small.

Recruitment of New Individuals

During the autumn sampling periods, abrupt increases in the number of new unmarked individuals occurred among the Perognathus flavus population at the Grassland grid, and among the Peromyscus truei population at the Cold Desert Shrub.

As is illustrated in Table 8, there is an obvious fluctuation in the per cent of new silky pocket mice captured per sample on the Grassland grid. As would be expected, as the grid hadn't been trapped since September of 1976, the first two sampling periods showed high percentages of new individuals, both over 50 per cent. Also to be expected is the drop in percentage values in the following trapping periods. Low values continued through the summer months, but the September sampling period was marked by a striking jump in the percentage of new pocket mice. The October sample rises to an extremely high value of 88 per cent followed by a 66 per cent value in November. The cause

of this impressive rise in recruitment, for which there is no similar evidence in the fall of 1976, is uncertain. A likely explanation would seem to be that the large amount of rainfall (Table 14; Figure 1) during the months of July and August, 1977, resulting in increased grass production of seed crop, may have led to a decrease in juvenile mortality, and a rapid rise in pocket mouse recruitment.

Table 9 shows the percentages of new pinyon mice per sampling period at the Cold Desert Shrub quadrat. Though the number of individuals per sample is much lower in this case than with the Grassland pocket mice, a somewhat similar pattern is discernible. While there are rather high values for several of the summer samples, it should be pointed out that these values were derived from very small samples. A definite increase is evident in the fall samples, not only in per cent new mice, but also in total number captured on the grid. This evidence tends to agree with the idea of increased plant productivity due to high summer precipitation. It also suggests the possibility that individual pinyon mice may range over relatively large areas in their foraging, perhaps out of the vicinity of the trapping grid for periods of time. This might serve to explain the variability in P. truei sample size for different trapping periods.

Rodent Activity

A rough index to rodent activity is the number of animals caught in a given number of trap-nights. This assumes that all species are equally trappable by the methods employed, and that the effectiveness of these methods does not vary seasonally. While the attractiveness of the bait perhaps does vary, both seasonally and between rodent species, it is our feeling that the per cent trapping success at each quadrat is a reasonably accurate means of estimating nocturnal rodent activity.

The per cent trapping success for each of the grids during each sampling period is expressed in Table 10. This index is based on all captures during the two nights trapping of each sampling period; hence, the total number of captures in a sampling period was divided by 288 to determine trapping success.

As was the situation in 1976, the Cold Desert Shrub quadrat produced the greatest trapping success. Averaging 22.7 per cent trapping success for all sampling periods, this grid produced the highest trapping success, by a significant margin, in each of the nine sampling periods.

The results of the 1977 trapping contrast strikingly with those of 1976 in regard to percent trapping success at the Grassland and Juniper/Grassland grids. In 1976, trapping success was consistently higher at the Juniper/Grassland grid than at the Grassland. The situation in 1977 has completely reversed, with the trapping success higher in the Grassland than the Juniper/Grassland in all sampling periods except two, in which Grassland trapping success was greatly decreased due to disturbance of traps by cattle. The cause of this reversal is not an increase in trapping success at the Grassland quadrat, but, rather, a significant drop in trapping success at the Juniper/Grassland (down from an average of 14.78% in 1976 to 7.25% in 1977).

The peak of nocturnal rodent activity occurs at all three habitats in mid-summer. From this time until the last sample, there is a general, though somewhat inconsistent trend on all three grids toward a decrease in activity. It is known that many rodents, particularly members of the Heteromyidae, become torpid under conditions of cold or low food supply. A sharp drop in trapping success among the different species of pocket mice on the three grids was anticipated in the fall sampling. There is no indication, however, of any sharp decrease in activity except in the Arizona pocket mouse in the Cold Desert

Shrub. This drop in activity was not detectable until the November sampling period. There was no striking decrease in the activity of the silky pocket mouse populations in either the Grassland or the Juniper/Grassland grids. In these habitats, pocket mouse activity continued at moderate levels throughout the autumn sampling.

