

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

**FINAL REPORT
(PHASE III)**

JANUARY, 1980

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

**PREPARED BY MEMBERS OF THE
DEPARTMENT OF BIOLOGICAL SCIENCES
NORTHERN ARIZONA UNIVERSITY
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Office of Natural Resources Management
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GENERAL INTRODUCTION

In order to understand more thoroughly the nature of the biological resources existing at Sunset Crater and Wupatki National Monuments in Arizona, the National Park Service has contracted with some members of the Department of Biological Sciences at Northern Arizona University, Flagstaff to conduct a floral and faunal survey and analysis of the Monuments.

This project was begun in early 1976 and two annual reports have been prepared summarizing the results obtained through 1977. This report presents the results of work conducted in 1978 (Phase III) under terms of contract No. CX-702980016.

Research assistants involved in collecting data and analyzing results were: Stephen D. Duke (waterhole survey), L.T. Green, III (grazing studies), David M. Nelson (general vegetation studies), Curtis Overcast (amphibians and reptiles), Bruce Palmer (livestock food habits), and Jon Peters (arthropods).

Dr. C.D. Johnson, Professor of Biology at N.A.U., was instrumental in planning certain portions of the research and reviewed the sections on general vegetation and arthropods. Dr. G.C. Bateman, Associate Professor of Biology, was the project director and principal editor of this report.

The investigators gratefully acknowledge the fine cooperation provided by members of the National Park Service, including, but not limited to: Ms. Marjorie Hackett, Superintendent, and Mr. Bill Paleck, Chief of Interpretation and Resources Management, Sunset Crater and Wupatki National Monuments, and Dr. Milford Fletcher, Regional Biologist, National Park Service. We also appreciate the financial support from the National Park Service which made this work possible.

I

GENERAL VEGETATION STUDIES

INTRODUCTION

Sunset Crater and Wupatki National Monuments are currently being studied for basic biological information which will assist in the formulation of intelligent decisions regarding future management of these unique natural areas. All available information concerning the composition and ecology of the biota of these areas will undoubtedly be of great value in making wise decisions. It is our responsibility to provide this information and to help as much as possible to preserve these resources.

This section of the report deals with the vegetation of these monuments. Objectives of this year's work include:

1. Mapping the distribution of and determining population numbers of threatened and endangered species on both monuments.
2. Determining the manner and rate of plant invasion on the Sunset Crater volcanic cone.
3. Determining conifer densities on Sunset Crater National Monument.
4. Surveying the aquatic plants on the monuments.
5. Mapping the distribution of invading plant species at Wupatki National Monument.
6. Making management recommendations concerning any or all of the above.

METHODS AND MATERIALS

Sunset Crater Successional Study

A ten m wide transect was placed on the north slope of Sunset Crater. This transect was 900 m long and was divided into 90-10x10 m plots. Densities of tree and shrub species were determined for each plot. Herbs were counted in a two m wide side transect which was run along the west side of and included within the wider transect. All data were obtained using methods designed by Egger (1964) except that crown cover was used for measuring tree size as opposed to basal area. All data we gathered were compared with that obtained by Egger.

A transect similar to the one on the north slope was placed on Sunset Crater's south slope. It was shorter in length (700 m) and was divided into 70-10x10 m plots. Densities of trees, shrubs and herbs were determined as they were for the north slope except that the two m wide side transect was run along the east side of and included within the wider transect. All data were compared with those recorded in 1964.

Sunset Crater Conifer Densities

Conifer densities were determined for two locations on Sunset Crater National Monument using the plotless point-quarter method (Cottam and Curtis, 1956; Greig-Smith, 1964). Mean distance from point to tree species was determined using the following formula:

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

Mean area covered per tree was determined using:

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

This gives the number of trees per hectare by the following formula:

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

Density and frequency values were calculated using these formulae:

$$\text{relative density} = \frac{\text{individuals of species A}}{\text{total individuals of all species}} \times 100$$

$$\text{absolute density} = \frac{\text{relative density of species A}}{100} \times \text{total density of all species}$$

$$\text{absolute frequency} = \frac{\text{number of points at which species A occurs}}{\text{total number of points sampled}} \times 100$$

$$\text{relative frequency} = \frac{\text{frequency value for species A}}{\text{total frequency value for all species}} \times 100$$

Crown diameters were measured for each tree species and converted to crown cover values by the formula πr^2 . Total crown cover was determined and was divided by the total number of trees measured to obtain mean crown cover. Percent absolute crown cover per species was calculated using:

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

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 three (Risser and Rice, 1971). Importance values given in this report are importance percentages based on 100.

Wupatki Invader Species

Three transects were run across the tamarix-camelthorn sump at Black Falls on Wupatki National Monument. For each transect plants were counted within 1x1 meter quadrats placed at 30 m intervals along the tape. Data which were obtained from each transect were analyzed separately and were also combined to obtain density and frequency values for the entire sump. The formulae used when the data were analyzed are identical to those described in the previous section for relative density, absolute density, relative frequency, and absolute frequency.

In order to re-locate Transect 1, the road to Black Falls must be travelled until a fork in the road is encountered which branches left directly into the sump. This branch of the fork must be travelled until it forks again. From this intersection Transect 1 is located 75 m away in a direction 30° east of due north and is marked by a metal shaft driven into the ground. From this marker, Transect 1 runs 100° west of due north for 240 m until it emerges from the other side of the sump.

Transect 2 is located 200 m north of Transect 1 and runs in the same direction. It is also marked by a metal stake and is 210 m long. Transect 3 is located 150 m north of Transect 2 and is also marked by a metal stake. Transect 3 runs 30° west of due north and is terminated at the Little Colorado River. It is also 210 m long.

THREATENED AND ENDANGERED PLANTS

Wupatki National Monument

Four species of plants known to occur at Wupatki National Monument are found listed as threatened species in the Smithsonian Institution publication, Endangered and Threatened Plants of the United States. These plants were lo-

cated and their distribution was mapped. Phenological notes for the four threatened species, Amsonia ^{Deqbone family} peeblesii Woodson., Phacelia serrata Voss., Phacelia crenulata Torr., and Astragalus lancearius Gray. were prepared using both field observation and other references. Also included in the mapping project was Oenothera boothii Dougl. which is only scantily represented on the Monument and deserves management consideration (see threatened, endangered and invader species map for Wupatki National Monument).

Amsonia peeblesii was discovered at five locations on Wupatki National Monument. The first of those locations is in Section 7 approximately 0.4 miles south of Citadel Sink and halfway between the base of South Mesa and the road. One hundred sixteen individual clusters of Amsonia were counted. Soil in the area consisted of a sandy base with a light cinder cover and was bare with the exception of a few four-winged saltbushes and a few grasses.

The second and third locations at which Amsonia were found are nearly adjacent to one another at the merging of two jeep trails in Section 13 of the Monument. Forty-two clusters were counted near the intersecting jeep trails at the base of a rocky ledge. Approximately 100 m northwest of this location, 106 additional clusters of Amsonia peeblesii were counted in a small unnamed wash. Again the soil was sandy with a light cinder cover and the ground quite void of cover, supporting only a few grasses and the Amsonia.

Amsonia peeblesii was found in Sections 1 and 6 at the base of Cedar Canyon near Borrow Pit. Three hundred twenty-four clusters were counted in the grass - Atriplex-Fallugia association adjacent to the Juniper-Grassland, but none were found in association with junipers. Soil conditions at this location are the same as described above for Amsonia.

The fifth location at which Amsonia peeblesii was located is in Section 21 and immediately surrounding Wukoki Ruin. Fourteen clusters of Amsonia were counted. The soil in this area is, again, the same as described for

locations 1, 2 and 3.

Amsonia peeblesii is known only to Northern Arizona. It is reported in this area from Coconino and Apache Counties and perhaps also from Navajo County at 4500 to 6000 feet (McDougall, 1973). At Wupatki it is found at 5300 to 5500 feet. Amsonia peeblesii is a perennial shrub with alternate leaves and blue flowers in terminal compound cymes. The calyx is small and five parted. The corolla tube is a narrow, funnel-form tube with spreading lobes. The corolla tube is 16-18 mm long with lobes of 7-12 mm. The fruit is torulose and two parted to form a V-shape. Flowering was not observed during the field season as it occurs in May to early June (McDougall, 1973).

The second threatened species occurring on Wupatki National Monument is Phacelia serrata, which is also found on Sunset Crater National Monument. Phacelia serrata was located in Section 14 of the Monument on the northwest slope of Doney Mountain at elevations of 5100 to 5400 feet. The slope of Doney Mountain at this point is approximately 45° and is essentially devoid of plant life. The soil consists of deep cinders. Seven hundred twenty-six individual Phacelia plants were counted.

Phacelia serrata is an annual herbaceous plant which reaches a measured height of around 40 cm. Its leaves and stems are heavily glandular-pubescent and are sticky to touch. The largest leaf measured was 3 cm long and 0.9 cm wide but McDougall (1973) gives leaf size as 4 cm long and up to 1.5 cm wide. The measured length of the calyx was 3 mm and the corolla length was 7 mm. Both the stamens and the style are exerted from the corolla, the style being longer. Flowers have purple limbs and the corolla tube is white. Phacelia serrata is known only from Coconino County, Arizona. The type-specimen is from the San Francisco Peaks and the species is also reported from the Grand Canyon and from the area near Flagstaff. Flowering occurs from April to

September (McDougall, 1973).

Another threatened species found on Wupatki National Monument is Phacelia crenulata, a close relative of Phacelia serrata. Phacelia crenulata is very abundant and widely distributed throughout the Monument. It can be easily located during the month of May simply by standing on high ground overlooking the grassland areas. Extensive patches which are purple in color will be evident and represent patches of several hundreds to thousands of Phacelia crenulata plants.

Phacelia crenulata is an annual plant, 10 to 60 cm in height, glandular and very strong-scented. It is very similar in appearance to Phacelia serrata especially when the flowers are observed. The most evident difference between the two is in the shape of the leaves. Phacelia serrata has an oblong shaped leaf with deeply serrate, jagged margins whereas Phacelia crenulata has an oblong shaped leaf with pinnately lobed margins, not nearly so jagged. Phacelia crenulata occurs in our area in Coconino, Mohave, and Yavapai counties at 2500 to 4500 feet. Flowering occurs from January to early June (McDougall, 1973).

The final threatened species, Astragalus lancearius, is found at only one location on Wupatki property. Twenty-two plants have been located. These occur in the northeast corner of Section 11 just 15 meters east of the road to Black Falls. Astragalus lancearius is found only in southwestern Utah and adjacent parts of Arizona (McDougall, 1973). This site at Wupatki National Monument may very well represent the most southernly record of Astragalus lancearius.

Astragalus lancearius has been represented in the Wupatki Herbarium since 1976, however, this record was incorrectly identified and actually represents Astragalus praelongus Sheldon. The record of Astragalus lancearius referred to

in this report was collected on 14 June, 1979.

A. lancearius stands 20 to 45 cm high with few or solitary stems. Leaves are from 4 to 10 cm long, the uppermost ones reduced to a naked rachis, the lower ones bearing 1 to 3 pairs of distant linear leaflets from 2 to 14 mm in length. Racemes bear 10 to 25 white flowers fringed with pink. Pods are deflexed, sessile or nearly so, 2 to 3 cm in length and with nearly flat sides. Flowering occurs in April to June (McDougall, 1973).

Oenothera boothii was included in the mapping project, not because it is listed as threatened or endangered, but because of its rarity on Wupatki National Monument. Oenothera boothii is not on either the state or federal threatened and endangered species list, but perhaps it should be (Rominger, pers. comm.).

Oenothera boothii was discovered at only one location on the Monument. One hundred sixty-seven plants were counted almost directly in the center of Section 12 where Antelope Wash empties into the Wupatki Basin. Their extent covers about one-quarter mile of the bottom of the wash. Soil in the area is sandy gravel with a light cinder cover. The slope is nearly level.

An annual herb, Oenothera boothii ranges from 10 to 40 cm in height. Leaf blades are ovate and subentire to denticulate in shape, measuring up to 5 cm in length. Sepals range from 3 to 7 mm and petals from 4 to 9 mm in length. Field measurements closely match those given in McDougall. The corolla is white becoming pink at maturity. Flowers appear in June lasting till late August.

Sunset Crater National Monument

Sunset Crater National Monument hosts Phacelia serrata which is on the federal threatened list and also Penstemon clutei which is on the endangered list. Both of these species have a widespread distribution on the Monument

and surrounding area (see 1978 vegetation map for Sunset Crater National Monument for detailed distributions).

Phacelia serrata has been located on Sunset Crater National Monument at elevations ranging from 6800 to 8000 feet. Its preferred microhabitat is bare, fine cinder soil with little or no shading. Phacelia serrata appears to be an aggressive colonizing plant in bare cinder areas and seems to be increasing in this area (Rominger, pers. comm.).

The only plant found on either monument and appearing on the federal endangered list is Penstemon clutei. Penstemon clutei is a perennial herb known to occur only from Sunset Crater National Monument and adjacent areas. It grows from 30 to 80 cm tall. Leaf blades are lanceolate to broadly ovate, finely and sharply serrate-dentate, the lower ones petioled, the cauline ones sessile and the uppermost leaves connate-perfoliate forming disks up to 8 cm long and 4 cm wide. Sepals are 3 to 5 mm long and the corolla is deep pink, 15 to 25 mm long and nearly regular. The corolla throat is 9 to 12 mm long (McDougall, 1973).

Penstemon clutei has been located on the cinder hills of Sunset Crater National Monument at about 7000 feet. A number of plants have been found at 7300 feet on the south slope of O'Leary Peak (S. Russell, pers. comm.) and more were located on Sunset Crater Cone as high as 7800 feet.

Flowering of P. clutei begins early in June and normally continues until late in June in areas of low plant density. In areas of higher plant densities the bloom has been observed as late as the middle of August. Flowering plants observed as late as 17 September in 1976 indicate that a second bloom is possible at higher ranges. These observations were made on O'Leary Peak at above 7300 feet. It is possible that a cold period induced the plants to flower again during the late season warmth in 1976 (Russell, pers. comm.). This flow-

ering behavior did not occur during 1978, however.

Pollinators of P. clutei include two hummingbirds (Broad-tailed and Rufous), the White-lined Sphingid Moth (Hyles linneata), and several hymenopterans observed visiting P. clutei include at least two families, the Apidae and Megachilidae. Three species of the family Apidae were observed, two of the genus Anthophora (digger bees) and one of the genus Bombus (bumble bee). Of these, the most frequent visitors were the digger bees. The other observed visitor of P. clutei was the leaf-cutter bee of the family Megachilidae. Leaf-cutter bees have been observed entering the flower by chewing an entry hole through the corolla tube (R. Hevly, pers. comm.).

DISCUSSION

A difference in height was observed between the population of Phacelia serrata growing on Wupatki National Monument and those growing on Sunset Crater National Monument. The largest specimens at Wupatki measured 40-50 cm in height. Those measured at Sunset Crater were considerably smaller, reaching heights of only 30 cm. Three possible explanations for this difference are:

1. The growing season is longer at Wupatki than it is at Sunset Crater.
2. The population of Phacelia at Wupatki is growing adjacent to a paved road where runoff rainfall supplies additional moisture.
3. Phacelia serrata is listed in the standard Arizona floras at elevational ranges of 5000 to 7000 ft. Those plants found at Sunset Crater range in elevation from 6800 to 8000 ft. while those found at Wupatki are at 5100 to 5400 ft., well within their given range.

Probably explanations 2 and 3 are better than explanation 1. Wupatki specimens were observed at full height in June, indicating that Phacelia does not require a long growing season to attain maximum vegetative growth. Specimens which

were found close to the road at Sunset Crater were larger, on the average, than plants found away from the road. This indicates that the runoff from the road does have an effect on plant size and supports explanation 2. Phacelia that were found at 8000 ft. on Sunset Crater Cone were very stunted, averaging only 5-10 cm per plant. Plants found at 6800 ft. were much larger. Those found at Wupatki were larger yet. This indicates that plants growing on Sunset Crater National Monument are existing in a marginal habitat. Perhaps the reason that P. serrata is found on Sunset Crater Cone at 7800 ft. at all is because the mulch effect produced by the cinders provides additional capillary water which would otherwise not be present at that altitude.

Current research regarding the speciation of Penstemon clutei indicates that Penstemon pseudospectabilis Jones, the presumed parental species, may have occurred at Sunset Crater before its eruption (Russell, pers. comm.). Climatic conditions at that time were warmer and more humid than at present. Penstemon pseudospectabilis ssp. connatifolius (Nels.) Keck occurs today in the upper regions of Oak Creek Canyon and on Schnebly Hill. The species tends to prefer volcanic soil presumably for the mulch effect. It has not been seen above Oak Creek or anywhere nearer Sunset Crater. All of these factors indicate that geographic isolation of P. clutei from a parental population of P. pseudospectabilis ssp. connatifolius could possibly have occurred.

Other evidence that indicates the origin of P. clutei from P. pseudospectabilis ssp. connatifolius includes preliminary results from flavonoid chromatography, which show many similar spots for the two species (Russell, pers. comm.). Also, chromosome counts suggest that P. clutei is a mere segregate of the population of P. pseudospectabilis ssp. connatifolius that was present at or near the time of eruption of Sunset Crater. Theoretically, as the climate changed, this created the segregate population and later speciation possibly

took place due to pollinator-mediated selection toward more effective hymenopterian pollinator species. The corolla shape especially reflects this possibility in that it is inflated more than the parental species to accomodate pollinators that must bodily enter the flower (Russell, pers. comm.).

Endangered species are those in danger of extinction throughout all or a significant portion of their range. Recently extinct species are those no longer known to exist after repeated search of localities where they once existed or could be expected to exist.

The Endangered Species Act of 1973 is the first federal law to protect endangered plants as well as endangered animals. Consequently, the Smithsonian's study is the first effort ever made to assemble data on endangered and threatened plants on a large scale. Ten percent of our nation's native vascular plants have become endangered, threatened, or extinct. Arizona alone has 64 endangered species and 58 species listed as threatened (Smithsonian report, 1978). Sixty to seventy percent of endangered species of plants in the continental United States are on federal and state lands (NPCA Report, 1975).

Under legislation provided in the Endangered Species Act of 1973, threatened and endangered species are strictly protected. All federal departments are obligated to utilize all their authority to ensure that conservation programs are initiated for the protection of endangered and threatened species. Also, all actions authorized by these departments must be such that they do not jeopardize the continued existence of these species or result in destruction or modification of their habitat. Endangered species occurring on federal land must be protected from the effects of timber harvesting, human utilization, mining, and cattle and sheep grazing.

SUNSET CRATER SUCCESSIONAL STUDY - NORTH SLOPE

In 1964, a vegetational survey was conducted on the north slope of Sunset Crater by Willis Egler of Tulane University. Tables 1, 2, and 3 are taken from the final report (1964). On 1-3 October, 1978, we conducted a survey employing similar methods for the purpose of comparing new data with those obtained in 1964.

A 10 m wide transect was established on Sunset Crater's north slope for the purpose of measuring the densities of herbs, shrubs and trees. The transect was 900 m in length and was divided into 90 - 10 X 10 m plots. Trees and shrubs were counted in the 10 m wide transect and herbs were counted in a two m wide transect which was included within the larger transect and run along its west side. Plot number 90 was located at the summit of the crater, plot number 20 at its base and plot number 1 was 200 m north from the base. To relocate the transect, the north side of the crater must be climbed and the highest point on the north rim must be located. The highest point on the north rim is also the highest point on the crater and will be obvious to sight as it is a rock which juts about two or three m above everything else. Approximately six or eight m due north of that rock is a metal U.S.G.S. marker. The marker is in the exact center of plot number 90 from which the transect runs downhill, due north.

Trees

Data obtained in 1964 for tree species are presented in Table 1. Those obtained from the 1978 study are summarized in Tables 4 and 5. Three species were recorded in 1964 and four were found in 1978 with Pinus ponderosa Lawson dominant in both cases. The fourth species recorded in 1978 and represented by only one individual was Pseudotsuga menziesii (Mirb.) Franco. The first

tree recorded in both years was in plot number 58 which is 380 m up from the base of the crater at an altitude of around 7500 feet. Beyond plot 58 is a shrub-grass-herb zone.

There is very little difference between the data obtained for 1978 and that recorded 14 years ago regarding tree species. Table 1 shows the largest trees, D.B.H. classes 10" to 16", to be found in plots 19 to 26. (plots 1-18 not included in data). Table 5 supports this tendency showing crown diameter to be greatest in plots 1-31. The greatest number of seedlings recorded in Table 1 are in plots 40-52 and this is also strongly supported by data shown in Table 5 for 1978.

In 1964, Pinus flexilis James was reported as present in plots 27 to 45, and Pinus edulis Engelm. represented in plots 53-56 which indicates that each occupies its own altitudinal position. This is not supported by the 1978 study, however, and data from Table 4 show the two pine species to be coextensive from plots 24 to 54. Pseudotsuga menziesii was located in plot 42.

Shrubs

Shrub species in 1978 were represented by five as opposed to four species located on the north slope in 1964 (see Tables 2 and 6). Two species were dominant, each having its own range. Eriogonum aureum Jones was located in plot 89 in both studies and was found to occur in high densities in plots 47 - 89. The 1964 study shows its range ending in plot 28 while in 1978 it was found to extend beyond the base of the crater to plot number 5. Fallugia paradoxa (D. Don.) Endl. was distributed most abundantly in the nearly flat area beyond the base of Sunset Crater, in plots 1-20. In both studies Fallugia paradoxa was found to extend up the crater to around plot number 62 with one straggler being found in 1978 in plot number 79.

Eriogonum aureum appears to be more drought resistant than Fallugia paradoxa (Eggler, 1964). Crown cover values indicate that light shading factors are not of major significance to Fallugia, so it may grow best at the bottom of the crater due to differences in moisture. However, there may be a shading factor involved with the success of Eriogonum because numbers drop off radically with the increase in shading, possibly due to increasing tree densities descending from plots 58-50. This decrease in Eriogonum could also be the result of direct competition for moisture with pines.

Lygodesmia spinosa Nutt. was found only in plot number 5 in 1978 although it was found in patches in 1964 in plots 40-41, 52-54 and 67-68, reaching numbers of 26 per plot in two cases. Ribes cereum Dougl. and one new member in the 1978 study, Chrysothamnus nauseosus (Pall.) Britton were minor members of the shrub population.

Herbs

Table 3 gives the quantitative data and distributions of herbs for the 1964 study. Table 7 gives the same data for 1978 and Table 8 presents data for those herbs counted in 1978 which were not found during the 1964 study. Because data are presented in each case on a single sheet, values were combined as indicated.

To provide reference points the transect will be considered in four segments. Plots 1-19 are in the interconal forest at the north base of the crater; 20-45 include the most nearly closed pine forest and will be referred to as forest; 46-58 will be referred to as open woodland. Plots 59-90 are in the shrub-herb zone (Eggler, 1964).

The grass, Andropogon hallii Hack., occurred throughout all four sections of the transect in 1978 but was not found extending into the shrub-herb zone

in 1964. In both cases it was found in greatest abundance in plots 40-60. Artemisia includes two species and a variety as indicated by Egger in Table 3. Artemisia occurred only in the lower two zones in 1964 but occupied the lower three zones in 1978 and was coextensive with pine. Bouteloua gracilis (H.B.K.) Lag. was found occurring mainly in the interconal forest and forest with a slight overlap into the open woodland in 1978 but was only found in the interconal forest in 1964. Euphorbia fendleri Torr. and Gray was in all zones in both cases but extended farther into the shrub-herb zone in 1964. Euphorbia lurida Engelm. decreased its distribution and was only found in the forest in 1978 as opposed to forest and interconal forest in 1964. Galium rothrockii Gray grew mainly in the forest and open woodland in 1964 but has extended its range to include the shrub-herb zone. Gilia aggregata has persisted in the open woodland and the shrub-herb zones. Monardella odoratissima Benth. had nearly the same range in both studies, occupying all four zones but scantily represented in the interconal forest and only extending about 40 m into the shrub-herb zone. Oenothera caespitosa Nutt., was sparsely scattered throughout all four zones in both studies. Orobanche fasciculata Nutt., a root parasite, was only represented by one specimen in 1978, which was just above the timberline in the shrub-herb zone. In 1964, the root parasite was found to extend about 80 m past the timberline. Oryzopsis hymenoides (Roem. and Shult.) Rick-er was abundant above the timberline in both studies. Penstemon barbatus (Cav.) Roth was found in the lower three zones in 1964 but was confined largely to the forest and open woodland in 1978. Penstemon clutei A. Nels ranges from open woodland to the lower shrub-herb zone. Phacelia integrifolia Torr., which was re-identified as Phacelia serrata Voss. in 1979, was found in the open woodland and shrub-herb zone in 1964 but only located in the shrub-herb zone in 1978. Physaria newberryi Gray was mostly confined to the upper three zones and

excluded from the interconal forest in both studies. Poa fendleriana (Steud.) Vasey was reported from the upper cone forest and lower open woodland in 1964 but did not appear at all in 1978. Sitanion hystrix was above the timberline in 1964 but was found only in open woodland and upper forest in 1978.

Five new species turned up during the 1978 study which were not previously found. Stipa neomexicana (Thurb.) Scribn. was represented in the forest and open woodland in low numbers. Bahia dissecta (Gray) Britton was limited to the forest. Brickellia multiflora Kellogg was found in the lower forest and Opuntia sp. was in the interconal forest. The last new species was a mustard, Sisymbrium linnearifolium Barneby and was represented by a single individual in the interconal forest.

SUNSET CRATER SUCCESSIONAL STUDY - SOUTH SLOPE

A study was conducted on the south slope of Sunset Crater employing methods similar to those used in the north slope study. Three wooden stakes were left remaining on the south slope to mark the course of the transect. One stake marks the beginning of the transect, plot 70, at the summit of the crater, one the midpoint of the transect, and the third stake marks the point at which the transect ends, at plot 1. Just as in the north slope study, trees and shrubs were counted in a 10 m wide transect and herbs were recorded in a two m wide transect which was run down the east side of and included within the 10 m transect. Data obtained were compared with those obtained by Egler in 1964, although exact relocation of Egler's transect was impossible.

Trees

Data presented in Table 9 represent those obtained by Egler for tree species on the south slope. Those presented in Tables 12 and 13 were obtained on 24-25 June 1979. Three tree species were recorded during the 1964 study

while only two were located within the transect in 1979. Only Pinus ponderosa and Pinus edulis were found in both studies.

Twenty-one Pinus ponderosa were recorded in 1964 compared to 31 in 1979. The area which contributed the most to the increase was at the base of the crater in plots 1-10. Ponderosa pine were found only in plots 1-6 in 1964. Data obtained for ponderosa pine at the rim of the south slope were similar in both studies with respect to both number and distribution, being found in only the top two plots in 1964 and in the top three plots in 1979. In plots 11-67, only one ponderosa pine was recorded in 1979 compared to three in 1964.

Pinus edulis was located within the transect five times in 1964 and three times in 1979. In the present study, pinyon pine was not recorded above plot number 13 while in 1964 it was recorded twice above that point in plots 16 and 67. These trees were observed all the way to the top of Sunset Crater in 1979, however, and it is not believed that their distribution has changed significantly.

Shrubs

The shrub community on the south slope of Sunset Crater was represented by the same four species in both 1964 and 1979. The numbers and distributions of all four species, Chrysothamnus nauseosus, Eriogonum aureum, Fallugia paradoxa and Ribes cereum, remained fairly stable over the past fifteen years. Eriogonum aureum is the only possible exception to this as it has more than doubled in number while existing within the same range in the top nine plots of the transect. Data obtained in 1964 for shrubs is presented in Table 10 while that for 1979 is in Table 14.

Herbs

Data for herbs are summarized in Table 11 for 1964 and in Table 15 for 1979. Twenty different species of herbs were counted in 1964 and only 18 were counted in 1979. This difference in herb composition was accounted for by the presence of two new species in the 1979 study and the deletion of four species which were present in 1964. The name used when referring to the herb Phacelia integrifolia Torr. in the 1964 study was changed to Phacelia serrata in the 1979 study.

Two new species were within the transect in 1979 which were not present in the data from 1964. The first of these is Lupinus argenteus Pursh. which was found in plot 5 and was represented by only a single individual. The other new member to the south slope community is the grass, Poa fendleriana, which was found in plots 1-4 and in plot 26. The four species which were included in the 1964 study and not included in the 1979 data are: Aster canescens Pursh., Euphorbia lurida Engelm., Kuhnia rosmarinifolia Vent., and Opuntia compressa var. macrorhiza Benson. None of these was found in more than one plot in the 1964 study.

Of all the other herbs found on Sunset Crater's south slope, only two seem even remotely likely to have varied in their distribution over the last 15 years. Andropogon hallii was found in plots 1-12 in 1979 and although it was also found in that zone in 1964, it was also found in plots 67-68. Its presence in one transect and not the other is probably due to chance alone, however. The other difference which was noted was in the distribution of Erisymum capitatum, which was located in both the upper and lower ten plots of the 1964 transect and was only found in the lower ten plots of the 1979 transect.

DISCUSSION

Eggler (1964) proposed that perhaps the timberline on Sunset Crater was fixed in its present position. Two observations support this. First, the timberline has not moved over the last 14 years; it has remained in plot number 58. The other observation supporting a stable timberline is that seedlings which were present in 1964 are still present throughout the same range in 1978. This indicates that they live only a short while, die, and are replaced by new seedlings. Apparently moisture is sufficient in that altitudinal range to allow germination of pine seeds but once the seedlings roots become established they must compete with one another for the available moisture.

Data comparisons between 1964 and 1978 indicate that no rapid plant invasion is presently occurring on the north or south slopes of Sunset Crater. Any differences in data that were observed could easily be the result of environmental variability between 1964 and 1978. Almost all plants which are presented in Table 3 for 1964 are still present on Sunset Crater in virtually the same numbers and with similar distributions. The addition of five infrequent new species in 1978 is also probably insignificant. Modern ecological theory suggests that as more sampling is done within a community, more rare species will be found and species diversity will be increased. This could explain the five new species which were found without suggesting that they are recent invaders of the crater.

Plant life will probably remain quite stable on Sunset Crater for several years or even decades until some environmental or ecological factor alters habitat conditions there. Environmental factors such as fire or invasion by some exotic plant competitor could drastically alter the vegetation type. More

likely, the habitat will be slowly changed to accomodate more or different plant forms by ecological factors such as the buildup of animal and plant litter which would increase the organic content of the soil. Pine litter could change the pH of the soil and cause a vegetation change also. Succession on Sunset Crater will probably be dependent on slow habitat alterations such as these and observable differences in the vegetation will take years to develop.

SUNSET CRATER CONIFER DENSITIES

Two point-quarter transects were established on Sunset Crater National Monument to determine tree densities. One was located in Section 13, beginning at a point approximately 200 m west of the Monument's boundary and 50 m north of the main road. This transect, which will be referred to as SSC1, is directed toward O'Leary Peak Lookout Tower for the first 13 points then is redirected 90° toward Quadrant B for the remaining seven points. The total 20 points are spaced approximately 30 m apart (for more exact location, see vegetation map for 1978 field season).

Data from SSC1 are summarized in Table 16. Pinus ponderosa is by far the most abundant tree species, occurring at an absolute density of about 144 trees per hectare. Pinus edulis is second in abundance at about 10 trees per hectare followed by one-seeded juniper (Juniperus monosperma) at about six trees per hectare. The largest species with respect to crown cover is the one-seeded Juniper, averaging about 27 square m per tree, followed by Pinus ponderosa at about 24 square m per tree and Pinus edulis at almost 2 square m per tree. Total percent ground cover by trees for this area is about 37%.

The second point-quarter transect, referred to as SSC2, is located in Section 24 about 200 m due south of the View Point and is directed at 160° west

of due north. SSC2 consists of 10 consecutive sample points spaced about 30 m apart (see vegetation map for 1978).

Table 17 summarizes the data from SSC2. Pinus ponderosa again was most dense at 153 trees per hectare. Pinus edulis occurs at an absolute density of over 33 trees per hectare while Juniperus monosperma is represented by just less than five individuals per hectare. The largest trees are the ponderosa pines having an average crown area of 13.155 square m followed closely by one-seeded juniper at 12.56 square m. The smallest trees are Pinus edulis which have an average crown area of 6.14 square m. Absolute crown cover is less than 23% for all tree species combined.

AQUATIC PLANTS

Several locations on both monuments were searched for the possible presence of submergent and emergent aquatic plant life. No standing water is present on Sunset Crater National Monument and hence, no aquatic plants were located. Wupatki National Monument has several water sites including Heiser Spring, a water tank in Section 30, two sewage ponds at the monument headquarters and two others near employee housing in Section 32. All of these locations were visited but no higher aquatic plants were found.

Water samples were collected from all sites on 21 June, 1978 and examined for microscopic algae. All water samples contained phytoplankton of similar composition. Those which were identified were green algae of the genus Chlor-ella, and many species of diatoms.

NOXIOUS PLANTS

Included in this year's mapping project at Wupatki National Monument were sites of occurrence of noxious and invader plant species. These species

include Alhagi camelorum Fisch. and Tamarix pentandra Pall. Mapping of these noxious plants was done so that their extent can be monitored for future management purposes (see threatened, endangered and invader species map for Wupatki National Monument).

Major problem areas for these invader species occur in Sections 1 and 2 along the Little Colorado River. Invader species occur in high densities in these Sections in an area known as Black Falls Sump. Three transects, in which a 1m^2 quadrat was included every 30 m, were used to determine density and frequency values for Tamarix and camelthorn in Black Falls Sump (see Table 18). A more detailed description of the methods used and of the re-location of the transects is given in the methods section of this report. One plant for either species is defined as a stem which has its origin at soil level.

When data from Transects 1, 2 and 3 were combined, the overall density for each species in Black Falls Sump was obtained. Tamarix pentandra occurs there at an absolute density of 230,833 individuals per hectare and Alhagi camelorum occurs at 63,750 individuals per hectare. Transect number 1 is located the farthest away from the river while Transect number 3 is nearest the river with Transect number 2 between them. When data from the three transects are compared they reveal that camelthorn becomes more dense away from the river at the invading edges of the sump, rising from an absolute density of 10,000 individuals per hectare in Transect 3 to 156,250 individuals per hectare in Transect 1, about 600 meters from the river. Tamarix was found to occur in its lowest density in Transect 1 also, at 108,570 individuals per hectare. Highest density values for Tamarix were obtained in Transect 2 at the center of the sump where an absolute density of 449,857 Tamarix per hectare was observed. The density of Tamarix then decreases again in Transect 1 to 205,000

individuals per hectare.

Probably the reason that Tamarix occurs in the lowest densities nearest the river is because the individual Tamarix which occur there are older, established individuals and have claimed their space, not allowing younger plants to compete. Many of the Tamarix which were counted in Transect 2 were very small, young stems, supporting this idea. In Transect 3, the lower density of Tamarix is probably due to the increased competition for water created by the high occurrence of camelthorn there.

The occurrence of Tamarix pentandra and Alhagi camelorum in Black Falls Sump is a major problem due to extremely high densities of these plants. Other locations at which these plants have been discovered in lower densities were mapped and will be briefly described here.

Alhagi camelorum has been observed in Section 13 of the Monument near the intersection of the main road with a dirt road leading to a borrow pit. Seventeen plants were counted in this location which is about eight miles from the Little Colorado River. Tamarix has been discovered in Section 19 about six miles away from the river at the end of a dirt road which leads from the main road to a ruin only about 100 m from the road. One Tamarix tree was recorded here which was about ten feet in height. Also in Section 19, where Deadman Wash crosses the main road, a site of both Tamarix and camelthorn occurrence exists. Nine clusters of Tamarix and many camelthorn were noted in this area.

Another site in Deadman Wash in which these invader species occur includes one located almost centrally in Section 20. Both Tamarix and camelthorn occur at this location. Thirteen clusters of Tamarix and approximately 100 camelthorn plants occur at this site. Other locations in Deadman Wash include only Tamarix and include four sites in Section 11 and one site in a sidewash in

Section 10 at the edge of Section 11. These sites have from one to four clusters of Tamarix with an average of about 15 stems per cluster.

Two small clusters of Tamarix are located in Kana a wash near the intersection of two dirt roads near the center of Section 12. The final location which was mapped for the occurrence of both Tamarix and camelthorn is at Heiser Spring where the area is infested with sparsely scattered camelthorn plants and nine small clusters of Tamarix.

MANAGEMENT RECOMMENDATIONS

Threatened and Endangered Species

Populations of threatened and endangered species for which quantitative data were given in this report should be monitored and plants should be periodically re-counted so that any changes in population numbers can be determined. All precautions should be taken to ensure minimal habitat alteration in areas where threatened and endangered species occur. If a decrease in population numbers is detected for any of these populations, all measures necessary should be taken to determine which ecological factors are causing the decrease and all efforts should be made to correct any habitat alterations which are detrimental to those populations. If any population is threatened with total extinction and all efforts to save them are in vain, then artificial propagation could be the only method to restore population numbers large enough to be replanted and survive. This should be done only in extreme cases when all efforts to restore plant hardiness in the natural habitat are unsuccessful.

Presently, these populations are being disturbed very little by tourists (although some disturbance occurs where cattle grazing is intense and some trampling may be taking place). Perhaps these threatened and endangered plants should be displayed in Wupatki and Sunset Crater Visitor Centers, but posting

their presence at their natural growing sites would probably only draw attention from vandals who would otherwise be unaware of their presence. Therefore, this practice should probably be avoided.

Noxious and Invader Species

The greatest concentrations of these undesirable plant species are located at sites very close to the Little Colorado River where ecological damage caused by their presence has already become significant and perhaps irreversible. Spread of this damage should be a major concern of the National Park Service and control of it does appear to be feasible, both economically and with respect to manpower, in those areas such as Deadman Wash and Kana a Wash. Until such a time when biological control of these species becomes possible, the most effective method of eradication would be to cut the tamarix present in these washes with chain saws and pruning shears, treat stumps with Silvex (Dow Chemical Company name, Kuron) in early May before seed formation, and monitor the results. These stands of tamarix are small and only minimal amounts of herbicide need to be used.

Three species of plants, Dalea terminalis Jones, Dalea whitingii Kearney and Peebles, and Iva axillaris (Pursh.) Woodruff, which were collected at or near Black Falls Crossing between 1938 and 1945 were searched for unsuccessfully in 1978. This may be because the invasion of tamarix and camelthorn have altered the habitat and those species which once occupied that niche have now been replaced. An effort should be made to prevent any further occurrence of such habitat alteration by these invaders.

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Table 1. Density and total basal area of trees in consecutive 10 m X 10 m plots (divisions of transect) on the north side and base of Sunset Cone. Cone slope begins with plot 19; 90 is on summit. fl = *Pinus flexilis*

Plot number	Seedlings	Diameter size classes						Total basal area in. ²		
		<1"	1"-3"	3"-6"	6"-10"	10"-16"	16"	<i>Pinus ponderosa</i>	<i>Pinus edulis</i>	<i>Pinus flexilis</i>
90										
58	-	-	1	-	-	-	-	.85	-	-
57	-	1	-	-	-	-	-	.78	-	-
56	1	-	2	-	1	-	-	3.0	52.8	-
55	-	-	-	-	-	-	-	-	-	-
54	-	-	1	1	1	-	-	57.0	3.2	-
53	-	1	1	-	-	-	-	.2	7.0	-
52	1	-	-	-	-	-	-	-	-	-
51	-	1	-	-	1	-	-	50.5	-	-
50	1	1	3	1	-	-	-	26.1	-	-
49	-	2	-	-	-	-	-	0.4	-	-
48	10	1	1	-	-	-	-	3.16	-	-
47	31	-	-	-	-	-	-	-	-	-
46	-	1	1	-	-	-	-	3.6	-	-
45	1 fl	-	-	-	2	1	-	263.0	-	-
44	2	-	2	-	-	-	-	1.8	-	-
43	-	-	2	-	-	-	-	4.3	-	-
42	-	-	-	-	-	-	1	985.2	-	-
41	1 fl	2	3	1	-	-	-	11.4	-	15.1
40	4	2	4	2	1	-	-	62.0	-	0.8
39	-	-	2	-	-	1	-	108.0	-	0.78
38	-	1	1	-	-	-	-	0.7	-	0.8
37	-	-	-	1	-	-	-	12.0	-	-
36	-	1	-	-	-	-	-	0.5	-	-
35	-	-	-	-	-	-	1	415.0	-	-
34	-	-	-	1	-	-	-	19.0	-	-
33	-	2	1	-	-	-	-	0.4	-	0.8
32	1	2	4	1	-	-	-	9.7	-	10.0
31	3	1	4	-	1	-	1	353.9	-	50.0
30	2	1	-	-	-	1	1	380.1	-	154.0
28	-	-	-	1	1	-	1	274.8	-	-
27	-	2	3	3	-	-	-	47.7	-	0.5
26	-	8	5	4	-	-	-	56.7	-	-
25	-	-	-	-	-	-	1	255.0	-	-
24	-	-	-	-	-	4	2	1792.0	-	-
23	-	1	-	2	1	3	2	852.0	-	-
22	-	-	-	-	1	4	1	797.0	-	-
21	-	-	-	-	-	2	1	524.5	-	-
20	-	-	1	-	-	2	1	413.0	-	-
19	-	-	-	-	-	-	1	491.0	-	-
18	1	-	-	-	-	1	1	372.0	-	-
17	-	-	-	-	-	-	-	-	-	-
16	2	-	-	-	-	-	1	314.0	-	-
15	-	-	-	-	-	1	-	115.0	-	-
14	-	-	-	-	-	1	1	314.0	-	-
13	-	-	-	-	-	2	-	187.0	-	-
12	-	-	3	-	-	-	-	8.8	-	-
								9586.59		

Table 2. Density of shrubs in consecutive 10 X 10 m plots (divisions of transect) on north side and base of Sunset Cone. Cone slope begins with plot 19.

Plot number	<u>Eriogonum aureum</u>	<u>Fallugia paradoxa</u>	<u>Lygodesmia spinosa Nutt.</u>	<u>Ribes cereum Dougl.</u>	Plot number	<u>Eriogonum aureum</u>	<u>Fallugia paradoxa</u>	<u>Lygodesmia spinosa Nutt.</u>	<u>Ribes cereum Dougl.</u>
90	Summit of cone				50	4	25	-	-
89	191	-	-	-	49	1	-	-	-
88	136	-	-	-	48	1	-	-	-
87	72	-	-	-	47	-	-	-	-
86	32	-	-	-	46	-	-	-	-
85	12	-	-	-	45	1	2	-	-
84	8	-	-	-	44	1	4	-	-
83	7	-	-	-	43	6	2	-	-
82	39	-	-	-	42	5	5	-	-
81	36	-	-	-	41	12	10	1	-
80	43	-	-	-	40	3	8	26	-
79	5	-	-	-	39	2	-	-	-
78	2	-	-	-	38	1	-	-	-
77	5	-	-	-	37	2	1	-	-
76	2	-	-	-	36	1	-	-	-
75	13	-	-	-	35	2	1	-	-
74	59	-	-	-	34	7	-	-	-
73	96	-	-	-	33	4	-	-	-
72	73	-	-	-	32	3	3	-	-
71	71	-	-	-	31	2	-	-	-
70	95	-	-	-	30	5	2	-	-
69	153	-	-	-	28	1	3	-	-
68	130	-	26	-	27	-	-	-	4
67	129	-	1	-	26	-	1	-	-
66	116	-	-	-	25	-	-	-	-
65	95	-	-	-	24	-	-	-	1
64	105	-	-	-	23	-	-	-	-
63	90	-	-	-	22	-	-	-	-
62	88	-	-	-	21	-	-	-	-
61	111	-	-	-	20	-	-	-	-
60	101	-	-	-	19	-	3	-	-
59	63	20	-	-	18	-	74	-	-
58	66	1	-	-	17	-	135	-	-
57	42	23	-	-	16	-	164	-	-
56	24	18	-	-	15	-	159	-	-
55	26	-	-	-	14	-	133	-	-
54	20	-	2	-	13	-	115	-	-
53	13	-	2	-	12	-	48	-	-
52	5	3	1	-					
51	2	17	-	-					

Table 3. Density of herbs in 2 m wide transect, north side and base of Sunset Cone; each value is sum of two 10 m plots. Cone slope begins with plot 19. *Artemisia* includes *A. caruthii* Wood, *A. caruthii* var. *wrightii* (A. Gray) Blake and *A. pacifica* Nutt. 6/29-7/10/64.