No clear trends are detectable in rodent activity patterns in response to temporary meteorological conditions. Rain fell during one night in both sampling periods 2 and 5. The only noticeable drop in trapping success occurred in the Cold Desert Shrub and Juniper/Grassland grids from sampling period 4 to 5. However, this decrease in trapping success continues through the next several sampling periods, so the actual effect of the rain is unclear. Weather conditions were fairly moderate during the remainder of the sampling periods except the November sample when, though there was no precipitation, the temperature dropped to around freezing and the wind blew extremely hard during both nights of trapping. There was no great decrease in general trapping success on any of the grids, though P. amplus activity did drop considerably at the Cold Desert Shrub, as previously described.

Rodent Diversity

Based simply on the number of species per area, rodent diversity was found, as in the 1976 sample, to be greatest in the Cold Desert Shrub plant community (Table 4). Here, eight species were found, representing two families and five genera of nocturnal rodents. Of these eight species, four were unique to this quadrat, these being the heteromyid species Dipodomys ordii, Perognathus amplus and Perognathus intermedius, as well as the cricetid Peromyscus eremicus. The Juniper/Grassland grid produced four species, as in 1976 (Table 3). None of these four was unique to the Juniper/Grassland habitat. On the Grassland

grid, which in 1976 produced only Perognathus flavus and Peromyscus maniculatus, two new species were captured (Table 2). Both Neotoma stephensi and Reithrodontomys megalotis were captured only once and should be considered incidentals. Thus, the Grassland grid should again be viewed as least diverse of the three, though in strict terms of species per area it had an equivalent value with the Juniper/Grassland.

The Shannon index (Table 11), which takes into account the relative importance (numbers, biomass, energy transfer) of the species, was used as an additional, and perhaps more realistic estimate of rodent species diversity. As in 1976, the Shannon method indicated that the Grassland community had the least overall species diversity in 1977 ($H' = .8269$). Intermediate in diversity was the Juniper/Grassland with a value of 1.4702, and the greatest overall diversity was found in the Cold Desert Shrub plant community with a Shannon Index value of 1.6901.

Rodent species diversity on the three quadrats was also determined on a seasonal basis using the Shannon Index. The trend of increasing diversity from a low at the Grassland to a high at the Cold Desert Shrub was found again in the first and third seasonal samples. However, in the middle, or late summer period, a higher diversity value was obtained for the Juniper/Grassland grid than for the Cold Desert Shrub. This decline in rodent species diversity at the Cold Desert Shrub grid is attributable mainly to a decrease in the occurrence of Peromyscus truei, Perognathus intermedius, and Dipodomys ordii, coupled with an increase in Perognathus amplus numbers. This decrease in the evenness in the proportions of individuals contributed by each species caused the Cold Desert Shrub diversity value to drop slightly below that of the Juniper/Grassland which remained relatively steady.

Rodent diversity levels at the Grassland grid were also quite steady during the first two seasonal samples, but dropped sharply in the autumn sample. This decline can be attributed to the drop in Peromyscus maniculatus numbers and the disappearance of Neotoma stephensi and Reithrodontomys megalotis from the samples, leaving Perognathus flavus to comprise most, if not all, of the captures.

Biomass

The average number of individuals of each species occurring on the trapping grids per sampling period was calculated (Table 12). The average number of individuals per hectare was determined by dividing this number by the area sampled (3.240 ha). An estimate of biomass (grams per hectare) of each species per sampling period was arrived at by multiplying the mean body weights for a sample of each species by the estimated number of individuals per hectare. An estimate of total biomass per sampling period was calculated by summing these products.