Plot number	<i>Andropogon hallii</i>	<i>Artemisia</i>	<i>Bouteloua gracilis</i>	<i>Euphorbia fendleri</i>	<i>Euphorbia turida</i>	<i>Galium rothrockii</i>	<i>Gilia aggregata</i>	<i>Monardella odoratissima</i>	<i>Oenothera caespitosa</i>	<i>Orobancha fasciculata</i>	<i>Oryzopsis hymenoides</i>	<i>Penstemon barbatus</i>	<i>P. clutei</i>	<i>Phacelia integrifolia</i>	<i>Physaria newberryi</i>	<i>Poa fendleriana</i>	<i>Sitanion hystrix</i>
39-90	-	-	-	5	-	-	-	-	-	-	-	-	-	-	2	-	-
37-88	-	-	-	3	-	-	-	-	-	-	-	-	-	-	6	-	-
85-86	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5	-	-
83-84	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
91-82	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-
79-80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
77-78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75-76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
73-74	-	-	-	10	-	-	4	-	-	-	7	-	-	25	6	-	-
71-72	-	-	-	33	-	-	2	-	-	-	48	-	-	18	5	-	-
69-70	-	-	-	28	-	-	3	-	-	-	63	-	-	18	5	-	1
67-68	-	-	-	27	-	-	6	-	-	-	54	-	-	19	10	-	5
65-66	2	-	-	30	-	-	9	-	-	-	65	-	-	9	8	-	1
63-64	15	-	-	22	-	-	13	-	-	1	50	-	-	7	8	-	-
61-62	-	-	-	19	-	-	18	21	1	2	47	-	-	6	11	-	2
59-60	4	-	-	14	-	-	30	87	2	1	35	-	-	5	12	-	8
57-58	107	-	-	8	-	8	21	138	1	3	7	-	-	5	14	-	7
55-56	60	-	-	3	-	21	16	92	-	-	3	1	-	7	12	-	1
53-54	81	-	1	1	-	17	10	145	2	-	-	2	28	-	25	-	1
51-52	52	-	-	-	-	3	10	97	-	-	-	3	-	2	13	18	-
49-50	18	-	2	1	-	6	8	123	-	-	4	7	1	-	6	6	-
47-48	54	-	-	-	-	9	1	190	-	-	-	6	-	-	7	24	-
45-46	5	-	-	-	-	2	1	78	-	-	-	4	-	1	6	11	-
43-44	13	-	-	-	-	3	-	38	-	-	-	-	-	-	4	-	-
41-42	-	-	-	-	-	4	-	53	1	-	-	7	-	10	1	1	-
39-40	19	-	1	-	-	1	-	38	-	-	-	7	-	-	-	-	-
37-38	-	-	-	-	-	1	-	48	-	-	-	3	-	-	2	40	-
35-36	-	-	-	-	-	1	1	44	-	-	-	4	-	-	-	7	-
33-34	2	-	-	2	2	-	-	51	3	-	-	-	5	-	-	2	-
31-32	2	-	-	-	-	1	-	26	-	-	-	-	4	-	-	2	-
29-30	-	-	-	-	-	-	-	6	-	-	-	-	3	-	-	-	-
27-28	13	15	-	4	-	1	-	56	2	-	-	7	-	-	-	-	-
25-25	5	1	-	-	5	1	-	2	1	-	-	9	-	-	-	-	-
23-24	9	-	-	-	-	-	-	-	-	-	-	13	-	-	-	-	-
21-22	9	2	-	1	1	1	-	7	1	-	-	11	-	-	-	-	-
19-20	6	2	43	-	1	1	-	23	-	-	-	12	-	-	-	-	-
17-18	9	2	5	-	10	-	-	1	2	-	-	6	-	-	-	-	-
15-16	7	22	22	7	9	-	1	3	6	-	-	9	-	-	-	-	-
13-14	-	14	15	-	2	-	-	-	1	-	-	1	-	-	1	-	3
11-12	15	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-10	18	4	10	-	-	-	-	-	-	-	-	2	-	-	-	-	-
7-8	4	5	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5-6	8	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-
3-4	2	1	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-
1-2	-	24	57	-	-	-	-	-	4	-	-	-	3	-	-	-	-

Table 4. Densities and percent cover values for tree species in consecutive 10 X 10 m plots on the north slope of Sunset Crater. 1-3 October, 1978. Summit is at plot 90.

Plot number	<u>Pinus ponderosa</u>	<u>Pinus flexilis</u>	<u>Pinus edulis</u>	<u>Pseudotsuga menziesii</u>	% cover for all tree species combined	Plot number	<u>Pinus ponderosa</u>	<u>Pinus flexilis</u>	<u>Pinus edulis</u>	<u>Pseudotsuga menziesii</u>	% cover for all tree species combined
58	2	-	-	-	5	29	1	-	-	-	40.53
57	-	-	-	-	0	28	2	1	-	-	25.9
56	1	-	-	-	7.54	27	1	-	-	-	0.16
55	6	-	-	-	16.02	26	7	1	-	-	29.36
54	4	2	-	-	12.79	25	2	-	-	-	54.04
53	1	-	1	-	0.785	24	2	-	2	-	37.07
52	2	-	-	-	22.3	23	2	-	-	-	6.6
51	5	-	1	-	8.8	22	11	-	-	-	39.9
50	4	1	-	-	17.12	21	8	-	-	-	50.1
49	2	-	-	-	19.48	20	7	-	-	-	47.75
48	2	-	-	-	23.25	19	1	-	-	-	0.16
47	2	-	-	-	5.65	18	-	-	-	-	0
46	9	1	-	-	11.94	17	4	-	-	-	25.76
45	3	-	-	-	2.04	16	1	-	-	-	20.42
44	2	-	1	-	16.64	15	1	-	-	-	17.9
43	7	-	-	-	33.14	14	2	-	-	-	0.63
42	18	-	-	1	39.11	13	14	-	-	-	64.25
41	22	-	-	-	30.94	12	4	-	-	-	7.7
40	9	-	-	-	25.92	11	3	-	-	-	3.77
39	4	-	-	-	43.67	10	9	-	-	-	63.77
38	15	-	-	-	51.2	9	2	-	-	-	16.34
37	1	-	-	-	29.53	8	3	-	-	-	17.28
36	-	-	-	-	0	7	3	-	-	-	27.96
35	1	-	-	-	8.48	6	1	-	-	-	18.85
34	3	-	-	-	42.73	5	1	-	-	-	23.25
33	1	-	-	-	9.20	4	2	-	-	-	14.45
32	5	1	-	-	48.85	3	2	-	-	-	23.25
31	2	-	-	-	38.95	2	1	-	-	-	23.75
30	1	-	-	-	0.16	1	2	-	-	-	22.63

Table 5. Crown diameter classes for tree species on Sunset Crater's north slope in consecutive 10 X 10 m plots. 1-3 October, 1978.

Plot number	0-100 cm	101-500 cm	501+ cm	Plot number	0-100 cm	100-500 cm	501+ cm
58	1	1	-	29	-	-	1
57	-	-	-	28	2	-	1
56	-	1	-	27	1	-	-
55	5	1	-	26	5	3	-
54	4	2	-	25	-	-	2
53	2	-	-	24	2	-	2
52	1	-	1	23	1	1	-
51	6	-	-	22	6	5	-
50	2	3	-	21	2	5	1
49	1	2	-	20	1	6	-
48	-	2	-	19	1	-	-
47	1	1	-	18	-	-	-
46	10	-	-	17	-	4	-
45	3	-	-	16	-	-	1
44	2	-	1	15	-	-	1
43	4	3	-	14	2	-	-
42	18	2	-	13	6	7	1
41	19	3	-	12	4	-	-
40	6	3	-	11	3	-	-
39	-	3	1	10	3	5	1
38	6	9	-	9	-	2	-
37	-	-	1	8	-	3	-
36	-	-	-	7	-	3	-
35	-	1	-	6	-	-	1
34	-	2	1	5	-	-	1
33	-	1	-	4	2	-	-
32	1	5	-	3	-	2	-
31	-	-	2	2	-	-	1
30	1	-	-	1	1	-	1

Table 6. Densities of shrubs in consecutive 10 X 10 m plots on north slope Sunset Crater. 1-3 October, 1978.

Plot number	<u>Eriogonum</u> <u>aureum</u>	<u>Fallugia</u> <u>paradoxa</u>	<u>Lygodesmia</u> <u>spinosa</u>	<u>Ribes</u> <u>cereum</u>	<u>Chrysothamnus</u> <u>nauseosus</u>	Plot number	<u>Eriogonum</u> <u>aureum</u>	<u>Fallugia</u> <u>paradoxa</u>	<u>Lygodesmia</u> <u>spinosa</u>	<u>Ribes</u> <u>cereum</u>	<u>Chrysothamnus</u> <u>nauseosus</u>
90	-	-	-	-	-	45	-	-	-	-	-
89	138	-	-	-	-	44	-	1	-	-	-
88	156	-	-	-	-	43	-	6	-	-	-
87	81	-	-	-	-	42	1	1	-	-	-
86	75	-	-	-	-	41	2	5	-	-	-
85	24	-	-	-	-	40	2	-	-	-	-
84	25	-	-	-	-	39	-	1	-	-	-
83	10	-	-	-	-	38	1	2	-	-	-
82	108	-	-	-	-	37	2	-	-	-	-
81	64	-	-	-	-	36	1	-	-	-	-
80	68	-	-	-	-	35	2	-	-	-	-
79	70	1	-	-	-	34	2	-	-	-	-
78	72	-	-	-	-	33	1	-	-	-	-
77	39	-	-	-	-	32	1	-	-	-	-
76	35	-	-	-	-	31	2	-	-	-	-
75	120	-	-	-	-	30	1	-	-	-	-
74	76	-	-	-	-	29	2	-	-	-	-
73	104	-	-	-	-	28	4	-	-	-	-
72	147	-	-	-	-	27	-	-	-	-	-
71	161	-	-	-	-	26	-	-	-	-	-
70	140	-	-	-	-	25	2	-	-	-	-
69	107	-	-	-	-	24	4	-	-	-	-
68	63	-	-	-	-	23	-	-	-	-	-
67	76	-	-	-	-	22	1	-	-	1	-
66	40	-	-	-	-	21	-	-	-	2	-
65	46	-	-	-	-	20	1	-	-	6	-
64	42	-	-	-	-	19	-	-	-	1	-
63	39	-	-	-	-	18	-	3	-	-	-
62	58	2	-	-	-	17	-	59	-	-	-
61	57	3	-	-	-	16	-	76	-	-	-
60	41	9	-	-	-	15	-	59	-	-	-
59	14	-	-	-	-	14	-	111	-	-	-
58	56	-	-	-	-	13	-	65	-	-	-
57	16	18	-	-	1	12	-	85	-	2	-
56	25	-	-	-	-	11	-	20	-	-	-
55	29	6	-	-	-	10	-	26	-	-	-
54	16	-	-	-	-	9	-	3	-	-	1
53	3	-	-	-	-	8	-	1	-	-	1
52	5	-	-	-	-	7	-	-	-	-	-
51	5	-	-	1	-	6	-	14	-	-	-
50	-	-	-	-	-	5	2	72	1	-	1
49	11	-	-	-	-	4	-	10	-	-	-
48	5	3	-	-	-	3	-	54	-	-	-
47	12	-	-	-	-	2	-	83	-	-	-
46	-	-	-	-	-	1	-	59	-	-	-

Table 8. Densities of herbs counted in 2 m wide transect on north slope Sunset Crater. Each value is the sum of 2 consecutive plots. These herbs were not found in 1964. October 1-3, 1978.

Plot number	<u>Stipa</u> <u>neomexicana</u>	<u>Bahia</u> <u>dissecta</u>	<u>Opuntia</u> sp.	<u>Brickellia</u> <u>grandiflora</u>	<u>Sisymbrium</u> <u>linearifolium</u>	Plot number	<u>Stipa</u> <u>neomexicana</u>	<u>Bahia</u> <u>dissecta</u>	<u>Opuntia</u> sp.	<u>Brickellia</u> <u>grandiflora</u>	<u>Sisymbrium</u> <u>linearifolium</u>
89-90	-	-	-	-	-	39-40	2	-	-	-	-
87-88	-	-	-	-	-	37-38	-	-	-	-	-
85-86	-	-	-	-	-	35-36	-	4	-	-	-
83-84	-	-	-	-	-	33-34	-	-	-	-	-
81-82	-	-	-	-	-	31-32	-	17	-	-	-
79-80	-	-	-	-	-	29-30	-	2	-	-	-
77-78	-	-	-	-	-	27-28	1	-	-	-	-
75-76	-	-	-	-	-	25-26	-	-	-	-	-
73-74	-	-	-	-	-	23-24	-	-	-	5	-
71-72	-	-	-	-	-	21-22	-	-	-	5	-
69-70	-	-	-	-	-	19-20	-	-	-	3	-
67-68	-	-	-	-	-	17-18	-	1	-	-	-
65-66	-	-	-	-	-	15-16	-	-	-	-	1
63-64	-	-	-	-	-	13-14	-	-	-	-	-
61-62	-	-	-	-	-	11-12	-	-	-	-	-
59-60	-	-	-	-	-	9-10	-	-	-	-	-
57-58	1	-	-	-	-	7-8	-	-	1	-	-
55-56	-	-	-	-	-	5-6	-	-	-	-	-
53-54	3	-	-	-	-	3-4	-	-	-	-	-
51-52	-	-	-	-	-	1-2	-	-	-	-	-
49-50	-	-	-	-	-						
47-48	-	-	-	-	-						
45-46	-	-	-	-	-						
43-44	-	-	-	-	-						
41-42	1	-	-	-	-						

Table 9. Density of trees and total basal area of trees in 10 m x 10 m plots (divisions of transect) on south side and base of Sunset Cone. Cone slope begins with plot 12; 68 is at summit. No trees present in omitted numbers.

Plot number	Diameter size classes						Total basal area in. ²		
	<1"	1"-3"	3"-6"	6"-10"	10"-16"	>16"	<u>Pinus ponderosa</u>	<u>Pinus edulis</u>	<u>Juniperus deppeana Steud.</u>
68	-	2	1	-	1	-	197.5	-	-
67	2	1	4	-	-	-	43.2	-	0.7
.									
27	-	-	-	-	1	-	140	-	-
.									
16	1	-	-	-	-	1	700	0.2	-
.									
14	-	-	-	-	-	1	346	-	-
.									
9	-	-	1	1	-	-	-	52.5	-
8	-	-	-	1	-	-	-	29	-
.									
6	-	-	-	-	-	1	210	-	-
5	-	-	-	-	-	1	283	-	-
4	-	1	-	-	-	-	-	0.78	-
3	-	-	-	-	1	1	426	-	-
2	-	-	-	-	1	-	113	-	-
1	-	-	-	-	3	-	371	-	-

Table 10. Density of shrubs in consecutive 10 m X 10 m plots (divisions of transect) on south side and base of Sunset Cone. Cone slope begins with plot 12. No shrubs present in omitted numbers.

Plot number	<u>Chrysothamnus</u> <u>nauseosus</u> var. <u>graveolens</u> (Nutt.) Hall.	<u>Eriogonum</u> <u>aureum</u>	<u>Fallugia</u> <u>paradoxa</u>	<u>Ribes</u> <u>cereum</u>
68	-	11	98	-
67	-	4	171	-
66	-	3	20	-
65	-	-	45	-
64	-	1	157	-
63	-	-	176	-
62	-	-	127	-
61	-	1	333	-
60	-	-	130	-
:				
21	-	-	46	-
20	-	-	168	-
19	-	-	32	-
18	-	-	175	-
17	-	-	16	-
16	-	-	79	1
15	3	-	53	-
14	2	-	21	-
13	2	-	-	-
.				
.				
10	-	-	86	-
9	-	-	330	-
8	-	-	434	-
7	-	-	296	-
6	-	-	216	-
5	-	-	271	-
4	-	-	138	-
3	-	-	173	-
2	-	-	259	-
1	-	-	209	-

Table 11. Density of herbs in 2 m wide transect, south side and base of Sunset Cone: each value is sum of two 2 m X 10 m plots. Cone slope begins with plot 12. 6/29-7/10/64.

Plot number	<u>Andropogon hallii</u>	<u>Aster canescens Pursh.</u>	<u>Bouteloua gracilis</u>	<u>Brickellia californica</u> (Torr. and Gray) Gray	<u>Erisimum capitatum</u> (Dougl.) Greene	<u>Euphorbia fendleri</u>	<u>Euphorbia lurida</u>	<u>Gallium rothrockii</u>	<u>Gilia aggregata</u>	<u>Kuhnia rosmarinifolia</u> Vent.	<u>Mentzelia pumila</u> (Nutt.) Torr. and Gray	<u>Oenothera caespitosa</u>	<u>Opuntia compressa</u> var. <u>macrorhiza</u>	<u>Penstemon barbatus</u>	<u>Penstemon clutei</u>	<u>Phacelia integrifolia</u>	<u>Physaria newberryi</u>	<u>Senecio spartioides</u> Torr. and Gray	<u>Sitanion hystrix</u>	<u>Verbascum thapsus</u> L.
67-68	7	-	-	-	7	14	-	-	5	-	-	-	-	3	-	6	5	-	16	-
65-66	-	-	-	-	-	18	-	-	6	-	3	-	-	-	-	15	28	-	-	-
63-64	-	-	-	-	1	2	-	-	3	-	1	4	-	-	-	6	21	-	-	-
61-62	-	-	-	-	-	-	-	-	3	-	1	-	-	-	-	1	33	1	-	-
59-60	-	-	-	-	-	11	-	1	5	-	-	4	-	-	-	8	28	-	-	-
57-58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-
55-56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-
53-54	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-	-
51-52	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-
49-50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	4	-	-	-
47-48	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	20	18	-	-	-
45-46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36	16	-	-	-
43-44	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	19	13	-	-	-
41-42	-	-	-	-	-	-	-	-	14	-	19	2	-	-	-	41	10	-	-	-
39-40	-	-	-	-	-	-	-	-	10	-	59	5	-	-	-	130	18	-	-	-
37-38	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	13	11	-	-	1
35-36	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	18	28	-	-	-
33-34	-	-	-	-	-	15	-	-	3	-	11	-	-	-	-	307	26	-	-	8
31-32	-	-	-	-	-	28	-	-	2	-	31	4	-	-	-	189	18	-	-	-
29-30	-	2	-	1	-	20	-	-	2	-	15	2	-	-	-	68	24	-	4	1
27-28	-	-	-	-	-	22	-	1	5	-	5	-	-	-	-	58	23	-	6	-
25-26	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	-	11	-	-	-
23-24	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	5	-	-	-
21-22	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	1	-	-	-
19-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17-18	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-
15-16	2	-	12	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13-14	80	-	88	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
11-12	94	-	12	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-10	4	-	69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7-8	-	-	22	1	-	-	-	-	-	-	-	1	1	2	-	-	-	-	-	-
5-6	-	-	71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3-4	-	-	14	-	1	-	-	-	-	1	-	7	-	2	2	-	-	-	-	-
1-2	-	-	5	-	-	-	7	-	-	2	-	-	-	4	-	-	-	-	-	-

Table 12. Densities and percent cover values for tree species in consecutive 10 x 10 m plots on the south slope of Sunset Crater. 24-25 June, 1979. Summit is at plot 70.

Plot number	<u>Pinus ponderosa</u>	<u>Pinus edulis</u>	% cover for all tree species
70	6	-	33.14
69	4	-	17.12
68	3	-	8.92
.			
.			
.			
.			
.			
24	1	-	12.8
.			
.			
.			
.			
.			
13	-	1	.88
.			
.			
.			
.			
10	2	1	21.25
9	1	-	7.04
8	1	-	2.5
7	2	-	41.68
6	1	1	12.62
5	3	-	30.44
4	1	-	16.01
3	2	-	15.60
2	3	-	42.89
1	1	-	7.55

Table 13. Crown diameter classes for tree species on Sunset Crater's south slope in consecutive 10 X 10 m plots. 24-25 June, 1979.

Plot number	0-100 cm	101-500 cm	500+ cm
70	3	3	-
69	3	1	-
68	2	1	-
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24	-	1	-
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13	1	-	-
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10	1	2	-
9	-	1	-
8	-	1	-
7	-	-	2
6	-	2	-
5	-	2	1
4	-	-	1
3	1	1	-
2	-	1	2
1	-	1	-

Table 14. Densities of shrubs on south slope Sunset Crater in consecutive 10 X 10 m plots. 24-25 June, 1979.

Plot number	<u>Chrysothamnus</u> <u>nauseosus</u>	<u>Eriogonum</u> <u>aureum</u>	<u>Fallugia</u> <u>paradoxa</u>	<u>Ribes</u> <u>cereum</u>
70	-	21	106	-
69	-	7	13	-
68	-	9	124	-
67	-	1	61	-
66	-	-	93	-
65	-	2	114	-
64	-	2	112	-
63	-	-	177	-
62	-	1	231	-
61	-	-	84	-
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42	-	-	2	-
41	-	-	1	-
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17	2	-	36	-
16	-	-	41	-
15	-	-	97	-
14	-	-	41	-
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.				
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12	-	-	102	-
10	1	-	212	1
9	-	-	69	-
8	2	-	281	-
7	-	-	303	-
6	-	-	84	2
5	-	-	177	-
4	-	-	171	-
3	-	-	134	-
2	-	-	206	-
1	-	-	220	-

Table 15. Density of herbs in 2 m wide transect on south slope of Sunset Crater
Each value is the sum of 2 adjacent plots. 24-25 June, 1979

Plot number	<u>Andropogon hallii</u>	<u>Bouteloua gracilis</u>	<u>Brickellia californica</u>	<u>Erisymum capitatum</u>	<u>Euphorbia fendleri</u>	<u>Galium rothrockii</u>	<u>Gilia aggregata</u>	<u>Lupinus argenteus</u>	<u>Mentzelia pumila</u>	<u>Oenothera caespitosa</u>	<u>Penstemon barbatus</u>	<u>Penstemon clutei</u>	<u>Phacelia serrata</u>	<u>Physaria newberryi</u>	<u>Poa fendleriana</u>	<u>Senecio spartioides</u>	<u>Sitanion hystrix</u>	<u>Verbascum thapsus</u>
70-69	-	-	-	-	22	1	-	-	-	2	-	-	27	11	-	-	-	-
68-67	-	-	-	3	13	-	2	-	-	2	-	-	4	12	-	-	4	-
66-65	-	-	-	-	14	-	-	-	-	6	-	-	15	4	-	-	-	-
64-63	-	-	-	-	8	-	6	-	-	1	-	-	101	14	-	-	-	-
62-61	-	-	-	1	11	-	1	-	-	-	-	-	72	21	-	-	-	-
60-59	-	-	-	-	2	-	3	-	-	1	-	-	6	26	-	-	-	-
58-57	-	-	-	-	-	-	-	-	8	-	-	-	-	10	-	-	-	-
56-55	-	-	-	-	1	-	1	-	1	-	-	3	9	40	-	-	-	-
54-53	-	-	-	-	-	-	1	-	41	2	-	1	-	6	-	-	-	-
52-51	-	-	-	-	-	-	-	-	16	-	-	-	6	-	-	-	-	-
50-49	-	-	-	-	-	-	-	-	-	-	-	1	6	-	-	-	-	-
48-47	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-
46-45	-	-	-	-	2	-	-	-	4	2	-	-	39	13	-	-	-	-
44-43	-	-	-	-	-	-	-	-	-	-	-	-	112	11	-	-	-	-
42-41	-	-	-	-	-	-	11	-	19	-	-	-	190	29	-	-	-	-
40-39	-	-	-	-	2	-	4	-	24	1	-	-	21	21	-	-	-	-
38-37	-	-	-	-	-	-	-	-	17	4	-	-	24	19	-	-	-	-
36-35	-	-	-	-	-	-	-	-	12	4	-	-	6	24	-	-	-	-
34-33	-	-	-	-	-	-	9	-	31	-	-	-	61	6	-	-	-	-
32-31	-	-	-	-	-	-	-	-	8	1	-	-	11	-	-	-	-	-
30-29	-	-	-	-	-	-	4	-	8	-	-	-	-	4	-	-	-	-
28-27	-	-	-	-	-	3	-	-	2	-	-	-	-	-	-	-	-	1
26-25	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	3
24-23	-	-	-	-	6	-	-	-	-	-	1	-	-	1	9	-	-	1
22-21	-	-	-	-	1	-	-	-	16	-	-	-	-	3	-	-	-	-
20-19	-	-	-	-	6	-	-	-	4	-	-	-	-	-	-	-	-	1
18-17	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
16-15	-	12	-	-	-	-	-	-	9	1	-	-	-	-	-	-	-	-
14-13	-	6	-	-	-	-	-	-	-	-	-	-	-	1	-	-	6	-
12-11	16	13	-	-	-	-	3	-	2	3	-	-	4	-	-	-	1	-
10-9	-	66	2	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-
8-7	31	51	-	-	-	-	4	-	-	-	1	1	-	-	-	-	-	-
6-5	4	49	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
4-3	61	13	-	-	-	-	-	-	-	-	-	-	-	2	13	-	-	-
2-1	9	19	-	-	-	-	1	-	-	-	1	1	-	-	6	-	-	-

Table 16. Point-quarter transect data from Sunset Crater transect #1 (SSC1).

	<u>Pinus</u> <u>ponderosa</u>	<u>Pinus</u> <u>edulis</u>	<u>Juniperus</u> <u>monosperma</u>
Relative Density	90%	6.25%	3.75%
Relative Frequency	74.07%	18.52%	7.40%
Absolute Density	143.83/hectare	9.99/hectare	5.99/hectare
Absolute Frequency	100%	25%	10%
Relative Crown Cover	95.02%	0.55%	4.43%
Mean Crown Cover	23.99 m ²	1.99 m ²	26.88 m ²
Absolute Crown Cover	34.5%	0.20%	1.61%
Importance Value	86.36	8.44	5.19

Table 17. Point-quarter transect data from Sunset Crater transect #2 (SSC2).

	<u>Pinus</u> <u>ponderosa</u>	<u>Pinus</u> <u>edulis</u>	<u>Juniperus</u> <u>monosperma</u>
Relative Density	80%	17.5%	2.5%
Relative Frequency	62.50%	31.25%	6.25%
Absolute Density	153.1/hectare	33.49/hectare	4.79/hectare
Absolute Frequency	100%	50%	10%
Relative Crown Cover	88.34%	9.02%	2.64%
Mean Crown Cover	13.16 m ²	6.14 m ²	12.56 m ²
Absolute Crown Cover	20.14%	2.06%	0.6%
Importance Value	76.95	19.27	3.78

Table 18. Density and frequency values obtained from Tamarix-Camelthorn transects 1-3 at Black Falls Sump. One plant equals one stem which emerges from the soil.

Transect #1	<u>Tamarix</u>	<u>Camelthorn</u>
Relative Density	56.74%	43.26%
Relative Frequency	38.46%	61.54%
Absolute Density	205,000/h	156,250/h
Absolute Frequency	62.5%	100%
Transect #2		
Relative Density	93.731%	6.269%
Relative Frequency	62.5%	37.5%
Absolute Density	449,857/h	30,000/h
Absolute Frequency	71.429%	42.857%
Transect #3		
Relative Density	91.566%	8.433%
Relative Frequency	50%	50%
Absolute Density	108,570/h	10,000/h
Absolute Frequency	28.57%	28.57%
Overall combined values for Black Falls Sump		
Relative Density	78.36%	21.64%
Relative Frequency	60%	40%
Absolute Density	230,833/h	63,750/h
Absolute Frequency	62.5%	41.66%

II

GRAZING STUDIES

INTRODUCTION

As a result of earlier work done by biologists at Northern Arizona University at Wupatki National Monument (see Final Reports 1976, 1978) and concern expressed by personnel of the National Park Service the need for continuing studies documenting the effects of livestock grazing on the monument has become obvious. A comprehensive study demonstrating these effects is underway (Green, in prep.) and the results presented here summarize in a general way some of the findings of this study made during 1978.

An efficient and effective way of determining grazing impacts is, obviously, to exclude grazing by fencing. Grazing exclosures have been erected at Wupatki National Monument and transects sampling the vegetation both inside and outside these exclosures were established and their results compared.

In addition, the U.S. Forest Service has established criteria for evaluating range conditions and trends. The goals of such evaluation include the continued maintenance of optimum forage production for livestock, maintaining the plant community in as natural and "healthy" a condition as possible, and protection of the delicate soil which, ultimately, supports the community. A series of standardized range condition measures, including pace transects and cluster transects, was established at Wupatki in 1978 to evaluate range trends by accepted means.

The Juniper/Grassland and Grassland communities at Wupatki National Monument are heavily used by domestic livestock in winter; the adjacent portion of the Coconino National Forest has been

subjected to little or no grazing pressure from domestic stock over the past several seasons (see Green, in prep. for a history of this grazing). Thus, a series of paired transects, one member of which was on the monument and the other member on adjacent forest service lands, was established to provide further evidence of the effects of grazing on the monument.

Finally, a series of measurements was made on a select sample of highly palatable forage grasses taken from areas on the monument and the adjacent Coconino National Forest lands. These measurements were to provide an indication of the general vigor of individual plants from grazed and ungrazed areas.

METHODS AND MATERIALS

Grazing Exclosures

Three 60 X 60 meter (m) fenced grazing exclosures were established within the Juniper/Grassland community of Wupatki National Monument in 1977. In all three cases, one 50 m base line was established inside the exclosure and one was established outside. In two instances, additional 50 m base lines were established as controls on the Coconino National Forest. Five 50 m transects were placed perpendicular to the base line at 10 m intervals, the first at 5 m and the last at 45 m, giving a total transect 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 exclosure, stone cairns

were built to mark the beginning points of the five 50 m transects.

Vegetational cover of all plants was determined by measuring their intercepts 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 m segments, and counts were recorded separately in each segment. A total of 50 segments was measured at 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 rather than 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.

Range Condition Transects

In order to determine present range condition in the Grassland and Juniper/Grassland communities of Wupatki National Monument, paced transects were established in different areas within each vegetation type. These transects were not permanently marked. Transects were run on as continuous a straight line as possible to measure a given area. A notch was cut in the toe of the right boot and at each of the 100 sample points per transect, a 0.75 inch (in) loop was placed immediately in front of the notch. Points were measured at five pace intervals (approximately 8 m). Hits on vegetation by species, rock, litter and bare ground were recorded as they occurred within the loop. In cases where the loop did not hit perennial vegetation, the nearest perennial plant within a 180° arc in front of the boot was recorded as a dot tally. Hits on vegetation were defined in terms of the live root crown, the crown spread of plants were ignored. Dead annuals, dead areas of perennial vegetation, or any material of

sufficient weight and size to minimize raindrop impact was classified as litter. As a measure of grass vigor, ten plants of the dominant grasses were randomly selected. The length of the longest leaf on each plant was measured and recorded by species.

All data gathered from pace transects were recorded on U.S.D.A. Forest Service form R-3 2200-22. The hits and dot tally along with rock, litter and bare soil hits were then summarized on U.S.D.A. Forest Service form R-3 2200-23. Hits and dot tally composition were separated into decreaser, increaser and invader categories according to the Species Classification List (revised, 1978) in Forest Service Handbook 2209.21 R3, the Range Environmental Analysis Handbook (R.E.A.H.). Decreaser composition was multiplied by plus 2, increaser composition was multiplied by plus 0.25 and invader composition was multiplied by minus 1. The values obtained were then totaled and a composition value was determined by the composition scorecard on page 34.11 of the R.E.A.H. Vegetation cover was determined by the actual plant hits within the 0.75 inch ring and a Forage Cover Index was determined. This value was determined using Forage Cover Index Scoring Guide b. Pine (other) and Pinyon Juniper and Associated Grasslands. A vegetation Condition Class was then determined with the total of the Forage Cover Index, the Composition value and the vigor value compared to a 100 point scale divided into five vegetation condition classes:

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

The soil stability was rated according to the total of the Erosion Hazard value and the Current Erosion value. The Erosion Hazard value was the number of bare soil hits within the 0.75 in ring compared to the Erosion Hazard Scorecard on page 34.52-1 of the R.E.A.H. The Current Erosion value was an ocular estimated value according to criteria established on pages 34.52-1 thru 34.52-3 of the R.E.A.H. A soil Condition Class was determined by the numerical total of these two values compared to a 100 point scale divided into five soil condition classes with the same value ranges as those for vegetation condition classes.

Cluster Transects

For the determination of long term range trend, cluster transects were established within the Grassland and Juniper/Grassland communities. These transects were permanently staked and each cluster consisted of three 100 foot transects. Stakes were set at the beginning, the 0.0 stake, the middle, the 50.5 stake, and at the end of the transect, the 101 stake. The three transects were arranged in a straight line with 100 feet between transects.

A transect within a cluster consists of a 100 foot tape stretched as tightly as possible and as close to the ground as allowable. The relation of the tape to the stakes was recorded, by exact location and height of the tape on stake, so as to make relocation more accurate. At the beginning of the transect, a 3 foot by 3 foot plot, beginning at 3.5 ft and extending to 6.5 ft, was centered over the tape. This plot was photographed and all perennial vegetation mapped out by species. Then a general view photograph down the transect was taken (These photos will be provided to the National Park Service upon

completion of L.T. Green's Master of Science Thesis). In both cases the camera was centered over the 0.0 stake. Measurement of the transect consisted of placing a 0.75 in loop vertically at each foot marker along the right hand side of the tape, allowing for 100 sample points per transect. Hits on perennial vegetation, litter, rock and bare ground were recorded as described for the pace transects. Dot tallies, when no perennial hit occurred, were taken in a 180° arc to the right hand side of the tape. No plant was recorded more than once. Plant vigor measurements on 10 randomly selected major forage producing grasses were taken along the transect as described for the pace transects. The data obtained from the cluster transects were analyzed in the same manner as for the pace transects.

Comparison Monument-to-Forest Transects

In addition to the transects established to sample the grazing exclosures, several transects were installed on the monument and on the Coconino National Forest to compare the vegetation of the two areas. The method used for these transects was a modification of the methods for sampling the grazing exclosures. 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 of transect at each site. No permanent stakes were set for these transects. Sample sites were restricted to the Juniper/Grassland and selected so as to depict representative areas of vegetation.

Vegetation cover, frequency and density for perennials were determined in the same manner as previously described; a belt one m wide, established on the left hand side and divided into 5 m lengths was used. A total of 90 m was sampled for perennials 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. An absolute cover value was also calculated to estimate the actual ground covered by vegetation. Importance Values were calculated for each transect as described.

Crown/Root Area Comparisons

As a further measure of plant vigor, several plants of black grama (Bouteloua eriopoda (Torr.) Torr.) were randomly selected on both the monument and the forest and were removed from the ground. Plants were removed to allow measurement of the above ground biomass, the crown weight, and to allow measurement of the below ground biomass, the roots. The plant was dug using air pressure, generated by a portable compressor, varying from 30 to 100 pounds per square in, depending upon the level of excavation. Attempts were made to collect any root fragments accidentally dislodged during excavation.

Once the plant was removed from the ground, the roots were cleaned of attached soil. The plant was then placed on a clean, flat, white surface in an attempt to duplicate the original position of the plant. Two measures of length and two of width, generally at the widest point, were then recorded for both the crown and roots. The height was measured from the base of the crown to the tallest leaf or seed stalk. The crown and roots were then separated and cleaned. The individual plant parts were labeled and placed in a drying oven set at 70° C where they were kept for at least 96 hours before weighing.

To determine the areas of the crown and roots, the two measurements, lengths or widths, were then averaged and the averages were multiplied

to give an estimate of area in square centimeters. All heights for each sample, monument or forest, were then averaged.

Values for area of shoots, area of roots, weight of shoots, and weight of roots for plants occurring on the two study sites, National Forest and Monument, were compared statistically using appropriate tests from the Minitab Program Series (N.A.U. Computer Services).

RESULTS

Grazing Exclosure I

Grazing Exclosure I is located in Hull's Canyon, a four-wing saltbush and galleta 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 on 15 May 1978. Another one immediately adjacent and to the north but outside of the exclosure was sampled on 29 June 1977, and on 20 May 1978. The third 50 m base line transect was established in the same community type on the Coconino National Forest on 17 June 1977 and was re-read on 21 May 1978. This transect is located approximately 350 m south of the boundary fence towards Arrowhead Tank.

The results for the 1978 sampling of the transect located inside the exclosure are presented in Table 1. Table 2 presents the 1978 sampling results for the transect adjacent to the exclosure. The data obtained from these two transects in 1977 were presented in Green (1978).

As was found in the 1977 sampling, galleta was the dominant in terms of importance values, the inside transect having a 50.40% value with the outside transect having a 43.43% value. Dead galleta was second in importance value for both the inside and outside transects. There were 6255 live galleta plants and 2074 dead galleta plants counted on the transect inside the exclosure while 5552 live galleta plants and 1785 dead galleta plants were counted for the outside transect. Four-wing saltbush was third in terms of importance value for both the

inside and outside transect with 14.06% and 13.52% values, respectively.

The total absolute ground cover value for the transect inside the exclosure was 28.11%. The value for the outside transect was 19.84%.

Table 3 presents the results of the 1978 sampling of the transect established on the Coconino National Forest. Live galleta was first in terms of importance value with 38.60% while dead four-wing saltbush was second with a 24.65% value. Live four-wing saltbush was third with a 16.18% value. A total of 1584 live galleta plants and 439 dead galleta plants was counted.

The total absolute ground cover value for the transect on the National Forest was 33.04%.

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. The transect inside the exclosure was established 12 August 1977 and re-read on 22 May 1978. The transect outside and adjacent to the exclosure was established on 29-30 June 1977 and re-sampled on 23 May 1978. The transect on the Coconino National Forest was established on 11-12 August 1977 and re-sampled on 23-24 May 1978. For exact locations of these transects refer to the 1977 Final Report for the National Resources Survey and Analysis of Sunset Crater and Wupatki National Monuments (Bateman, 1978).

Table 4 presents the results of the 1978 sampling for the transect inside Grazing Exclosure II with Table 5 presenting the 1978 results for the outside-adjacent transect. Galleta was first in importance

value for both the inside and outside transects with 61.10% and 47.41% values, respectively. Dead galleta was second for both transects with the inside value of 16.86% and the outside value of 19.27%. Inside the exclosure, totals of 8652 live galleta plants and 2135 dead galleta plants were counted. For the outside-adjacent transect, a total of 5929 live galleta plants and 2439 dead galleta plants was counted.

The total absolute ground cover value for the transect inside the exclosure was 26.87% with the transect outside the exclosure measuring 16.64%.

Table 6 presents the 1978 results for the transect established on the Coconino National Forest. Galleta had the highest importance value, 49.22% and dead galleta was second with 17.78%. Black grama ranked third with a 9.11% value. There were 4932 live galleta plants counted along the transect and 1830 dead galleta plants counted. The total absolute ground cover value of this transect was 24.58%.

Grazing Exclosure III

Grazing Exclosure III is located in Cedar Canyon, approximately 150 m west of the well site near Magnetic Mesa about 5 m west of the road. Only two 50 m base line transects were established in this area. The inside the exclosure transect was established on 9 August 1977 and re-read on 10 May 1978. The transect outside and adjacent to the exclosure was established on 13 June 1977 and re-sampled on 6-7 May 1978.

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 transects, with a value of 41.53% inside and 36.88% outside the exclosure.

Dead galleta was second in importance value inside the enclosure with a 16.39% value while rubber rabbitbrush was second outside the enclosure with a 14.21% value. Rubber rabbitbrush was third for the inside the enclosure transect (9.56%) while dead galleta plants were third outside the enclosure (12.03%). There were 4573 live galleta plants and 1930 dead galleta plants counted inside the enclosure. A total of 4204 live galleta plants was counted on the outside transect.

The total absolute ground cover value for the transect inside the enclosure was 20.89% while that for the transect outside the enclosure was 15.61%.

Range Condition Transects

The Juniper/Grassland and Grassland communities of Wupatki National Monument were each sampled by temporary paced transects to establish range condition. A total of 14 paced transects was established, two of these were established on the Coconino National Forest in the Juniper/Grassland community. Of the remaining 12 transects, five were established in the Juniper/Grassland community and seven were established in the larger Grassland community.

Table 9 presents the results of the seven paced range condition transects established in the Juniper/Grassland community. (For the location of these transects, see Green, in prep.) The paced transect (1a) on the National Forest had 11 hits on forage plants with transect 1b receiving only three hits. Both transects had an erosion hazard index (number of bare soil hits) of 85. The totals for the vegetation condition for transects 1a and 1b were 38 and 40 respectively resulting in a "high" poor vegetation condition class. The total for the soil

stability condition was 45 for both transects resulting in a fair soil condition class.

Paced transect Wupatki National Monument (WNM) 2 had only two hits on forage plants and had an erosion hazard index of 92. The total for the vegetation condition was 21 making the vegetation condition class a "low" poor. The total for the soil stability class was 13 resulting in a very poor soil condition class.

Paced transects WNM 3 and 4 both had an erosion hazard index of 98 with WNM 3 having zero hits on forage plants and WNM 4 only one forage plant hit. Both transects totaled 29 for the vegetation condition resulting in a poor condition class. Wupatki National Monument 3 and 4 totaled 13 and 12 respectively in the soil stability condition for a very poor condition class for both transects.

Paced transects WNM 5 and 6 both produced only one forage plant hit with WNM 5 having a 93 erosion index and WNM 6 having a 97 for the same index. These two transects, 5 and 6, totaled 25 and 26 respectively for the vegetation condition. Both transects had a poor vegetation condition classification. Total soil stability condition values of 18 and 11 were figured for WNM 5 and 6 respectively resulting in a very poor soil condition class.

Table 10 presents the results of the seven paced range condition transects. Wupatki National Monument transect 7 had six forage plants hits and an 84 erosion hazard index. The vegetation condition totaled 26 resulting in a poor vegetation condition class. The soil stability condition totaled 17 for a very poor soil condition classification.

Paced range condition transects 8 and 9 had 88 and 87 respectively

for an erosion hazard index with transect 8 receiving five forage plant hits. Transect 9 had six forage plant hits. Transect 8 had only 18 for a total on the vegetation condition resulting in a very poor condition class. A vegetation condition total of 27 was scored for transect 9 for a poor condition classification. Both transects had 14 for a soil stability condition total with both transects rated very poor for the soil condition class.

Both transects 10 and 11 had only two forage plant hits with transect 10 having a 97 erosion hazard index and transect 11 having a 94. Both transects were rated in a poor condition class with totals of 32 and 33 for the vegetation condition respectively. Transect 10 totaled 12 and transect 11 totaled 14 for the soil stability condition for a very poor condition class for both transects.

Both transects 12 and 13 had 96 for an erosion hazard index with transect 12 having three hits on forage plants. Transect 13 had only one forage plant hit. Transect 12 totaled 26 for the vegetation condition with transect 13 scoring 33. Both transects have a poor vegetation condition classification. Both transects totaled 13 for the soil stability condition resulting in a very poor soil condition classification.