Total rodent biomass was greatest in the Cold Desert Shrub by a large margin (206.09 gm/ha). Total biomass at the Juniper/Grassland grid was slightly higher (73.35 gm/ha) than in the Grassland (66.67 gm/ha). These values indicate a moderate decrease in biomass at the Cold Desert Shrub and Grassland grids and a severe decrease at the Juniper/Grassland grid in comparison with the 1976 sample. The biomass decrease in the Grassland community is due to a drop in the numbers of P. maniculatus, while at the Cold Desert Shrub grid the drop is attributable to a decrease in the numbers of D. ordii, P. truei and P. maniculatus. The radical drop in total biomass seen in the Juniper/Grassland (from 183.68 gm/ha in 1976 to 73.35 gm/ha in 1977) is due to a drop in P. truei biomass from 92.93 to 22.40 gm/ha, and a drop in P. maniculatus biomass from 36.78 to 5.73 gm/ha.

In an attempt to estimate the relative importance of each of the three basic rodent feeding strategies, each rodent species was assigned one of these strategies based upon information available in the literature. Though these designations cannot be considered absolute, for the purposes of this study all heteromyid rodents were considered granivores; all cricetids were considered omnivores with the exception of the harvest mouse and woodrat, which were considered herbivores. Classified as such, the relative importance of these feeding strategies at each of the three study areas was determined in terms of biomass (Table 13). Granivory was found to be the dominant feeding strategy at both the Grassland and Cold Desert Shrub grids, with omnivory of intermediate importance and straight herbivory of least prominence. The importance of granivory was greatly diminished at the Juniper/Grassland grid, however, with both omnivory and herbivory taking on added significance. It should be emphasized that this apparent decrease in granivory may be to a large extent an artifact of the classification scheme. That is, although designated omnivores, the two Peromyscus species inhabiting the Juniper/Grassland are probably at times relying quite heavily on seeds and, thus, operating to a large extent as granivores.

Discussion

In general, the degree of complexity of the rodent communities present at each of the three trapping quadrats can be related directly to the degree of complexity of the associated plant communities. The Grassland plant community, with juniper and shrubby plants very rare, is much the simplest of the three areas sampled. Of the nine nocturnal rodent species represented on the grids, only four were found at the Grassland grid. Of these, only Perognathus flavus and Peromyscus maniculatus were captured with any regularity. The Grassland also had a low rodent density (6.09 individuals/ha); the lowest biomass (66.67 gm/ha) and the least diversity as determined by the Shannon Index ($H' = 0.8269$).

The rodent exerting the greatest ecological impact in the Grassland is undoubtedly the silky pocket mouse (P. flavus). Composing 88.3 per cent of the total individuals and 71.8 per cent of the total rodent biomass, these mice maintained high population levels throughout the period of study. The turnover of individuals within the population was great, with newly marked individuals comprising nearly the entire sample in the fall sampling periods. Though the above ground activity of the silky pocket mouse is known to be somewhat curtailed during cold winter months (G.C.B., unpublished data), no evidence of a slowdown in activity was provided by the monthly trapping regime.

It should be noted that the trapping success during two of the fall sampling periods was substantially affected by the activities of cattle grazing in the trapping area. Cattle commonly use the stakes marking trapsites on the grid for scratching posts. Upon arriving on the scene to begin the monthly trapping, the majority of the stakes were usually knocked down or broken. Often, those stakes which were reset when baiting traps would already have been knocked down by the next morning. The apparently great attractiveness of the stakes as scratching posts to cattle leads to the conclusion that many of the exposed prehistoric Indian ruins on the Monument may also receive heavy use by cattle for scratching. Though the extent of such damage is unknown, it seems probable that the cattle grazing on the monument may be having a damaging impact on the exposed ancient Indian structures which represent perhaps the most valuable resource within Wupatki National Monument. Cattle sometimes significantly decreased trapping success on the Grassland grid by kicking over, and even destroying the live-traps. Thus, the low biomass and density values have been somewhat biased by the activities of cattle. It should also be noted that two diurnal rodent species not regularly sampled, the pocket gopher (Thomomys bottae) and the

spotted ground squirrel (Spermophilus spilosoma), would substantially increase the total rodent biomass and diversity values of the Grassland community.

The Juniper/Grassland trapping site also had four nocturnal rodent species occurring on it. The dominant species was again Perognathus flavus. Also occurring rarely were Peromyscus maniculatus and Neotoma stephensi. Peromyscus truei was of intermediate importance on the Juniper/Grassland grid, comprising 21.7 per cent of the individuals and 30.5 per cent of the total rodent biomass.

The greater diversity of the rodent community found here (Shannon Index $H' = 1.4702$) results from the increased numbers of Neotoma stephensi, and the presence of P. truei, both of which are attributable to the increase in complexity of the plant community due to presence of a large number of juniper trees and some shrubs. Density of rodents per hectare decreased from 9.00 in 1976 to 4.24 which is lower than the density found at the Grassland grid. The reason for this drop is the striking decrease in the numbers of deer mice and pinyon mice on the grid since last year (Bateman, 1976). The cause of this drop in population is unknown. Total rodent biomass, while remaining somewhat greater than on the Grassland grid, was down considerably since last year, with a value of 73.35 gm/ha as compared to 183.68 gm/ha in 1976.

There is a shift from granivory as the major feeding strategy, as in the Grassland and Cold Desert Shrub habitats, to omnivory at the Juniper/Grassland. This is due to the relative increase of Peromyscus truei.

As might be expected; the Cold Desert Shrub habitat, with its high degree of plant diversity, was by far the most complex and productive area in regard to rodents. Eight species were present here, twice the number occurring on the other two grids, and average trapping success was much greater. Total rodent density (13.2 individuals per hectare) and biomass (206.09 gm per ha) were both greater than twice the corresponding values for the Grassland and Juniper/Grassland grids. Of the eight species present, Peromyscus eremicus, Dipodomys ordii,

Perognathus intermedius and Perognathus amplus were found only in the Cold Desert Shrub. Perognathus amplus was, as found last year, the most numerous species on the grid, contributing an average of 9.29 individuals/ha and 97.58 gm/ha to the total rodent density and biomass. The size of this P. amplus population is quite impressive when one considers that, as an individual species, this animal provides more density and biomass than all four species present on the other two grids.

As was pointed out in the 1976 report, species diversity on the Cold Desert Shrub grid was increased significantly by the presence of the small side wash in the northeast corner of the grid. This provided suitable habitat for Perognathus intermedius and Neotoma stephensi, and it is probable that these species would not have been trapped had not the arroyo been present. This may also be the case for the single Peromyscus eremicus individual which was also captured in the wash. Since the wash brings in to the trapping grid a sample of some of the topographical and edaphic variability characterizing this portion of the monument, it is our feeling that it is most instructive and beneficial to continue trapping there.

Management Recommendations

A general ecological rule is that the greater the complexity of diversity of a habitat, the greater its stability. Thus, the three habitats sampled could probably be ranked 1) Grassland; 2) Juniper/Grassland; 3) Cold Desert Shrub in terms of increasing overall habitat stability. In other words, it seems probable that the impact of such unnatural forces as cattle grazing would be felt to the greatest extent by natural communities of plants and animals in the Grassland habitat, and to a lesser extent in the Cold Desert Shrub. It should be emphasized, however, that all of the naturally occurring plant and animal associations within the monuments must be considered fragile.

As it is one aim of the National Park Service to maintain the resources it governs in as undisturbed a condition as possible while still allowing certain forms of public use, the decision to allow the grazing of cattle on Wupatki National Monument land seems worth reexamination. Even in small numbers, it is probable that grazing cattle exert a significant impact on plant communities at a localized level. While the point might be taken that large, ungulate herbivores were naturally occurring in the area before man's disturbance, it should be recognized that there were mainly pronghorn antelope (Antilocapra americana) and mule deer (Odocoileus hemionus), and that no bovine grazer occurred naturally. (Bison is known from some Arizona archaeologic sites as late as the 15th century (R.H. Hevly, pers. comm.)). The possibility has been suggested that the pronghorn herd found within Wupatki National Monument might be enlarged by favorable management to a population level determined as comparable to that existing before European man's disturbance. This seems to be an idea well worth pursuing, and greatly preferable to the present policy of allowing continued cattle disturbance.