Cluster Transects

A total of three cluster transects was established on Wupatki National Monument to monitor range condition trends. One cluster each was established in the Juniper/Grassland and Grassland communities with a third cluster set up to monitor any change in the range condition of Hull's Canyon, a unique area within the Juniper/Grassland community.

Table 11 presents the results of these three cluster transects.

Cluster transect 1, measuring the Grassland community, was established on 1 November 1978. It is located in the NW 1/4, SW 1/4, SE 1/4, NE 1/4 of Section 5, T25N, R9E, near the mammal grid approximately 80 paces southwest of the road. The transects follow a 40° magnetic azimuth.

Cluster 1 averaged nine forage plant hits and a 78 for an erosion hazard index for the three transects. A total of 19 was scored for the vegetation condition resulting in a very poor vegetation condition. Cluster 1 totaled 21 for the soil stability condition for a poor condition class rating. Leaf lengths for galleta and New Mexico feathergrass plants were measured and averaged 10.12 cm and 13.57 cm in length respectively indicating poor vigor.

Cluster 2 was placed in the Juniper/Grassland community and was established on 1 November 1978. The beginning stake is located approximately 50 ft at a 10° magnetic azimuth from the northeast corner of Grazing Exclosure II. This is in the SE 1/4, SE 1/4, SE 1/4, SW 1/4 of Section 17, T25N, R9E. The three transects follow a 10° azimuth.

Only five forage plant hits were averaged for Cluster 2 with an average of 87 for the erosion hazard index. Cluster 2 totaled 15 for the vegetation condition for a very poor vegetation condition class. Only 19 was totaled for the soil stability condition resulting in a very poor soil condition class rating. Galleta was selected for the average leaf length measurements and an average of 10.18 cm was figured for Cluster 2 plants, again indicating poor vigor.

Cluster 3 was established in the upper area of Hull's Canyon in the SE 1/4, NW 1/4, SW 1/4, NE 1/4, Section 18, T25N, R9E. This cluster was originally read on 2 November 1978. The beginning stake is approximately 25 paces east of the road approximately 0.1 mile into the galleta'- four-wing saltbush association, with the stake between two small junipers. The transects follow a 286° magnetic azimuth.

Cluster 3 averaged only three forage plant hits and 93 was the erosion hazard index. It totaled 32 for a vegetation condition rating the area in a relatively "high" poor condition class. The soil stability condition totaled only 13 for a very poor condition class rating. Galleta was measured for leaf length and averaged only 6.61 cm indicating low vigor for this forage plant.

Comparison Monument-to-Forest Transects

A total of five Comparison Monument-to-Forest (CMF) transects was established in the Juniper/Grassland community. Each CMF transect consisted of two 30 m base line transects, one located on Wupatki National Monument (A) and one located on the Coconino National Forest (B). Transect locations were selected by walking an area along the Monument - Forest boundary fence determined to be similar areas from aerial photographs.

CMF transect 1A was established in the SW 1/4, SW 1/4, SE 1/4, SE 1/4 of Section 18, T25N, R9E. Transect 1B was located in the NW 1/4, NW 1/4, NE 1/4, NE 1/4 of Section 19, T25N, R9E and measured the area of Prospect Point to the east of Hull's Canyon. These transects were established on 28 June 1977, with the base line running west and the measuring perpendicular transects running north for 1A and south

for 1B. Approximately 20 m distance separates the two transects.

The results of CMF transect 1A are presented in Table 12 with the CMF transect 1B shown in Table 13. Galleta was first in importance value for both transects, 1A having a 49.2% value and 1B having a 51.55% value. Dead galleta was second in importance value (17.39%) on 1A but was rated third for transect 1B (12.71%). Black grama was second in importance value for 1B with a 18.05% value but was fifth for transect 1A (8.31%). Cowpies was third in importance value for 1A (9.77%). Transect 1A had 3520 galleta plants, 1078 dead galleta plants, and 160 black grama plants. There was a total absolute ground cover value of 13.46%. Transect 1B included 2577 galleta plants, only 369 dead galleta plants and 543 black grama plants with 22.13% for a total absolute ground cover value.

CMF transects 2A and 2B were both established on 14 August 1977, with 2A located in the SW 1/4, SE 1/4, SW1/4, SW 1/4 of Section 14, T25N, R9E and 2B located in the NW 1/4, NE 1/4, NW 1/4, NW 1/4 of Section 23, T25N, R9E. The perpendicular measurement transects for both 2A and 2B run west on an east facing slope of Antelope Wash. About 30 m separate these two transects. Tables 14 and 15 present the results of transects 2A and 2B, respectively.

Black grama was the dominant plant in terms of importance value for both transects, 2A having a 44.81% vlaue and 2B having a 58.82% value. Dead black grama was second for both transects (2A with 23.44% and 2B with 23.61%) and rubber rabbitbrush was third for both transects in importance value.

There were 1064 black grama plants and 646 dead black grama plants

counted on transect 2A while 1171 black grama plants and 582 dead black grama plants were counted on transect 2B. Transect 2A totaled 26.00% for a total absolute ground cover value with transect 2B totaling 46.30%.

CMF transects 3A and 3B were both established on 15 August 1977, with 3A located in the SE 1/4, SW 1/4, SE 1/4, SW 1/4 of Section 16, T25N, R9E with 3B located in the NE 1/4, NW 1/4, NE 1/4, NW 1/4 of Section 21, T25N, R9E. Transects were established to measure east of the 30 m base line for both transects with an approximate 30 to 35 m separating them. The results of CMF transect 3A are found in Table 16 with Table 17 presenting the results of CMF transect 3B.

Mesa dropseed was the dominant plant of this area in importance value for both transects, transect 3A having 25.14% and transect 3B having 21.27%. Galleta was second in importance value for transect 3A (19.01%) while dead mesa dropseed was second for transect 3B. Dead mesa dropseed was third in importance value on the Monument (16.72%) with black grama third on the Forest (11.68%). Dead galleta plants were fourth on the Monument while dead galleta was sixth on the Forest in terms of importance values.

Totals of 732 mesa dropseed plants, 395 dead mesa dropseed plants, 648 galleta plants, 351 dead galleta plants and 49 black grama plants were counted on transect 3A. The same values for transect 3B were 438, 271, 213, 174, and 112 respectively. Transect 3A had a total absolute ground cover value of 21.60% with 3B totaling 29.90% for the same value.

CMF transects 4A and 4B were both established on 3 June 1978, with 4A located in the SE 1/4, SE 1/4, SW 1/4, SE 1/4 of Section 15, T25N,

R9E and 4B located in the NW 1/4, NE 1/4, NW 1/4, NE 1/4 of Section 22, T25N, R9E. Transects were established to measure the bottom of the west fork of Antelope Wash with approximately 40 m separating the two transects. Tables 18 and 19 present the results of CMF transects 4A and 4B.

Black grama was first in importance values for both the Monument and the Forest with 32.35% for 4A and 41.21% for 4B. Dead black grama was second (16.15% for 4A and 14.63% for 4B) and galleta was third with values of 11.48% and 10.65% for transects 4A and 4B respectively.

Totals of 910 black grama plants, 498 dead black grama plants and 290 galleta plants were counted for transect 4A. The same values for 4B were 703, 301, and 248 respectively. A 15.78% absolute ground cover value was totaled for transect 4A while transect 4B totaled a 35.04% value.

CMF transects 5A and 5B were both established on 4 June 1978, with 5A located in the SW 1/4, SW 1/4, SW 1/4, SW 1/4 of Section 14, T25N, R9E, and 5B located in the NW 1/4, NW 1/4, NW 1/4, NW 1/4 of Section 23, T25N, R9E. The area sampled was the top of the bluff between the forks of Antelope Wash as it passes into the National Forest. The 30 m base lines were established so the perpendicular measurement transects ran north into the Monument for 5A and south into the National Forest for 5B. Approximately 30 m separates the two transects.

Dead galleta was the first in importance value for transect 5A with a 30.19% value while galleta was first for transect 5B, 31.39%. The reverse was true for second position, galleta with 29.55% for 5A and Dead galleta 25.75% for 5B. One-seeded juniper was third for both

transects. Black grama was fourth in importance value on the Forest but was fifth on the Monument.

The same numbers of dead and live galleta were found for the Monument transect, 352. More live (410) and fewer dead (348) galleta plants were counted on the Forest transect. Eighteen black grama plants were counted on transect 5B while only four black grama plants were found on transect 5A. There was a 13.57% total absolute ground cover value for transect 5A and 16.09% for transect 5B.

Crown/Root Area Comparisons

Thirty black grama plants were excavated on both Wupatki National Monument and the Coconino National Forest. All 30 plants from each area were measured for area of crown and roots (Table 22). In terms of crown area, the 30 plants for the National Forest averaged 254.76 square centimeters (sq.cm.) in area while the 30 plants from the Monument averaged only 103.83 sq.cm. The 30 plant average for the area of roots from the Coconino National Forest was 2212.56 sq.cm. while the value for plants from Wupatki National Monument averaged 1114.69 sq. cm. These differences in root area and shoot area for plants from the two study sites were statistically significant at the $p < .05$ level (Table 22). Plants from the Monument, on average, were smaller than those from the adjacent Forest.

Twenty plants from each site were divided into root and shoot portions. After drying these were weighed (Table 22). The average shoot weight was 30.9 grams (g) on the Forest and 17.6 g on the Monument. This difference was significant at the .01 level. The root weights on the monument averaged 19.3 g while on the Forest this average was 14.1 g., the difference here was not significant.

Additionally 20 plants from each site were measured for maximum height. Plants on the Forest averaged 42 cm in height; those from the Monument averaged 16.38 cm.

Overall, from the above measures of plant size, those plants from the National Forest appeared to be larger than those from the Monument.

DISCUSSION

Grazing Exclosures

Numerous differences between the data obtained in the 1977 first sampling and that for the 1978 resampling of Grazing Exclosures I, II, and III were noted. The dominant plants for the various transects according to importance values for the most part remained the same with the general trend being one of increasing importance values. Total absolute ground cover values generally increased and in many cases, densities of important forage producing plants also increased, indicating a good, moist growing season for the entire area. Field observations during the study period also indicated a decrease in domestic livestock grazing pressure from the previous grazing season.

Total absolute ground cover values for all three transects of Grazing Exclosure I increased, with the largest increase found on the inside of the exclosure transect. There was an actual 13.67% increase in cover, galleta being the primary contributor with an additional 27.50% m of line intercept recorded in 1978. This increase amounts to a greater than 48% increase in total cover compared to the previous year's sample inside the exclosure. The transect outside the exclosure increased in total cover by 8.01% and increased by approximately 40% in total absolute ground cover compared to 1977. The National Forest transect increased 3.50% in actual cover which was an 11% increase from the previous year.

The density values for several of the dominant forage plants of Hull's Canyon varied between 1977 and 1978. Within the grazing exclosure, there were an additional 2328 galleta plants counted while

outside the exclosure, 1366 new plants were noted along the transect. A total of 467 new galleta plants was counted on the National Forest transect. A 988 plant increase in dead galleta was found for the inside transect, a 1088 increase in dead galleta for the outside-adjacent transect and only a 126 increase in dead galleta on the National Forest was noted from the 1977 sample. Inside the exclosure, there was a loss of 18 four-wing saltbushes while outside the exclosure there was a 28 plant decrease. Thirty-six new dead four-wing saltbushes were counted outside the exclosure with no change for the same noted inside the exclosure. These changes between the inside, outside and National Forest transects from 1977 to 1978 indicate that the area excluded from grazing within Hull's Canyon has benefited from the removal of grazing pressure.

The transect inside Grazing Exclosure II increased by an actual 7.62% ground cover while the outside-adjacent and National Forest transects increased only 3.05% and 3.48% respectively. This figures to a 28%, 18%, and 14% increase in cover compared to 1977 for the inside, outside and National Forest transects respectively. It is apparent from these figures that the inside transect increased the greatest in terms of absolute ground cover, again demonstrating recovery from grazing pressure.

The density figures for Grazing Exclosure II strongly support the inside exclosure transect as the most productive area between 1977 and 1978. The inside transect had 1738 new galleta plants, three new black grama plants, and had a decrease of 100 dead galleta plants and only one new dead black grama plant. But outside the exclosure, there

was a decrease of 782 galleta plants and a decrease of 63 black grama plants. The outside transect also recorded an increase of 736 dead galleta plants and an increase of 23 dead black grama plants. The National Forest had 542 new galleta plants, 21 new black grama plants, 106 new dead galleta plants and a decrease of 15 dead black grama plants. Both areas exempt from grazing, inside the exclosure and the National Forest, increased in values and reflect the good growing season. But values for the outside the exclosure transect reflect only the grazing pressure on the vegetation.

The change between 1977 and 1978 for Grazing Exclosure III support the trends exhibited at Grazing Exclosures I and II. Inside the exclosure, the actual ground cover increased by 3.72% (an 18% increase) and 992 new galleta plants were counted. Outside the exclosure, there was 2.59% additional ground cover (a 16% increase over 1977) and the loss of 363 galleta plants. Dead black grama increased by 67 outside but decreased by four inside the exclosure. Cowpies decreased by 35 inside the exclosure while the same value increased by six outside the exclosure. The recovery of the area inside the exclosure after removal of grazing pressure is not as evident as was seen for Exclosures I and II, but it is apparent that this area excluded from grazing has also benefited.

It is evident from the results of this one year study that once the areas on Wupatki National Monument were excluded from grazing, the vegetation responded accordingly. Galleta was the dominant plant in this response which would be expected because this plant is an increaser. The decreases or lower increases of dead galleta plants on

the inside the exclosure transects also reflect the positive response of grazing removal. In all cases, the total absolute ground cover values increased, but the greatest increases in these values were always found within the grazing exclosures. It is therefore apparent that the removal of domestic livestock grazing pressure has had beneficial effects on the vegetation within the exclosures on Wupatki National Monument.

Range Condition Transects

Over the 1978 field season, 12 paced transects were established in various areas of the Juniper/Grassland and Grassland Communities of Wupatki National Monument. Of the five transects within the Juniper/Grassland Community, all five had a poor condition class rating for vegetation and all had a very poor condition class rating for soil stability and condition. In the Soil Survey and Range Site and Condition Inventory for Wupatki National Monument prepared by the Soil Conservation Service in 1971, all areas within the Juniper/Grassland Community were classified as either good or fair. This apparent decrease in range condition from 1971 to 1978 indicated that there is a downward trend in vegetation and soil conditions in the Juniper/Grassland Community of Wupatki National Monument.

The seven paced range condition transects established in the Grassland Community support the results found within the Juniper/Grassland Community. Six of the seven transects were rated in a poor range condition class with one exception in a very poor range condition class. All seven of the transects were rated in a very poor condition class for soil stability and condition. All areas within this

were rated either excellent, good or fair in the S.C.S. Special Report, 1971. There is again an apparent downward trend in overall range condition for this community of the Monument from 1971 to 1978.

From the results of the 12 paced range condition transects it is apparent that there is a poor to very poor range condition throughout the Grassland and Juniper/Grassland Communities of Wupatki National Monument. It is also apparent that the soil stability and condition of these two communities are in very poor condition. The decrease in range condition of these communities from the 1971 Soil Conservation Service report clearly indicates a downward trend in range condition.

Cluster Transects

Cluster transect 1 was established in the Grassland Community near the north Monument boundary near East Mesa. This area was rated in a very poor vegetation condition class and a poor soil condition class. This same area was rated good in the 1971 S.C.S. report, a difference of three condition classes. Cluster transect 2 was established in the Juniper/Grassland Community near Grazing Enclosure II and rated a very poor vegetation condition class with a very poor soil condition class rating. This same area was rated in a fair condition class in the S.C.S. 1971 Special Report. Cluster transect 3 was established in upper Hull's Canyon to monitor changes within the four-wing saltbush and galleta association and this area received a poor condition class rating. The soil stability and condition of the area sampled rated a very poor condition classification. The 1971 S.C.S. report rated this area as in fair range condition.

The results of the three cluster transects support those from the

paced transects, that is that the range conditions of the Juniper/Grassland and Grassland Communities of the Monument are in poor to very poor condition. Changes in range condition from the 1971 S.C.S. report to 1978 seemingly indicate a downward trend. This trend is probably a reflection of damage due to grazing rather than damage caused by natural events. Soil stability and condition ratings also indicate a poor to very poor condition and there is probably again a downward trend. Field observations of erosion in Hull's Canyon, on the slopes of South, East, and West Mesas support the view that there exists a downward trend in soil stability and condition.

Comparison Monument-to-Forest Transects

Comparison Monument-to-Forest (CMF) transects 1A and 1B show several differences between the Monument and the National Forest. On the Monument, there was a total absolute ground cover value of 13.46% while the same value on the National Forest was 22.13%, almost a 65% increase in ground cover. On the Monument, there were 943 more galleta plants, 709 more dead galleta plants, 141 dead black grama plants and only 160 live black grama plants. The National Forest had 543 live black grama plants.

CMF transect 2B had a 46.30% total absolute ground cover value with the Monument having 26%, which constitutes 78% more ground cover on the Forest. There were 107 more black grama plants on the National Forest and 64 more dead black grama plants on the Monument. Between transects 3A and 3B, there was almost 30% more ground cover on the Forest, 294 more mesa dropseed plants on the Forest, and 124 more dead mesa dropseed plants on the Monument, more indications that the

National Forest lands are in better range condition.

CMF transects 4A and 4B sample the west fork of Antelope Wash, an area severely overgrazed. The Monument had only 15.78% total ground cover while the National Forest had 35.04% which is almost 122% more cover on the Forest. There was 13.57% absolute ground cover on CMF transect 5A with 16.09% ground cover found on the National Forest. This was 19% more cover on the National Forest in this case. Density value differences between the respective transects also reflect the grazed versus non-grazed situation. From all the data obtained from these Comparison Monument-to-Forest transects, it becomes obvious that domestic livestock grazing on the National Monument is detrimental to the vegetation and soil condition within the Juniper/Grassland Community.

Crown/Root Area Comparisons

The data regarding the sizes of randomly selected Black Grama plants from Wupatki National Monument and parts of the adjacent Coconino National forest show several ways in which these plants differ in size. In all cases where the differences in area or weight were significant statistically (Table 22), those plants from the National Forest were larger. This supports the view that plants growing under the heavy grazing pressure at Wupatki were less vigorous than those growing on the Forest where grazing effects were minimal.

MANAGEMENT RECOMMENDATIONS

We believe that recommendations suggested in previous reports are still valid. We suggest the following: to continue to monitor vegetation and soil conditions on the Monument to determine effects of grazing. We anticipate that transects within the exclosures will continue to improve over the next few seasons and that all comparison transects are likely to fluctuate due to variations in the growing season.

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Table 1. Results of the inside transect of Grazing Exclosure I, 1978.

Species	Absolute			Relative %			Importance Value
	Cover %	Den.	Freq.	Cover	Den.	Freq.	
<u>Hilaria jamesii</u>	16.51	6255	50	58.75	72.05	20.41	50.40
Dead <u>Hilaria jamesii</u>	.56	2074	50	1.99	23.89	20.41	15.43
<u>Atriplex canescens</u>	7.70	44	35	27.38	.51	14.29	14.06
SdIng/yng <u>Atriplex canescens</u>		207	47		2.39	19.18	7.19
Dead <u>Atriplex canescens</u>	2.96	30	22	10.52	.35	8.98	6.62
Cowpie	.33	43	26	1.18	.50	10.61	3.70
<u>Bouteloua eriopoda</u>		6	4		.07	1.63	.57
<u>Sphaeralcea subhastata</u>		4	3		.05	1.22	.42
<u>Verbena gooddingii</u>		4	3		.04	1.22	.42
<u>Sporobolus flexuosus</u>		9	2		.10	.82	.31
<u>Aster arenosus</u>		2	2		.02	.82	.28
<u>Bouteloua gracilis</u>	.05	3	1	.18	.03	.41	.21

Table 2. Results of the outside transect of Grazing Exclosure I, 1978

Species	Absolute			Relative %			Importance Value
	Cover %	Den.	Freq.	Cover	Den.	Freq.	
<u>Hilaria jamesii</u>	8.60	5552	50	43.34	69.52	17.42	43.43
Dead <u>Hilaria jamesii</u>	.72	1785	50	1.45	22.35	17.42	13.74
<u>Atriplex canescens</u>	5.24	76	38	26.38	.95	13.24	13.52
Dead <u>Atriplex canescens</u>	4.26	65	35	21.44	.81	12.20	11.49
Cowpie	.92	93	45	4.65	1.17	15.68	7.17
SdIng/yng <u>Atriplex canescens</u>		382	47		4.78	16.38	7.05
<u>Bouteloua eriopoda</u>	.04	14	9	.22	.18	3.14	1.18
Dead <u>Bouteloua eriopoda</u>		10	5		.13	1.74	.62
<u>Verbena gooddingii</u>		2	2		.03	.70	.24
<u>Aristida fendleriana</u>		1	2		.01	.70	.24
<u>Erigeron concinnus</u>		2	1		.03	.35	.13
<u>Muhlenbergia porteri</u>		2	1		.03	.35	.13
<u>Sphaeralcea subhastata</u>		1	1		.01	.35	.12
<u>Astragalus</u> species	.06	1	1	.32	.01	.35	.12

Table 3. Results of the Forest Service transect of Grazing Enclosure I, 1978.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	7.86	1584	50	23.80	69.17	22.83	38.60
Dead <u>Atriplex canescens</u>	16.28	116	43	49.26	5.07	19.63	24.65
<u>Atriplex canescens</u>	8.06	93	44	24.39	4.07	20.09	16.18
Dead <u>Hilaria jamesii</u>	.60	439	50	1.82	19.17	22.83	14.61
SdIng/yng <u>Atriplex canescens</u>		54	28		2.36	12.78	5.05
<u>Muhlenbergia porteri</u>	.24	1	1	.73	.04	.46	.41
<u>Aster arenosus</u>		1	1		.04	.46	.17
<u>Aristida fendleriana</u>		1	1		.04	.46	.17
<u>Verbena gooddingii</u>		1	1		.04	.46	.17

Table 4. Results of the inside transect of Grazing Exclosure II, 1978.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	21.41	8652	50	79.69	77.83	25.77	61.10
Dead <u>Hilaria jamesii</u>	1.51	2135	50	5.61	19.21	25.77	16.86
<u>Aster arenosus</u>	.17	117	20	.63	1.05	10.31	4.00
SdIng/yng <u>Gutierrezia sarothrae</u>	.12	29	15	.45	.26	7.73	2.81
<u>Juniperus monosperma</u>	1.92	1	1	7.15	.01	.53	2.56
<u>Sphaeralcea subhastata</u>	.12	33	13	.43	.30	6.70	2.48
<u>Sporobolus flexuosus</u>	1.20	69	2	4.48	.62	1.03	2.04
<u>Aristida fendleriana</u>		12	10		.11	5.15	1.75
Cowpie	.11	10	9	.42	.09	4.64	1.72
Dead SdIng/yng <u>Gutierrezia sarothrae</u>		28	9		.25	4.64	1.63
<u>Stipa neomexicana</u>	.02	10	6	.07	.09	3.09	1.08
<u>Bouteloua eriopoda</u>	.06	7	4	.22	.06	2.06	.78
Dead <u>Sporobolus flexuosus</u>	.21	9	2	.79	.08	1.03	.63
<u>Stephanomeria pauciflora</u>	.02	1	1	.06	.01	.53	.20
Dead <u>Bouteloua eriopoda</u>		1	1		.01	.53	.18
<u>Mirabilis multiflora</u>		2	1		.02	.53	.18

Table 5. Results of the outside transect of Grazing Exclosure II, 1978.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	9.38	5929	50	56.36	65.71	20.16	47.41
Dead <u>Hilaria jamesii</u>	1.77	2439	50	10.62	27.03	20.16	19.27
<u>Juniperus monosperma</u>	4.41	4	4	26.51	.04	1.61	9.39
<u>Bouteloua eriopoda</u>	.41	228	33	2.45	2.53	13.31	6.10
Dead <u>Bouteloua eriopoda</u>	.30	147	28	1.80	1.63	11.29	4.91
<u>Aster arenosus</u>	.07	163	26	.43	1.81	10.48	4.24
Cowpie	.29	14	9	1.73	.16	3.63	1.84
<u>Aristida fendleriana</u>		23	12		.25	4.84	1.70
<u>Stipa neomexicana</u>		31	11		.34	4.43	1.59
SdIng/yng <u>Gutierrezia sarothrae</u>		16	10		.09	4.03	1.40
Dead SdIng/yng <u>Gutierrezia sarothrae</u>		8	7		.18	2.82	.97
Dead <u>Stipa neomexicana</u>		17	4		.19	1.61	.60
<u>Sphaeralcea subhastata</u>	.02	3	3	.10	.03	1.21	.45
<u>Zinnia grandiflora</u>		1	1		.01	.42	.14

Table 6. Results of the Forest Service transect of Grazing Exclosure II, 1978.