Finally, the highly variable nature of the land within Sunset Crater and Wupatki National Monuments makes it a biologically interesting area, and exceptional in its potential for ecological study. For this reason, recent years have seen a surge in interest in these Monuments as sites for such studies among the faculty and students at Northern Arizona University and elsewhere. Some of these studies may have direct management implications, while others may contribute to a better understanding of the ecology of a particular species or community. In either case, such studies are of benefit to the National Park Service, and the general scientific community as well, and should be encouraged.

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Table 1. Dates of live-trapping during 1977 on each small mammal grid. Sampling periods are given the date of the first morning on which animals were examined.

Sampling Period	Grassland	Juniper/Grassland	Cold Desert Shrub
1	16 June	16 June	18 June
2	29 June	29 June	1 July
3	12 July	12 July	14 July
4	26 July	26 July	24 July
5	13 Aug.	13 Aug.	11 Aug.
6	21 Aug.	21 Aug.	21 Aug.
7	24 Sept.	24 Sept.	24 Sept.
8	22 Oct.	22 Oct.	22 Oct.
9	19 Nov.	19 Nov.	19 Nov.

Table 2. Total numbers of individuals present on the Grassland grid during each of the sampling periods.
 σ = male, φ = female, unk. = undetermined sex

Sampling Period	<u>Perognathus flavus</u> σ / φ / unk. total		<u>Peromyscus maniculatus</u> σ / φ / unk. total		<u>Neotoma stephensi</u> σ / φ / unk. total		<u>Reithrodontomys megalotis</u> σ / φ / unk. total		Totals
1	7/4/1	12	3/5/0	8					20
2	12/6/5	23	1/1/0	2					25
3	15/8/0	23	0/2/0	2	1/0/0	1			26
4	10/8/1	19							19
5	8/9/5	22	0/2/0	2					24
6	6/8/2	16	2/0/1	3			0/1/0	1	20
7	4/3/0	7	1/0/0	1					8
8	6/11/0	17	0/1/0	1					18
9	6/12/0	18							18
Totals		157		19		1		1	178

Table 3. Total number of individuals present on the Juniper/Grassland grid during each of the sampling periods

Sampling Period	<u>Perognathus flavus</u>		<u>Peromyscus truei</u>		<u>Peromyscus maniculatus</u>		<u>Neotoma stephensi</u>		Totals
	♂/♀/unk	total	♂/♀/unk	total	♂/♀/unk	total	♂/♀/unk	total	
1	5/0/1	6	2/2/0	4					10
2	5/4/1	10	0/1/0	1					11
3	9/2/1	12	5/3/0	8	0/1/0	1	0/2/0	2	23
4	6/3/1	10	1/3/0	4	1/0/0	1	0/1/0	1	16
5	5/5/2	12					1/0/0	1	13
6	5/6/0	11	0/1/0	1	0/0/1	1			13
7	3/3/0	6	2/1/0	3	1/1/0	2			11
8	4/4/0	8			1/0/0	1			9
9	4/6/0	10	3/3/0	6	2/0/0	2			18
Totals		85		27		8		4	124

Table 4. Total numbers of individuals present on the Cold Desert Shrub grid during each of the sampling periods

Sampling Period	<u>Dipodomys</u> <u>ordii</u> ♂/♀/unk total	<u>Perognathus</u> <u>amplus</u> ♂/♀/unk total	<u>Perognathus</u> <u>intermedius</u> ♂/♀/unk total	<u>Peromyscus</u> <u>maniculatus</u> ♂/♀/unk total	<u>Peromyscus</u> <u>truei</u> ♂/♀/unk total	<u>Peromyscus</u> <u>eremicus</u> ♂/♀/unk total	<u>Reithrodontomys</u> <u>megalotis</u> ♂/♀/unk total	<u>Neotoma</u> <u>stephensi</u> ♂/♀/unk total	Total
1	0/1/0 1	13/8/2 23	2/2/1 5	1/0/0 1	4/3/0 7			0/1/0 1	38
2	0/2/0 2	14/10/3 27	1/2/0 3		0/2/0 2				34
3	2/2/0 4	14/14/8 36	4/3/1 8		4/3/0 7				55
4	1/1/0 2	14/25/4 43	2/3/0 5		3/2/0 5			0/1/0 1	56
5		13/16/6 35	2/1/1 4		4/1/0 5		0/1/0 1	0/1/0 1	45
6	1/0/0 1	15/14/7 36	1/1/0 2		1/0/0 1		0/1/0 1	0/1/0 1	42
7		18/13/3 34	1/1/0 2		3/1/0 4				40
8	1/0/0 1	14/14/3 31	0/1/0 1		4/4/0 8	0/1/0 1			42
9	1/0/0 1	1/4/3 8	0/1/0 1	3/0/0 3	10/10/0 20		1/1/0 2		35
Totals	12	271	31	4	59	1	4	4	386