Species	Cover %	Absolute		Freq.	Relative %		Importance Value
		Cover	Den.		Cover	Den.	
<u>Hilaria jamesii</u>	15.58		4932	50	63.42	64.87	49.22
Dead <u>Hilaria jamesii</u>	2.43		1830	50	9.90	24.07	17.78
<u>Bouteloua eriopoda</u>	2.49		277	35	10.13	3.64	9.11
<u>Aristida fendleriana</u>	.97		131	27	3.94	1.72	5.38
Dead <u>Bouteloua eriopoda</u>	.34		139	28	1.37	1.83	4.59
<u>Juniperus monosperma</u>	2.28		1	1	9.26	.01	3.22
Dead Sdng/yng <u>Gutierrezia sarothrae</u>			75	21		.99	3.04
<u>Aster arenosus</u>	.14		121	14	.57	1.59	2.53
Sdng/yng <u>Gutierrezia sarothrae</u>			31	11		.41	1.56
<u>Zinnia grandiflora</u>	.04		27	6	.16	.36	.95
<u>Stipa neomexicana</u>	.10		10	5	.41	.13	.83
Dead <u>Gutierrezia sarothrae</u>			18	4		.24	.59
<u>Sphaeralcea subhastata</u>			6	4		.08	.54
Dead <u>Aristida fendleriana</u>	.18				.73		.24
<u>Bouteloua gracilis</u>	.03		4	1	.11	.05	.18
Dead <u>Stipa neomexicana</u>			1	1		.01	.13

Table 7. Results of the inside transect of Grazing Exclosure III, 1978.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	8.37	4573	50	40.08	66.14	18.38	41.53
Dead <u>Hilaria jamesii</u>	.45	1980	50	2.16	28.64	18.38	16.39
<u>Chrysothamnus nauseosus</u>	4.04	35	24	19.34	.51	8.82	9.56
<u>Juniperus monosperma</u>	3.49	5	4	16.71	.07	1.47	6.08
Cowpie	.27	49	25	1.30	.71	9.19	3.73
<u>Sphaeralcea subhastata</u>	.57	37	21	2.74	.54	7.72	3.67
SdIng/yng <u>Chrysothamnus nauseosus</u>		51	25		.74	9.19	3.31
Dead <u>Chrysothamnus nauseosus</u>	1.81			8.66			2.87
<u>Bouteloua eriopoda</u>	.45	27	14	2.14	.39	5.15	2.56
Dead <u>Bouteloua eriopoda</u>		24	10		.35	3.68	1.34
<u>Hoffmanseggia jamesii</u>	.16	8	8	.77	.12	2.94	1.28
<u>Atriplex canescens</u>	.69	1	1	3.31	.01	.37	1.23
SdIng/yng <u>Gutierrezia sarothrae</u>		25	8		.36	2.94	1.10
<u>Gutierrezia sarothrae</u>	.11	11	7	.52	.16	2.57	1.08

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Table 7. Continued

Species	Absolute			Relative %			Importance Value
	Cover %	Den.	Freq.	Cover	Den.	Freq.	
<u>Aster arenosus</u>	.14	50	5	.65	.72	1.82	1.06
<u>Aristida fendleriana</u>	.11	6	4	.52	.09	1.47	.69
<u>Muhlenbergia porteri</u>	.16	2	2	.77	.03	.74	.51
<u>Stipa neomexicana</u>		4	4		.06	1.47	.51
<u>Psilostrophe sparsiflora</u>		4	4		.06	1.47	.51
<u>Zinnia grandiflora</u>		16	3		.23	1.10	.44
<u>Chamaesaracha coronopus</u>		4	1		.06	.37	.14
<u>Stephanomeria pauciflora</u>		1	1		.01	.37	.13
<u>Cryptantha jamesii</u>		1	1		.01	.37	.13
Dead <u>Gutierrezia sarothrae</u>	.07			.33			.11

Table 8. Results of the outside transect of Grazing Exclosure III, 1978.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	5.31	4204	49	34.03	62.21	14.41	36.88
<u>Chrysothamnus nauseosus</u>	5.04	61	32	32.32	.90	9.41	14.21
Dead <u>Hilaria jamesii</u>		1484	48		21.96	14.12	12.03
<u>Bouteloua eriopoda</u>	1.14	375	39	7.33	5.55	11.47	8.12
<u>Juniperus monosperma</u>	2.82	4	4	18.06	.06	1.18	6.43
Dead <u>Bouteloua eriopoda</u>		355	40		5.25	11.76	5.67
Cowpie	.30	67	30	1.95	.99	8.82	3.92
SdIng/ yng <u>Chrysothamnus nauseosus</u>		41	21		.61	6.18	2.26
<u>Sphaeralcea subhastata</u>	.14	27	15	.90	.40	4.41	1.90
<u>Psilostrophe sparsiflora</u>	.08	17	11	.54	.25	3.24	1.34
<u>Atriplex canescens</u>	.35	3	5	2.26	.04	1.47	1.26
<u>Stipa neomexicana</u>	.09	24	9	.56	.36	2.65	1.19
<u>Hoffmanseggia jamesii</u>		13	11		.19	3.23	1.14
<u>Aster arenosus</u>		51	9		.75	2.65	1.13

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Table 8. continued

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Muhlenbergia porteri</u>	.27	3	3	1.69	.04	.88	.87
<u>Gutierrezia sarothrae</u>	.06	16	5	.36	.24	1.47	.69
SdIng/yng <u>Atriplex canescens</u>		9	4		.13	1.18	.44
<u>Aristida fendleriana</u>		2	2		.03	.59	.21
<u>Stephanomeria pauciflora</u>		2	2		.03	.59	.21
SdIng/yng <u>Gutierrezia sarothrae</u>		1	1		.02	.29	.10

Table 9. Results of the pace transects of the Juniper/Grassland community of Wupatki National Monument and the Coconino National Forest.

	WNM	WNM	WNM	WNM	WNM	CNF	CNF
Transect Number	2	3	4	5	6	1 a	1 b
Hits: All Plants	2	0	1	1	2	13	4
Rock	2	0	0	3	0	2	3
Litter	4	2	1	3	1	0	8
Bare soil	92	98	98	93	97	85	85
Total	100	100	100	100	100	100	100
Hits: All Forage Plants	2	0	1	1	1	11	3
Erosion Hazard Index	92	98	98	93	97	85	85
Forage Cover Index	1	0	1	1	1	2	2
Composition	13	22	21	17	21	24	28
Vigor	7	7	7	7	4	7	10
Total	21	29	29	25	26	38	40
Condition class	poor	poor	poor	poor	poor	poor	poor
Erosion Hazard	3	1	1	3	1	5	5
Current Erosion	10	12	11	15	10	40	40
Total	13	13	12	18	11	45	45
Condition class	very poor	very poor	very poor	very poor	very poor	fair	fair

Table 10. Results of the pace transects of the Grassland community of Wupatki National Monument.

Transect Number	7	8	9	10	11	12	13
Hits: All Plants	6	5	6	2	3	3	2
Rock	0	0	1	0	2	0	1
Litter	10	7	6	1	1	1	1
Bare soil	84	88	87	97	94	96	96
Total	100	100	100	100	100	100	100
Hits: All Forage Plants	6	5	6	2	2	3	1
Erosion Hazard Index	84	88	87	97	94	96	96
Forage Cover Index	4	3	4	1	1	2	1
Composition	19	12	20	29	28	19	27
Vigor	3	3	3	2	4	5	5
Total	26	18	27	32	33	26	33
Condition Class	poor	very poor	poor	poor	poor	poor	poor
Erosion Hazard	5	4	4	1	2	2	2
Current Erosion	12	10	10	11	12	11	11
Total	17	14	14	12	14	13	13
Condition Class	very poor	very poor	very poor	very poor	very poor	very poor	very poor

Table 11. Results of cluster transects established on Wupatki National Monument.

	Cluster 1					Cluster 2					Cluster 3				
Transect Number	1	2	3	total	ave.	1	2	3	total	ave.	1	2	3	total	ave.
Hits: All Plants	10	10	9	29	10	1	6	8	15	5	4	2	0	6	3
Rock	2	0	0	2	1	0	0	0	0	0	0	0	0	0	0
Litter	6	15	13	34	11	5	5	14	24	8	7	3	3	13	4
Bare soil	82	75	78	235	78	94	89	78	261	87	89	95	97	281	93
Total	100	100	100	300	100	100	100	100	300	100	100	100	100	300	100
Hits: All Forage Plants	9	9	8	26	9	1	6	8	15	5	4	2	0	6	3
Erosion Hazard Index	82	75	78	235	78	94	89	78	261	87	89	95	97	281	93
Forage Cover Index	6					3					2				
Composition	10					9					28				
Vigor	3					3					2				
Total	19					15					32				
Condition class	very poor					very poor					poor				
Erosion Hazard	6					4					3				
Current Erosion	15					15					10				
Total	21					19					13				
Condition class	poor					very poor					very poor				
	near Mammal grid-grassland					by Exclosure 2 in Jun/Gr.					Upper Hull's Canyon Atriplex-Hija				

Table 12. Results of comparison Monument-to-Forest transect 1A, Monument.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	7.82	3520	18	58.13	70.90	18.56	49.20
Dead <u>Hilaria jamesii</u>	1.60	1078	18	11.89	21.71	18.56	17.39
Cowpie	1.88	45	14	13.96	.91	14.43	9.77
Dead <u>Bouteloua eriopoda</u>	.98	141	17	7.27	2.84	17.53	9.21
<u>Bouteloua eriopoda</u>	.42	160	18	3.14	3.22	18.56	8.31
<u>Chrysothamnus nauseosus</u>	.69	2	2	5.12	.04	2.06	2.41
<u>Sphaeralcea subhastata</u>	.06	13	5	.50	.26	5.15	1.97
<u>Aristida fendleriana</u>		3	2		.06	2.06	.71
<u>Stephanomeria pauciflora</u>		2	2		.02	2.06	.70
<u>Stipa neomexicana</u>		1	1		.04	1.03	.35

Table 13. Results of comparison Monument-to-Forest transect 1B, Forest.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Hilaria jamesii</u>	14.66	2577	18	66.21	67.75	20.69	51.55
<u>Bouteloua eriopoda</u>	4.24	543	18	19.18	14.27	20.69	18.05
Dead <u>Hilaria jamesii</u>	1.71	369	18	7.73	9.70	20.69	12.71
Dead <u>Bouteloua eriopoda</u>	1.46	268	18	6.58	7.05	20.69	11.44
<u>Sphaeralcea subhastata</u>	.07	39	9	.30	1.03	10.34	3.89
<u>Aristida fendleriana</u>		8	6		.21	6.89	2.37

Table 14. Results of comparison Monument-to-Forest transect 2A, Monument.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Bouteloua eriopoda</u>	13.51	1064	18	51.97	59.38	23.08	44.81
Dead <u>Bouteloua eriopoda</u>	2.91	646	18	11.20	36.05	23.48	23.44
<u>Chrysothamnus nauseosus</u>	8.83	6	5	33.97	.33	6.41	13.57
Cowpie	.23	17	12	.90	.95	15.38	5.74
<u>Cryptantha jamesii</u>		14	8		.78	10.26	3.68
<u>Hilaria jamesii</u>	.26	25	4	.98	1.40	5.13	2.50
<u>Psilostrophe sparsiflora</u>	.26	4	4	.98	.22	5.13	2.11
Dead <u>Hilaria jamesii</u>		8	2		.45	2.56	1.00
<u>Andropogon scoparius</u>		3	2		.17	2.56	.91
<u>Ephedra viridis</u>		1	1		.06	1.28	.45
Dead <u>Ephedra viridis</u>		1	1		.06	1.28	.45
<u>Stephanomeria pauciflora</u>		1	1		.06	1.28	.45
<u>Aster arenosus</u>		1	1		.06	1.28	.45
SdIng/yng <u>Chrysothamnus nauseosus</u>		1	1		.06	1.28	.45

Table 15. Results of comparison Monument-to-Forest transect 2B, Forest.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Bouteloua eriopoda</u>	38.29	1171	18	82.70	65.53	28.12	58.82
Dead <u>Bouteloua eriopoda</u>	4.70	582	18	10.15	32.57	28.12	23.61
<u>Chrysothamnus nauseosus</u>	2.26	5	4	4.87	.28	6.25	3.80
<u>Cryptantha jamesii</u>		9	6		.50	9.38	3.29
<u>Psilostrophe sparsiflora</u>	.30	5	4	.65	.28	6.25	2.39
Cowpie		4	4		.22	6.25	2.16
SdIng/yng <u>Chrysothamnus nauseosus</u>		3	3		.17	4.69	1.62
<u>Stephanomeria pauciflora</u>		3	2		.17	3.12	1.10
<u>Oryzopsis hymenoides</u>	.76	1	1	1.63	.06	1.56	1.08
Dead <u>Gutierrezia sarothrae</u>		1	1		.06	1.56	.54
<u>Aster arenosus</u>		1	1		.06	1.56	.54
Dead <u>Chrysothamnus nauseosus</u>		1	1		.06	1.56	.54
<u>Stipa neomexicana</u>		1	1		.06	1.56	.54

Table 16. Results of comparison Monument-to-Forest transect 3A, Monument.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Sporobolus flexuosus</u>	7.44	732	14	34.47	30.42	10.53	25.14
<u>Hilaria jamesii</u>	3.58	648	16	16.56	28.43	12.03	19.01
Dead <u>Sporobolus flexuosus</u>	4.69	395	14	21.71	16.42	10.53	16.22
Dead <u>Hilaria jamesii</u>	.51	351	16	2.37	14.59	12.03	9.66
<u>Gutierrezia sarothrae</u>	2.36	13	8	10.91	.54	6.02	5.82
<u>Bouteloua eriopoda</u>	.81	49	12	3.76	2.04	9.02	4.94
SdIng/yng <u>Gutierrezia sarothrae</u>		81	15		3.37	11.28	4.88
Dead <u>Gutierrezia sarothrae</u>	.84	20	10	3.91	.83	7.52	4.09
Cowpie	.43	13	7	2.01	.54	5.26	2.60
Dead <u>Bouteloua eriopoda</u>	.07	26	7	.31	1.08	5.26	2.22
<u>Juniperus monosperma</u>	.87	1	1	4.01	.04	.75	1.60
<u>Aster arenosus</u>		26	3		1.08	2.26	1.11
<u>Hoffmanseggia jamesii</u>		3	3		.12	2.26	.79
<u>Zinnia grandiflora</u>		7	2		.29	1.50	.60

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Table 16. continued

Species	Absolute		Freq.	Relative %		Freq.	Importance Value
	Cover %	Den.		Cover	Den.		
<u>Sphaeralcea subhastata</u>		2	2		.08	1.50.	.53
Dead <u>Opuntia whipplei</u>		1	1		.04	.75	.26
<u>Lycium andersonii</u>		1	1		.04	.75	.26
<u>Stipa neomexicana</u>		1	1		.04	.75	.26

Table 17. Results of comparison Munument-to-Forest transect 3B, Forest.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Sporobolus flexuosus</u>	6.22	438	14	20.81	32.23	10.77*	21.27
Dead <u>Sporobolus flexuosus</u>	5.18	271	14	17.32	19.94	10.77	16.01
<u>Bouteloua eriopoda</u>	4.57	112	15	15.27	8.24	11.54	11.68
<u>Hilaria jamesii</u>	1.80	213	14	6.02	15.67	10.77	10.82
<u>Gutierrezia sarothrae</u>	5.82	23	10	19.47	1.69	7.69	9.62
Dead <u>Hilaria jamesii</u>	1.69	174	13	5.65	12.80	10.00	9.48
Dead <u>Bouteloua eriopoda</u>	.46	63	15	1.52	4.64	11.54	5.90
SdIng/yng <u>Gutierrezia sarothrae</u>		38	15		2.80	11.54	4.78
<u>Juniperus monosperma</u>	2.59	1	1	8.66	.07	.77	3.17
Dead <u>Gutierrezia sarothrae</u>	.63	9	6	2.12	.66	4.62	2.47
<u>Opuntia whipplei</u>	.77	1	1	2.56	.07	.77	1.13
<u>Atriplex canescens</u>	.16	2	2	.52	.15	1.54	.74
<u>Sphaeralcea subastata</u>	.02	2	2	.07	.15	1.54	.59
SdIng/yng <u>Atriplex canescens</u>		2	2		.15	1.54	.56

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Table 17. continued.

Species	Absolute			Relative %			Importance Value
	Cover %	Den.	Freq.	Cover	Den.	Freq.	
<u>Hoffmanseggia jamesii</u>		2	2		.15	1.54	.56
<u>Aster arenosus</u>		5	1		.37	.77	.38
<u>Zinnia grandiflora</u>		1	1		.07	.77	.28
<u>Echinocereus engelmannii</u>		1	1		.07	.77	.28
Cowpie		1	1		.07	.77	.28

Table 18. Results of comparison Monument-to-Forest transect 4A, Monument.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Bouteloua eriopoda</u>	6.33	910	18	40.14	43.58	13.33	32.35
Dead <u>Bouteloua eriopoda</u>	1.78	498	18	11.27	23.85	13.33	16.15
<u>Hilaria jamesii</u>	1.49	290	15	9.44	13.89	11.11	11.48
<u>Stipa neomexicana</u>	1.63	108	14	10.35	5.17	10.37	8.63
Dead <u>Hilaria jamesii</u>	.17	93	14	1.06	4.45	10.37	5.29
Dead <u>Stipa neomexicana</u>	.	51	11		2.44	8.15	3.53
<u>Psilostrophe sparsiflora</u>	.37	27	9	2.32	1.29	6.67	3.43
<u>Gutierrezia sarothrae</u>	1.12	4	2	7.11	.19	1.48	2.93
<u>Stephanomeria pauciflora</u>	.46	13	7	2.89	.62	5.19	2.90
<u>Chrysothamnus nauseosus</u>	1.12	1	1	7.11	.06	.75	2.64
<u>Atriplex canescens</u>	.89	2	2	5.63	.10	1.48	2.40
SdIng/yng <u>Gutierrezia sarothrae</u>		34	7		1.63	5.19	2.27
Cowpie		6	6		.29	4.44	1.58
<u>Sporobolus flexuosus</u>	.29	24	2	1.83	1.15	1.48	1.49

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Table 18. continued.