Table 5. Lincoln index population estimates for species of small mammals on the Grassland trapping grid.

A = Population estimate

B = standard error

Sampling	<u>Perognathus flavus</u>		<u>Peromyscus maniculatus</u>	
	A	B	A	B
1	13.2	± 4.4	*	
2	23.0	± 3.5	*	
3	23.2	± 2.3	2.0	0
4	*		*	
5	22.6	± 2.2	*	
6	17.3	± 2.9	*	
7	*		*	
8	*		*	
9	*		*	

* indicates that the species was present on the grid during this period but no Lincoln Index estimate is available.

Table 6. Lincoln index population estimates for species of small mammals on the Juniper/Grassland trapping Grid

A = population estimate

B = standard error

Sampling Period	<u>Perognathus flavus</u>		<u>Peromyscus truei</u>		<u>Peromyscus maniculatus</u>	
	A	B	A	B	A	B
1	6.3	± 1.4	4.0	± 0		
2	10.0	± 1.1	1.0	± 0		
3	12.6	± 1.7	8.0	± 4.9	*	
4	*		*		*	
5	12.6	± 3.8				
6	15.0	± 5.5	*		*	
7	*		*		2.0	± 0
8	8.0	± 0	*		*	
9	11.2	± 2.7	6.7	± 1.9	2.0	± 0

Table 7. Lincoln Index population estimates for species of small mammals on the Cold Desert Shrub trapping grid.

Sampling Period	A = population estimate		B = standard error					
	<u>Perognathus</u> <u>amplus</u>	<u>Perognathus</u> <u>intermedius</u>	<u>Peromyscus</u> <u>truei</u>	<u>Peromyscus</u> <u>maniculatus</u>	<u>Neotoma</u> <u>stephensi</u>	<u>Dipodomys</u> <u>ordii</u>	<u>Reithrodontomys</u> <u>megalotis</u>	
	A B	A B	A B	A B	A B	A B	A B	
1	26.2 ± 4.9	6.0 ± 3.0	8.3 ± 3.0	*	*	1.0 ± 0		
2	28.1 ± 3.1	3.0 ± 0	2.0 ± 1.4			2.0 ± 1.4		
3	38.4 ± 4.8	8.0 ± 2.2	10.0 ± 5.0			6.0 ± 4.2		
4	46.7 ± 6.0	5.0 ± 1.1	6.0 ± 2.4		1.0 ± 0	*		
5	36.5 ± 2.6	3.0 ± 1.2	6.0 ± 3.0		1.0 ± 0	*		*
6	43.5 ± 6.7				*		1.0 ± 0	
7	39.0 ± 5.6	2.0 ± 1.4	6.0 ± 4.2					
8	32.4 ± 3.7	1.0 ± 0	10.5 ± 4.3			*		
9	8.0 ± 0	1.0 ± 0	23.8 ± 3.1			1.0 ± 0		*

* indicates that the species was present on the grid during this period but no Lincoln index estimate is available

Table 8. Per cent new individuals captured per sampling period within the Perognathus flavus population at the Grassland quadrat.