Species	Absolute			Relative %			Importance Value
	Cover %	Den.	Freq.	Cover	Den.	Freq.	
<u>Aristida fendleriana</u>		4	3		.19	2.22	.80
Dead <u>Sporobolus flexuosus</u>		16	2		.77	1.48	.75
Sdlnng/ynng <u>Atriplex canescens</u>		4	2		.19	1.48	.56
<u>Erigeron concinnus</u>		3	2		.14	1.48	.54
<u>Oryzopsis hymenoides</u>	.11			.70			.23
<u>Andropogon scoparius</u>	.02			.15			.05

Table 19. Results of comparison Monument-to-Forest transect 4B, Forest.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
<u>Bouteloua eriopoda</u>	20.47	703	18	58.40	47.40	17.82	41.21
Dead <u>Bouteloua eriopoda</u>	2.02	301	18	5.77	20.30	17.82	14.63
<u>Hilaria jamesii</u>	1.52	248	11	4.34	16.72	10.89	10.65
<u>Atriplex canescens</u>	5.27	8	5	15.03	.54	4.95	6.84
<u>Stipa neomexicana</u>	1.58	51	11	4.50	3.44	10.89	6.28
Dead <u>Hilaria jamesii</u>	.37	109	9	1.05	7.35	8.91	5.77
<u>Ephedra viridis</u>	1.24	5	2	3.55	.34	1.98	1.96
<u>Stephanomeria pauciflora</u>		6	5		.40	4.95	1.78
Dead <u>Stipa neomexicana</u>	.22	5	4	.63	.34	3.97	1.65
<u>Muhlenbergia porteri</u>	.86	7	2	2.44	.47	1.98	1.63
<u>Chrysothamnus nauseosus</u>	.74	2	2	2.12	.13	1.98	1.41
<u>Oryzopsis hymenoides</u>	.05	4	3	.17	.27	2.97	1.14
<u>Andropogon scoparius</u>	.58	11	1	1.65	.74	.99	1.13
<u>Cryptantha jamesii</u>		3	3		.20	2.97	1.06

-continued-

Table 19. continued.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
SdIng/yng <u>Gutierrezia sarothrae</u>		14	2		.94	1.98*	.97
SdIng/yng <u>Chrysothamnus nauseosus</u>		3	2		.20	1.98	.73
SdIng/yng <u>Atriplex canescens</u>		2	2		.13	1.98	.70
<u>Psilostrophe sparsiflora</u>		1	1		.07	.99	.35
Dead <u>Andropogon scoparius</u>	.12			.35			.12

Table 20. Results of comparison Monument-to-Forest transect 5A, Monument.

Species	Cover %	Absolute Den.	Freq.	Cover	Relative % Den.	Freq.	Importance Value
Dead <u>Hilaria jamesii</u>	.82	352	14	6.06	48.62	35.90.	30.19
<u>Hilaria jamesii</u>	.91	352	13	6.71	48.62	33.33	29.55
<u>Juniperus monosperma</u>	11.44			84.28			28.09
Cowpie	.28	3	3	2.05	.41	7.70	3.39
<u>Aster arenosus</u>	.12	6	2	.90	.83	5.13	2.29
<u>Bouteloua eriopoda</u>		4	2		.55	5.13	1.89
<u>Stipa neomexicana</u>		3	2		.41	5.13	1.85
<u>Psilostrophe sparsiflora</u>		2	1		.28	2.56	.95
Dead <u>Bouteloua eriopoda</u>		1	1		.14	2.56	.90
<u>Sitanion hystrix</u>		1	1		.14	2.56	.90

Table 21. Results of comparison Monument-to-Forest transect 5B, Forest.

Species	Abundance			Relative %			Importance Value
	Cover %	Den.	Freq.	Cover	Den.	Freq.	
<u>Hilaria jamesii</u>	2.82	410	14	17.54	49.70	26.92	31.39
Dead <u>Hilaria jamesii</u>	1.31	348	14	8.15	42.18	26.92	25.75
<u>Juniperus monosperma</u>	8.56			53.18			17.73
<u>Bouteloua eriopoda</u>	2.68	18	8	16.64	2.18	15.38	11.40
Dead <u>Bouteloua eriopoda</u>	.54	15	7	3.38	1.82	13.46	6.22
<u>Aster arenosus</u>	.10	24	2	.63	2.91	3.85	2.46
<u>Stipa neomexicana</u>	.08	2	2	.48	.24	3.85	1.52
<u>Aristida fendleriana</u>		5	2		.61	3.85	1.49
<u>Psilostrophe sparsiflora</u>		2	2		.24	3.85	1.36
Dead <u>Aristida fendleriana</u>		1	1		.12	1.92	.68

Table 22. Areas and weights of shoots and roots from black grama plants (Bouteloua eriopoda) selected at random from Coconino National Forest and Wupatki National Monument. Areas in square centimeters, weights in grams.

Plant Number	SHOOTS				ROOTS			
	Coconino N.F.		Wupatki N.M.		Coconino N.F.		Wupatki N.M.	
	Area ¹	Weight ²	Area ¹	Weight ²	Area ³	Weight	Area ³	Weight
1	381.06	60.8	105	22.4	2449.25	22.4	1775	25.6
2	51	16.4	138	31.8	585.75	4.8	1870.5	71.8
3	225	28.1	71.25	9.0	2349.5	11.7	881.25	7.5
4	325.5	30.6	150	19.4	2295	18.7	1100.5	9.2
5	256.5	52.6	121	22.4	1958	12.6	2082.5	32.6
6	575	35.4	105	11.8	2109	13.9	765	7.1
7	184	24.9	90	15.1	2034	9.7	1382.5	15.1
8	217.5	19.4	56	6.7	1618.5	11.0	728.5	10.1
9	121.5	17.3	105	26.2	1638	5.9	2371.5	11.7
10	2002	81.6	49	8.2	8601	63.7	891	5.1
11	132.25	20.2	93.5	13.3	2260	6.5	769.5	21.1
12	71.25	18.3	128.25	13.0	1479.25	5.7	940.75	18.0
13	40	14.4	57	9.7	2520	9.4	1140	3.4
14	189	35.5	126.5	32.5	2324	18.0	1397.5	49.4
15	63.75	11.8	54	13.9	1224.75	4.1	612.5	6.0
16	138	31.8	126.5	18.3	1696	5.8	1440	30.7
17	48	10.8	85.5	12.1	1464.75	3.7	594	10.7
18	150	17.0	115	19.7	3876	9.8	1906.5	15.3
19	306.25	39.2	143.75	27.2	1558	16.3	1093.5	18.8
20	456	51.9	92	19.9	3675	29.0	1482.25	16.1

Table 22. continued

Plant Number	SHOOTS				ROOTS			
	Coconino N.F.		Wupatki N.M.		Coconino N.F.		Wupatki N.M.	
	Area	Weight*	Area	Weight*	Area	Weight*	Area	Weight*
21	355.25		71.25		1618.2		750	
22	323.75		155		1867.5		1165.6	
23	56.19		198		628.63		1035	
24	105		33		7695.75		430.5	
25	72.25		72		1283.75		432	
26	63.75		75		808.25		637	
27	184		76		1740		1360	
28	132		24		1054		459	
29	313.5		365.5		1312		1441.75	
30	103.5		32.5		689		505.25	

* Weights were not taken for plants numbers 21 to 30.

1 = difference significant at $p < .05$

2 = significant at $p < .01$

3 = significant at $p < .005$

III

ARTHROPODS

INTRODUCTION

Wupatki and Sunset Crater National Monuments offer many interesting and different patterns of biota. Within these two monuments, four types of floral communities have been recognized (Green and Rominger, 1976). Sunset Crater National Monument is dominated by only one type, Ponderosa Pine. Wupatki National Monument contains three different vegetation types: Grassland, Juniper/Grassland, and Cold Desert Shrub.

To a great extent, the diversity and numbers of arthropods that are found in a given community depend on the floral composition in that particular area. These four very contrasting vegetation types offer an opportunity to study, contrast, and compare arthropod fauna within diverse communities.

In order to study the diversity and activity of insects in the two monuments, several sites were established within the four major plant communities on the monuments. Over 62,000 insects were collected and identified during six months in 1978. Occasional references are made to a similar study in 1977 using the same sites. This work was reported by Peters and Johnson (1978).

METHODS AND MATERIALS

The six sites that were established in the monuments for the 1977 study were also used in the 1978 survey. 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 24 hours per day throughout

the study period. The Sunset Crater Visitor Center is located in Ponderosa Pine at an elevation of 6927 feet; the Wupatki Visitor Center is predominantly Cold Desert Shrub or Great Basin Desert and is located at an elevation of 4870 feet.

Four additional sites, designated S1, S2, S3, and S4 , were 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 Pinderosa Pine at 7005 feet. Locations of all six sites in the monuments are shown in Figure 1.

At each of the four sites, a transect approximately 125 yards in length was established. Each transect consisted of 25 pitfall traps. These pitfall traps were made by setting a seven inch deep by five inch diameter plastic bucket in the ground. A 12 inch by 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 sweeping.

The insects were removed from the black-light traps twice per week from 10 July to 21 August, emptied once per week at other times between 1 May and 28 October. Insects were separated by site, date, quantity, and sample method. Borror et al. (1976) was employed for identification of insects.

Pitfall traps and black-light traps were started on 29 April, 1978. Sweeping was begun on 6 May, with the last sampling day for all sites and methods being 28 October.

RESULTS

Data collected from this study are summarized in the tables. Table 1 and 2 list the numbers of insects caught in the black-light traps at Visitor Center - Wupatki and Visitor Center - Sunset Crater respectively by date and family. Sites 1 through 4, which were not located at the visitor centers, have combined data for sweeping and pitfall traps (Tables 3-6). Tables 7 and 8 list the numbers of Hyles lineata, Manduca sexta, and M. quinquemaculata caught at Visitor Center - Wupatki and Visitor Center - Sunset Crater by date. Table 9 lists the species of Tenebrionidae (Coleoptera) caught in pitfall traps at all non-visitor center sites. Table 10 is a listing of lizard species caught in all pitfall traps. In this case, weekly totals have been combined into monthly figures. Lastly, Table 11 presents all insects caught at Wupatki and Sunset Crater National Monuments during 1978.

Last year, an outbreak of the small, sand-colored noctuid moth, Tridepia nova (Sm.) was reported (Peters and Johnson, 1978). This outbreak occurred in the Cold Desert Shrub of Wupatki National Monument around the visitor center and somewhat northwest of the center from 24-30 August, 1977. However, this year not one individual of this species was observed. In 1977, individuals of this species had been seen on Four-wing Saltbush (Atriplex canescens) in pitfall

traps and the Wupatki black-light trap, and had been taken by sweeping. None of these sampling methods or field observations produced any sightings of the moth adults or larvae in 1978.

The 1978 study produced the following totals of insects captured at each site: VCW- 19,654, VCS- 38,296, S1 - 440, S2 - 182, S3 - 714, and S4 - 2,937. The total of all insects captured during 1978 was 62, 230.

DISCUSSION

Wupatki Black-light Trap (VCW)

Of the two black-light traps operated at the monument visitor centers, the trap at the Wupatki Visitor Center had the smallest total number of insects caught during the study period (19,654). It showed, however, a more unpredictable activity of insects when compared to the Sunset Crater black-light trap. This can be seen in Figures 2 and 3.

The graph of Wupatki black-light captures (Figure 2) demonstrates that most insect activity in the Cold Desert Shrub occurs during the three month period of June, July, and August. The drop in the curve at the end of June may have been caused by low rainfall amounts during May and June; only 0.03 in. of precipitation were recorded during these two months. (Figure 8). There is also a very large peak in late September. This was due to an outbreak of noctuid moths (Noctuidae: Lepidoptera). In one week near the end of September, about 2,300 noctuid moths were captured in the black-light trap. This may also be due to rainfall patterns. Previous to the third week in September, the greatest weekly total of precipitation was 0.26 in.

in the first week of August. However, in the third and fourth weeks of September, 0.95 and 0.87 in. of rain fell. This two week total (1.82 in.) is much greater than monthly totals preceeding these two weeks. For example, May had 0.02 in., June 0.01 in., July 0.67 in., and August 0.42 in. of rain. Thus, heavy rainfall late in the season may have produced an outbreak of noctuid moths within the Cold Desert Shrub. However, it is not known why other groups of moths or beetles did not also increase during this time.

Several dominant families of beetles (Coleoptera) were seen to predominate at the Wupatki Visitor Center black-light trap. Three were most abundant: comb-clawed beetles (Alleculidae), predaceous diving beetles (Dystiscidae), and scarab or June beetles (Scarabaeidae). Of these three, scarab beetles were the most common with 1400 individuals collected during the six month study (Table 1).

Stink bugs (Pentatomidae: Hemiptera) were very abundant at the Wupatki trap in 1978. Nearly 2000 were caught during the study period. These bugs can do considerable damage to plants when they occur in high densities.

Of all insects attracted to the black-light traps, the predominant group was the moths. At Wupatki, noctuid moths slightly outnumbered snout moths (Pyralidae) 5055 to 4342. However, if the noctuid moths had not experienced an outbreak of 2300 in late September, snout moths would have represented a much larger relative total.

Several species of sphinx moths (Sphingidae) were drawn to the black-light trap. The white-lined sphinx moth, Hyles lineata (F.) was present in greatest numbers (Figure 4). Two other sphinx moths,

the tomato hornworm, Manduca quinquemaculata (Haworth) and the tobacco hornworm, M. sexta (L.), were also present but in much lesser numbers. The curve of the white-lined sphinx moth rises sharply around 1 July and falls rapidly to very low levels by the end of August. Its peak activity was around the first of August during 1978. The white-lined sphinx was recorded mostly between the last week in June and the last week of August. The hornworm moths were caught in much lower numbers, but seemed to be active over a longer period from the first week in June to mid-September.

A third sphinx moth, the big poplar sphinx (Pachysphinx modesta), was caught on 14 August, 1978. Only one individual was captured.

A large and conspicuous moth that was caught fairly often was Glover's silk moth, Platysamia gloveri (Strecker), in the family Saturniidae. This moth was captured on July 20, 27, 31, and August 3.

Most, if not all, of the aquatic insects caught in the Wupatki black-light trap came from two sewage ponds located near the visitor center. This results in more families and numbers of insects being collected at this trap than would otherwise be expected in the Cold Desert Shrub. This should be noted when comparing these data with those from other communities.

Sunset Crater Black-light Trap (VCS)

The other black-light trap was located at the Sunset Crater Visitor Center. Insects caught in this trap numbered 38,296. Nearly all of the insects captured were collected during July and August of 1978 (Figure 3). Thus, it appears that one major difference in

insect activity between Wupatki and Sunset Crater Monuments is that Wupatki has an additional month for activity (June).

Though the Sunset Crater area may have a shorter activity period, during this time its numbers far exceeded those of the Wupatki trap. In the third week of July over 10,000 insects were counted in the trap at the Sunset Crater Visitor Center, almost one-third of the monthly total. Figure 3 shows how quickly activity rose and fell in July.

Dominant families of Coleoptera captured at the light trap included comb-clawed beetles (Alleculidae), sap beetles (Nitidulidae), and scarab beetles (Scarabaeidae). Of the three, scarab beetles were the most numerous (570).

An outbreak of winged adult ants (Formicidae: Hymenoptera) was noted from 10-24 July, 1978. This may have occurred due to rainfall. Between 6 May and 10 July only 0.13 in. of precipitation was recorded at the Sunset Crater Visitor Center; of this amount, 0.10 in. fell in the week of 6 May. However, between 10-24 July, 1.35 in. were recorded. The winged adults did persist past this period, but in much lower numbers (Table 2).

Of the Lepidoptera caught at Sunset Crater, noctuid and pyralid moths were dominant families. Unlike the Wupatki black-light trap, snout moths (Pyralidae) far outnumbered noctuid moths: 14,318 compared to 9,769.

Flies (Diptera) were caught in large numbers this year, but because of time limitations and poor condition of specimens caught in the light trap, identification proved very difficult. Rather than

identify the flies to incorrect families, many were designated unknown.

Activity of white-lined and hornworm sphinx moths was similar to that at Wupatki. Figure 5 shows how steep and symmetrical was the curve for white-lined sphinx moth activity. It differs from the curve at Wupatki (Figure 4) by reaching a higher point and by beginning to rise two weeks later than that of the Wupatki graph. Note, however, that activity of white-lined moths at Wupatki and Sunset Crater areas both end around the last week of August. Manduca sexta was not identified at Sunset Crater, but this may not indicate its absence since some trapped hornworm moths were in very poor condition and identification to species was not possible. In contrast, both tomato and tobacco hornworm moths were definitely identified at Wupatki.

A third sphinx moth, the twin-spotted sphinx, Smerinthus jamaicensis (Drury), was caught on 13 May, 5 June, 27 July, and 31 July, 1978 at VCS. Also one individual of Glover's silk moth was caught on 24 July. On 6 May a pierid butterfly was found in the light trap. This specimen was a southern dogface, Zerene eurydice. Saturniid moths were very common in the light trap this year and were nearly all the pandora moth, Coloradia pandora Blake.

Click beetles (Elateridae) were often found in the black-light trap. Although most belonged to the genus Melantous, one uncommon "eyed elater", Alaus oculatus (L.), was caught on 3 July.

All silphid beetles collected in light traps or pitfall traps belonged to the genus Nicrophorus and no Silpha individuals were

caught by any sampling methods. Silpha individuals are very common around Flagstaff and although one may infer that they have different habits and so are not attracted to light traps, it is puzzling that none were collected in pitfall traps.

Pitfall Traps

Darkling beetles (Tenebrionidae: Coleoptera) was the most common group of insects found at all sites. Sites 3 and 4 had many more tenebrionid beetles than Sites 1 or 2 (Table 9). At Site 3, Eleodes hispilabris and E. extricata were the most common species. At Site 4, E. obscura was by far the dominant species in number (437) and size, since it is much larger than other species except perhaps E. longicollis. Two other species, E. extricata and E. hispilabris, were also very common at Site 4. At Site 4, caution should be exercised when considering the data for E. hispilabris. The classification is not clear at this site for this species, and we have chosen to lump several forms that may actually be different species into E. hispilabris. At Site 4, E. hispilabris as designated here may actually include three species.

Figure 6 shows total tenebrionid activity for Sites 3 and 4. Obviously, Site 4 has much more beetle activity than does Site 3. It appears that tenebrionid activity is more dependent on climatic fluctuations at Site 3 than Site 4. However, at Site 3 this summer little rain fell and year-to-year fluctuations in precipitation make comparisons difficult. Tenebrionid activity did seem to peak in early August at Site 3 and mid-July at Site 4, reflecting the differences in elevation and fewer warm months available at Site 4.

Another dominant family found in the pitfall traps was Gryllacrididae (Orthoptera). Within this family, camel crickets were found at all sites. Jerusalem crickets were only found at Site 4. Figure 7 shows the activity of Jerusalem and camel crickets at Site 4. Although camel crickets showed no definite pattern, Jerusalem crickets were caught in a pattern that resembles a "bell curve", with a peak occurring around the first week of August. A few Jerusalem crickets were seen in June, but most were active from July to September.

It seemed clear after sampling was concluded that the high number of insects captured at Site 4 was not indicative of more "typical" Ponderosa Pine areas found around Sunset Crater. Site 4 is located on the western edge of Bonito Park. Half of the Site 4 transect extends into Bonito Park, an old vacant field, and the other half into Ponderosa Pine. Within the Ponderosa Pine at Site 4, there are few cinders on the ground and shrubs are abundant. This is not "typical" of areas around Sunset Crater. Therefore, the data from Site 4 probably represents a maximum that the other Ponderosa Pine areas could achieve and pertains more to ecotonal areas such as those around Bonito Park.

A large number of tiger moth caterpillars (Arctiidae: Lepidoptera) was caught in pitfall traps at Site 1. These were probably moths of the genus Apantesis.

Sweeping for Insects

Success in sweeping for insects depended on climatic factors much of the time. High winds or rain greatly reduced efficiency of

this type of sampling.

At Site 1, plants were widely spaced and tended to be woody shrubs such as Four-wing Saltbush. The most common insect family was that of leafhoppers (Cicadellidae), but weevils (Curculionidae) were also common. While sweeping, no insects were ever taken from Mormon Tea (Ephedra), due possibly to the lack of visible leaves for food.

The outbreak of Tridepia nova, a small noctuid moth, on the Four-wing Saltbush around Site 1 during 1977 did not occur in 1978. As a matter of fact, not a single individual of this moth species was seen or taken during 1978. It is possible that the relative lack of rain before September suppressed the emergence of this moth, or that the moth emerged elsewhere in the monument on the Atriplex.

At Site 3, leafhoppers were also in greatest abundance. From 21-29 May, 1978 soft-winged flower beetles (Melyridae) were seen in great numbers on flowers of cacti. Wanting to preserve equipment and personal health, these flowers were not swept.

At the Ponderosa Pine site, many more families were collected by sweeping than at the other sites. Many families of Diptera and Hymenoptera were noted (Table 6). However, as discussed earlier, this is because Site 4 does not represent a very "typical" area of Sunset Crater's Ponderosa Pine. The diversity of shrubs and tall grasses found at Site 4 would be expected to produce many more families than at the other sites.

Arthropods Other Than Insects

Pseudoscorpions were found in the black-light traps at both visitor centers during June, July, and August. Occasionally, close

to 15 per three day sampling period were found. Since they cling to insects and are carried about, the more insects in the black-light traps, the greater chance of finding pseudoscorpions.

Sun-scorpions were found at all sites except Site 1. These solpugids probably belonged to the family Eremobatidae.

Centipedes were fairly common at Site 3. All centipedes caught in pitfall traps at Site 3 were of the genus Scolopendra.

Other Observations

At Sites 2 and 3, cicadas (Cicadidae) were heard and seen from 29 May to 26 June. There appeared to be at least two species. These were not captured by sweeping due to their excellent eyesight and quick movements.

Another group that was not collected in general were ants. Because an ant colony was occasionally established at or near the lip of a pitfall trap, collection of individuals in those pitfall traps would not lead to a better understanding of overall insect activity, but would bias the results. Therefore, non-winged ants were generally not counted in pitfall traps.

A total of 105 individual lizards representing seven species and two families was taken from the pitfall traps at the four sites in 1978 (Table 10). The greatest number taken during any single month was 38 for the month of September.

Park Rangers reported an outbreak of ladybird beetles (Coccinellidae: Coleoptera) on O'Leary's Peak around the 10th of June. This is a common behavior of these beetles.

Small bats of the species Myotis californicus were often

caught in the black-light trap at the Wupatki Visitor Center during May and October. This may be in response to lower insect levels at these times.

Finally, a small hole in the sweep net was noticed on 24 September that may have lowered the values of the data for that week and previous weeks' sampling. Any effect would probably show most at sites such as Sites 1 and 2 where low numbers of insects were usually captured.

CONCLUSIONS AND RECOMMENDATIONS

The Ponderosa Pine plant community showed the most diversity in insect fauna. More families and more individuals per family were counted here than in any other vegetation type.