Sampling Periods	number unmarked individuals/ captured Total # captured	Percent Unmarked
1	7/12	58.3
2	12/23	52.2
3	5/23	21.7
4	2/19	10.5
5	7/22	31.8
6	4/16	25.0
7	4/7	57.1
8	15/17	88.2
9	12/18	66.6

Table 9. Per cent New Individuals Captured per Sampling Period Within the Peromyscus truei Population at the Cold Desert Shrub Quadrat

Sampling Periods	# Individuals/ Unmarked Total # Captured	Percent Unmarked
1	6/7	85.7
2	0/2	0.0
3	4/7	57.1
4	1/5	20.0
5	2/5	40.0
6	0/1	0.0
7	2/4	50.0
8	5/8	62.5
9	14/22	63.6

Table 10. Per cent trapping success for all species on each of the grids during each sampling period.

Sampling Period	Grassland	Juniper/ Grassland	Cold Desert Shrub	Mean Trap Success per Sampling Period
1	9.02	5.55	19.09	11.22
2	13.88	7.29	19.79	13.65
3	15.97	11.11	29.16	18.74
4	13.19	11.11	29.86	18.05
5	13.88	6.25	23.95	14.69
6	10.41	5.20	19.79	11.80
7	2.77 *	4.51	20.13	9.13
8	7.29	4.51	22.56	11.45
9	6.59	9.72	20.13	12.14
Mean per cent trap success	10.33	7.25	22.71	

*disturbance by cattle caused significant decrease in trapping success

Table 11. Shannon Diversity Indices for communities of nocturnal rodents existing in each of the three major plant communities

	Grassland	Juniper/Grassland	Cold Desert Shrub
Late spring and early summer (1st 3 sampling periods)	.9596	1.4920	1.5851
Late summer (2nd 3 sampling periods)	.8020	1.2362	1.0725
Autumn (1st 3 sampling periods)	.3032	1.3511	1.6402
Overall Value of H'	.8269	1.4702	1.6901

Table 12. Numbers of individual nocturnal rodents per hectare and estimates of biomass per hectare in the three plant communities. A represents the average # of individual rodents per sampling period, B represents the estimated # of individual rodents per sampling period, C represents the estimated biomass per sampling period in grams per hectare and N represents the number of individuals from which average weight was estimated.

Species	Average weight (gm)	N	Grassland			Juniper/Grassland			Cold Desert Shrub		
			A	B	C	A	B	C	A	B	C
<u>Dipodomys ordii</u>	53.3	3							1.33	0.41	21.93
<u>Perognathus flavus</u>	8.9	74	17.40	5.38	47.91	9.44	2.91	25.94			
<u>Perognathus amplus</u>	10.5	50							30.10	9.29	97.58
<u>Perognathus intermedius</u>	12.7	6							3.44	1.06	13.50
<u>Peromyscus maniculatus</u>	20.9	15	2.11	0.65	13.61	0.88	0.27	5.73	0.44	0.14	2.86
<u>Peromyscus truei</u>	24.2	32				3.00	0.92	22.40	6.55	2.02	48.96
<u>Peromyscus eremicus</u>									0	-	-
<u>Reithrodontomys megalotis</u>	11.3	7	0.11	0.03	0.33				0.44	0.14	1.58
<u>Neotoma stephensi</u>	140.6	12	0.11	0.03	4.82	0.44	0.14	19.28	0.44	0.14	19.68
Totals			19.73	6.09	66.67	13.76	4.24	73.35	42.74	13.20	206.09

Table 13. The percent of the biomass in each habitat type that is supported by the three general feeding strategies: herbivory, granivory and omnivory

Feeding Strategy	Habitats		
	Grassland	Juniper/Grassland	Cold Desert Shrub
herbivory	7.7	26.3	10.3
granivory	71.9	35.4	64.5
omnivory	20.4	38.3	25.2

Table 14. Monthly precipitation totals, May to November, 1978 and 1977 at Wupatki National Monument Headquarters

Month	Precipitation in Inches	
	1976	1977
May	0.42	0.01
June	trace	0.405
July	2.56	2.73
August	0.24	3.0
September	2.60	0.51
October	0.45	0.50
November	0.13	0.31
Total	6.40	7.465

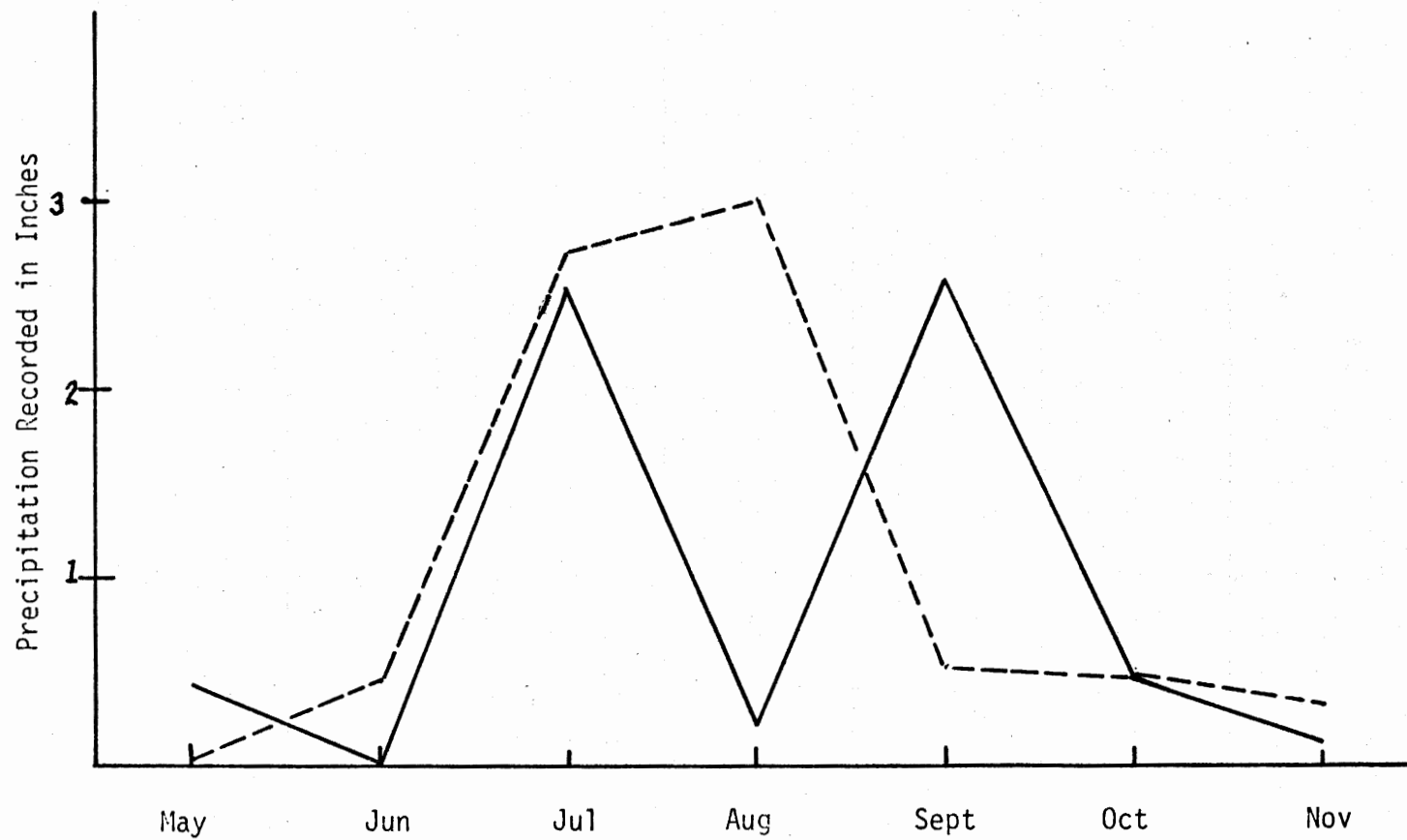


Figure 1. Monthly precipitation at Wupatki National Monument Headquarters. 1976, solid line; 1977, dashed line.