The data from the black-lights show that many families are represented by only one or two individuals. This is a common result of light trapping (Williams, 1964; Preston, 1948). This suggests that many additional families may not have been caught in the light trap. Probably, it would be impossible to detect all insect species in even a simple community due to sampling errors and fiscal restraints. However, the dominant and generally more visible families and species can be determined.

During this study, 130 families of insects were identified including the unknown categories and 62,230 insects were counted. Together with the total for 1977, 108,338 insects have been counted and identified.

The summer of 1978, especially in May and June, was very dry compared to that of 1977. As a result, much of the insect activity

was depressed. Insect activity within the Cold Desert Shrub community was concentrated between June and August. Insect activity in Ponderosa Pine was restricted mainly to July and August but exhibited much more variety and greater numbers than the Wupatki areas.

Insect abundances seem highly dependent on climate and vegetation. Climate may affect insects through its effects on vegetation. Since insects are such an important part of the diets of lizards, birds, and certain mammals, effects on vegetation by man through grazing or improper recreational use will eventually have an effect on all trophic levels of a community. Therefore, care should be taken in planning and management to allow the communities to exist in their most natural state.

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Table 1. VCW: Summarized Data for the Black Light Trap at Wupatki Visitor Center, 1978.

	May				June				July								August							September					October				TOTAL
	6	13	21	29	5	12	19	26	3*	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	
COLEOPTERA																																	
Alleculidae						1			96	4	202	73	132	38	128		126	124	3	3		2	3										935
Anobiidae			1			1				1																							3
Anthicidae					2							4		2			1						3										12
Bostrichidae			1																														1
Cantharidae																				1													1
Carabidae			2		16	2	10	2		14	2	8	18	3	17	2	23	18	2	6	1	3	18		6	4	1	4	2	6			190
Cerambycidae					1	1	1	1		1		2	3	1	3			1				1	1		1								18
Chrysomelidae						1						1		1				1				1					3						8
Cicindelidae									2		4						2	2															10
Cleridae						1			1			3					1	1	1	1	1	1	1	1	1	2	1						16
Coccinellidae			1														17	6	1	1													26
Curculionidae									6	1	1											1			2								11
Dermestidae					1		1						9				1	2	4			1											19
Dytiscidae	2	2			16	2	1		6	13	7	72	25	31	12	26	39	48	1	12	2	6	8		26		13	6	3	2			381
Elateridae									1	3	1	8	1	5	2	2	5	3	1				1	1									34

Table 1. continued

	May				June				July								August							September					October					
	6	13	21	29	5	12	19	26	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	TOTAL	
Heteroceridae					5																												5	
Histeridae																	1													2	2		5	
Hydrophilidae						1	1		1			1	2		2																		8	
Helyridae	1															1																	2	
Nitidulidae																						2					4	1		4	3	1	1	16
Scarabaeidae	3	9	40	15	11	7	11	10	1	51	10	196	41	99	56	223	141	119	31	40	6	29	182	4	61	2	1	1					1400	
Scolytidae									1							1																	2	
Silphidae						1	2	1															1	1		2		6	3	3	1		21	
Staphylinidae															1													1					2	
Tenebrionidae																						1											1	
Unknown									1																								1	
<u>DIPTERA</u>																																		
Asilidae										1																							1	
Bombyliidae																											1						1	
Calliphoridae					1			1																	1								3	
Empididae				1																													1	
Mycetophilidae	18	6	24		22	42	64	32	23		8		6	6						4	4				34				6	23	3		325	
Phoridae				1																													1	

Table 1. continued

	May				June				July								August							September					October				TOTAL	
	6	13	21	29	5	12	19	26	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28		
Sarcophagidae	1										1																							2
Sepsidae		2																																2
Syrphidae	2																																	2
Unknown	1	9			6	28	52	6	54	48	1	5	6	3	19	8	72	27	2	7	4	1	5	2	4	2	1	16	9	3		5		406
<u>HEMIPTERA</u>																																		
Coreidae																	2	1															3	
Corixidae	13	3	2		73	25	528	6	1	67	1	13	43	11	15	17	2	62	1	2		1	1		3	1				4			895	
Cydnidae																	14	3		2									1				20	
Lygaeidae	1		7	1	3	3	5	1		14		4	3		1	6	23	8	2	11	2	3	39	1		3	1	2	8	1			153	
Miridae		1			8	17	42	6	11	12		3	11	5		2	36	28	2	7	1	1	5	2		2		1	1		5	3	212	
Nabidae												2					2																4	
Notonectidae													1													1				3			5	
Pentatomidae	2	7			32	31	45		3	202	10	928	33	42	45	212	248	56	29		5	7	7	3	2								1949	
Reduviidae					3						1	2					2						2	1									11	
<u>HOMOPTERA</u>																																		
Cicadellidae					1											2	18			6											1		28	

Table 1. continued

	May				June				July								August							September					October				TOTAL	
	6	13	21	29	5	12	19	26	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28		
<u>HYMENOPTERA</u>																																		
Anthophoridae															1																		1	
Apidae							2						1																				3	
Braconidae																			1											3	1		5	
Formicidae										11	3	13	20	5	4	12		78	31	2				6	5								370	
Ichneumonidae	10	3	10	4	7	8	3					1	1				1						1			1			1		2	53		
Mutillidae		3	25	2	17	10	65	15	14	49	1	25	10	45	21	36	23	15	2	6			6	4		1	1						396	
Pompilidae															1																		1	
Sphecidae				1																													1	
Tiphiidae	1	2	17	8	2	8	25	42	15	51	4	31	41	49	26	36	26	26	13	7	3	11	9		6	5	1		1				466	
Unknown				1						1													1			3							6	
<u>LEPIDOPTERA</u>																																		
Arctiidae			10	5	9	2	3	13	2	6	3	4		1	4	3	2	6	6	3	1	5	8	7	7	2	1	2	1				116	
Ctenuchidae					2	18	17	7	2	5					1	7	1	3	1				1	1	4	7							77	
Geometridae	12					4	2	7	12	4				2		3	5			4				1	1	3	1			6	8		75	
Lasiocampidae								1											1	10	3	5	5	1									26	
Noctuidae	131	25	122	27	141	257	183	94	25	14	21	22	16	51	71	108	119	170	59	27	28	39	54	13	28	41	122	227	3	452	172	98	52	5055

Table 1. continued

	May				June				July								August								September					October				
	6	13	21	29	5	12	19	26	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	TOTAL	
Pterophoridae									1																								1	
Pyralidae	62	22	68	34	160	364	244	102	136	1020	20	581	124	92	142	232	306	328	16	25	18	7	23	7	19	15	6	23	43	18	29	56	4342	
Saturniidae												1			1	1	2	2					4	3	40	13	2						69	
Sphingidae	16	25	50	10	12	19	16	7		49	15	70	4	78	34	79	130	45	38	51	10	9	7	9	6	7			2				798	
Unknown	12		52		68		68	14		116	3	48	17	14	7	21	2			5	2									4			453	
<u>NEUROPTERA</u>																																		
Chrysopidae												1										2				1	1			1			6	
Hemerobiidae																		1		1													2	
Myrmeleontidae					4	4	1		2	7		4			1	2	2	1	2														30	
Raphidiidae					1																												1	
<u>ODONTA</u>																																		
Unknown											1																						1	
<u>ORTHOPTERA</u>																																		
Acrididae							1			11	1	39		3	4	5	14	2	11								1						92	
Blattellidae					2	3			1	5		1	2	1	2	5		1							2								25	

Table 1. continued

	May				June				July								August							September					October				TOTAL
	6	13	21	29	5	12	19	26	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	
Gryllacrididae	1				1				6						1																		9
Gryllidae										1	2			1	2		1	4	1				6		1								19
Mantidae																							1										1
Tettigoniidae					2																												2
TOTAL	268	116	456	110	586	859	1388	418	313	1887	119	2293	694	693	545	1168	1487	1146	231	242	87	147	414	58	257	116	157	2340	531	223	173	132	19654

*Black light found blown over

Table 2. VCS: Summerized Data for the Black Light Trap at Sunset Crater Visitor Center, 1978

	May				June				July							August							September					October							
	6	13	21	29	5	12	19	28	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	TOTAL		
COLEOPTERA																																			
Alleculidae							5		1	16	25	153	15	49	21	17	7					1											310		
Anobiidae	1			1	1	1	1					5		2	3	1	1	1	2					1									21		
Anthicidae											140	11	28	2	17			5	4														207		
Bostrichidae											8	3	7	15	2				5	2			3	1	2					1			49		
Buprestidae					1				1					3				2															7		
Cantharidae			2		2	5	3		1	1	2	8	1	15	4	8		1															53		
Carabidae			2		4					3	6	68	4	32	10	30	2	10	15			1	2		1	1			3				194		
Cerambycidae			1		1	2	6		4	13	3	14	4	2	3	3	4	1						1									62		
Chrysomelidae							1				1	11	2	1	4	10	3	2						1				2	5				43		
Cicindelidae												1																					1		
Cleridae										2	1	9			3	2	4		1	3	1				1	1							28		
Coccinellidae			1		1	1							2																				5		
Colydiidae												1							1														2		
Cucujidae					1																												1		
Curculionidae											3				2				1														6		
Dytiscidae					1	1					7	2	9		1	3	7	3	1	1			1	3	2				2				44		

Table 2. continued

	May				June				July							August							September					October				TOTAL
	6	13	21	29	5	12	19	28	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28
Elateridae					4				2		32	4	24	7	6		5	4														88
Histeridae																								1								1
Hydrophilidae					1																					1						2
Lampyridae																												1				1
Lycidae									1	1	4		1	5	2	1																15
Melyridae													2						1	2	3	1	2									11
Monomniidae																													1			1
Mordellidae											3	1				1																5
Nitidulidae		3			1		1	1			127	53	91	24	46		13	54	31	1	21	48	11	6	14	4		1	2	1	2	556
Phengodidae											1	2	4	9			3	1	2	2												24
Pyrochroidae															1																	1
Scaphidiidae											1																					1
Scarabaeidae	4	42			14	23	9	21	7	13	43	64	39	59	37	45	32	27	16	7	8	7	12	9	23	4	1	2	2			570
Scolytidae		14				2					1	1	1	7		1		2	2					2								33
Silphidae						2	5	5	2		8	2	14	4	3		1	2	3	2	2	3	10		11	4			2	1		86
Staphylinidae											1	4	5	1	2	1	1		1		1											17
Tenebrionidae		1				1		1		3	7	5		22	8	23	4	4	24		2	5	2	4	3				1			120

Table 2. continued

	May				June				July								August							September					October				
	6	13	21	29	5	12	19	28	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	TOTAL
Troglisitidae														5	1		1															7	
Unknown							1		1																					1		3	
<u>DIPTERA</u>																																	
Acroceridae										1																						1	
Bibionidae	5																															5	
Calliphoridae																													1			1	
Cecidomyiidae														1																		1	
Chironomidae												1		66																		67	
Culicidae														11											1	7	3	23	4		7	19	75
Drosophilidae																						1										1	
Muscidae	1																															1	
Mycetophilidae			54		16	50	28	14	4	23			309	540	124				49	96	93	83		86	12	2						1583	
Sarcophagidae															3							3										6	
Sciaridae	3																															3	
Syrphidae														1									1									2	
Tephritidae	1		1									5			1		9	1				1										19	
Tipulidae					1							2		5			1	1		1					1				6			18	

Table 2. continued

	May				June				July								August							September					October				
	6	13	21	29	5	12	19	28	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	TOTAL
Unknown			19	3	2	5	12	7	3	46	122	3	180	590	208	327	48	73	168	7	23	5	1	4	6		13	4	3	2		2982	
<u>HEMIPTERA</u>																																	
Coreidae														4																		4	
Corixidae			4				32			6	9	98	12	7	15	3	2		5					1			1					195	
Lygaeidae											19		3	1	14		4	2	4								2		1			50	
Miridae			3					1	3		4	146	6	63	46	234	71	68	417	9	3	3		2	5	3			1			1088	
Nabidae											9		2		3		5		3					1								23	
Notonectidae																								1			2					3	
Pentatomidae										2	4	131	3	21	1	98	41	5	3													309	
Reduviidae							1	1																								2	
<u>HOMOPTERA</u>																																	
Cicadellidae													2		6									1								9	
<u>HYMENOPTERA</u>																																	
Braconidae													2	13			9		1	4		2										31	
Eurytomidae																				1												1	
Formicidae					2		9		159	796	584	191	33	32	6	22	8	32	5		5	11		6			12					1913	
Ichneumonidae	2		2	2	2	3	3					3	4	5	26	4	2	1	4	1				1	2		1		1			69	
Mutillidae							1			3	20	2	4		13	1		2		2				1								49	

Table 2. continued

	May				June				July								August							September					October				
	6	13	21	29	5	12	19	28	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	TOTAL
Pteromalidae																	2			1													3
Siricidae													1																				1
Tiphiidae							1	1			1		1	5		1				1													11
Vespidae								1		6	1	7	2	4	5	4	3	6	1						5	2							47
Unknown											90			168																			258
<u>LEPIDOPTERA</u>																																	
Arctiidae					1	5	3	5	7	25	21	20	4	3	11	5	31	1	3							1							146
Drepanidae										12	41	20	9	3	3	3		1															92
Ethmiidae											4						3																7
Geometridae	7	2	43	30	50	13	5	20	6	46	36	182	13	76	39	51	31	18	28	4	6	17	6	15	8	4		7	6	9			778
Lasiocampidae							21	3	6	4	3		2	4	8		8	12	9	4	4	2	7	7	13	2	16	27	29	7	4		202
Noctuidae	35	217	502	128	210	422	198	87	302	633	327	2153	174	1446	101	572	51	254	171	24	64	120	86	88	87	117	36	352	447	129	148	88	9769
Pieridae	1																																1
Pterophoridae										1	1	3	1														1						7
Pyralidae	17	3	89	42	20	18	72	79	58	2560	493	2870	284	1969	997	1489	856	1128	624	86	84	102	59	26	14	42	29	38	76	29	37	28	14318
Saturniidae		4	11		1	8	8	22	23	28	2	4	1	3	1	5	3	3	1	1			3	4	1								137

Table 2. continued

	May				June				July								August								September					October																																	
	6	13	21	29	5	12	19	28	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	TOTAL																														
Sphingidae	8	12	17	8	13	9	23	12	15	19	25	71	16	187	54	299	103	106	65	14		13	5	3	5	5							1107																														
Unknown					10		12	63	39			36					11					16											187																														
<u>NEUROPTERA</u>																																																															
Chrysopidae			1									2		1		2	8	4	2						2								22																														
Hemerobiidae			2						2		5	19		4		8	1	43						2									86																														
Inocelliidae													3																				3																														
Myrmeleontidae											1	1		1									1										4																														
Raphidiidae									1		2	1									1												5																														
<u>ORTHOPTERA</u>																																																															
Acrididae												1																						1																													
Gryllacrididae											1																							1																													
Gryllidae															1	1	1							1	1								5																														
Tettigoniidae																1																		1																													
<u>TRICHOPTERA</u>																																																															
Limnephilidae										1				1										3	2	2		2						11																													
TOTALS	81	242	813	215	340	573	424	391	486	3633	1856	8702	1056	5533	1847	3378	1414	1818	1700	226	321	436	320	285	221	202	85	490	585	186	202	135	38296																														

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

	May				June				*	July					August				September					October				**	Pittraps	Sweeps	Total
	6	13	21	29	5	12	19	26		3	10	17	24	31	7	14	21	27		1	9	16	24	30	7	14	21	28			
<u>COLEOPTERA</u>																															
Buprestidae						/1							/1	/1																4	4
Carabidae				1/												1/												2			2
Cerambycidae						1/																						1			1
Chrysomelidae													/2			/1							/7							10	10
Coccinellidae			/1		/1																									2	2
Curculionidae		1/		2/									/5	/15	/4	/16	1/3				1/	/1					5	44		49	
Histeridae				1/																							1			1	
Melyridae	/1	/6		/2	/1																		/9						19	19	
Scarabaeidae															1/		1/						1/				3			3	
Staphylinidae															/1															1	1
Tenebrionidae	3/	3/	1/	4/	1/	1/	2/	2/	3/		7/	3/	4/	4/	3/	9/	1/	4/	2/	1/		3/	1/	2/	1/	65				65	
Unknown			/1																										1	1	
<u>DIPTERA</u>																															
Sciaridae	/1																													1	1
Syrphidae	1/3																										1	3		4	

Table 3. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total	
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28				
Tephritidae	/1		/2																						/1			4	4	
Unknown			/2		/2									1/							/2	/1					1	7	8	
<u>HEMIPTERA</u>																														
Cydnidae				1/																							1		1	
Lygaeidae			/7																									7	7	
Miridae	/1		/2	/2	/7				2/														/1	1/		3	14	17		
Pentatomidae	1/		1/		1/9	1/3	1/				/1																5	13	18	
Reduviidae			/1																									1	1	
Tingidae	/3	/14	/11	/8																	/1							37	37	
Unknown				/3	/3																							6	6	
<u>HOMOPTERA</u>																														
Aphididae	/4		/1	/1	/2																							8	8	
Cicadellidae	/1	/14	/18	/4	/5	/5	/1				/2			/1							/3			/1				55	55	
Flatidae											/1																	1	1	
Fulgoridae			/1											/1														2	2	
Psyllidae	/1																											1	1	
Unknown			/1	/1		/2	/1																					5	5	

Table 3. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Totals	
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28				
<u>HYMENOPTERA</u>																														
Anthophoridae				1/																							1		1	
Braconidae					/1															/1								2	2	
Chalcididae						/2																						2	2	
Formicidae	/1																											1	1	
Halictidae				/1																								1	1	
Megachilidae																			1/								1		1	
Mutillidae				1/		1/	1/	2/			2/	1/	2/	1/	1/			3/	1/	1/	1/	2/	1/				21		21	
Pompilidae																			1/					2/			3		3	
Pteromalidae		/1		/2									/1							/1								5	5	
Sphecidae	/1			1/																							1	1	2	
Tiphiidae									1/																		1		1	
Unknown	/2	/1	/2																									5	5	
<u>LEPIDOPTERA</u>																														
Arctiidae		1/	2/	2/		1/	1/				1/							3/		1/	7/	5/	14/	4/	1/		43		43	
Geometridae				/1																								1	1	
Pieridae					1/																						1		1	

Table 3. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28			
Unknown					/2			/1	1/					/1													1	4	5
<u>ORTHOPTERA</u>																													
Acrididae								/1					/1																
Blattellidae								1/																				2	2
Blattidae				1/					1/									2/									1		1
Gryllacrididae		1/																									4		4
Mantidae																					2/						3		3
Pitfall traps	4	6	3	15	3	4	5	6	9	1	7	6	1	8	5	4	11	4	11	6	5	8	11	16	9	2	1		
Sweeps	9	33	50	29	26	28	7				4		9	19	7	17	3			15	11		2		1		170		
Total	13	39	53	44	29	32	12	6	9	1	11	6	10	27	12	4	28	7	11	6	20	19	11	18	9	3		270	440

* High winds, no sweeping done

** Rain, no sweeping done

Table 4. Combined Data for Site 2; Juniper/Grassland: Pitfall Traps and Sweeping (# per Pitfall trap/# per Sweeps)

	May				June				July					August				September					October				Pittraps	Sweeps	Total			
	6	13	21	29	*5	12	19	26	*3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	**21	28						
<u>COLEOPTERA</u>																																
Anthicidae		/1		/1																									2	2		
Chrysomelidae											/2	/1									/1	/1							5	5		
Curculionidae		1/		1/	1/						/1	1/1						1/		1/	1/1							7	3	10		
Elateridae																							1/					1		1		
Melyridae			/2	/2		/2			/1					/1	/1	/1													10	10		
Scarabaeidae				1/							1/			1/			1/		1/		2/							7		7		
Tenebrionidae	4/	1/	1/						1/	1/	1/	4/		2/	2/	2/	3/	2/	1/	1/	4/			1/				31		31		
Unknown											/1																		1	1		
<u>DIPTERA</u>																																
Pipunculidae																					/1								1	1		
Tephritidae																					1/								1	1		
Unknown	/1				/1				1/	/1				/1						/3		/8	/1	1/			2	16	18			
<u>HEMIPTERA</u>																																
Coreidae											/1																		1	1		
Lygaeidae														/1						/3									4	4		
Miridae		/2																											2	2		
Pentatomidae					/1																			1/		1		1	1	2		

Table 4. continued

	May				June				July				August				September					October				Pittraps	Sweeps	Total		
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28				
Phymatidae					/1								/1															2	2	
Reduviidae													1/														1	1		
<u>HOMOPTERA</u>																														
Cicadellidae			/10	/3	/1	/1	/6						/9	/3						/1			/1					35	35	
Unknown													/1															1	1	
<u>HYMENOPTERA</u>																														
Braconidae	/1																			/1								2	2	
Formicidae				1/																							1		1	
Mutillidae				1/	1/	2/	1/	2/				3/	2/	1/							2/						15		15	
Pompilidae					1/				1/																		2		2	
Pteromalidae			/6																									6	6	
Tiphidae				1/1																							1	1	2	
Unknown					/1								/1															2	2	
<u>LEPIDOPTERA</u>																														
Noctuidae									1/														1/				2		2	
<u>NEUROPTERA</u>																														
Myrmeleontidae			/1																									1	1	

Table 4. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total	
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28				
<u>ORTHOPTERA</u>																														
Acrididae			/1	/1	/1		/2		/1	/2	/1			/1		/1				/1	/1	/1						14	14	
Blattellidae							1/																				1		1	
Gryllacrididae																		1/						1/		2		2		
Mantidae							2/					1/														3		3		
<u>THYSANOPTERA</u>																														
Phaeothripidae					/1																							1	1	
Pitfall traps	4	2	1	5	2	3	1	5	3	2	1	8	5	1	3	2	3	4	4	2	4	7	1		1	3	77			
Sweeps	1	2	22	8		7	3	8		2	3	3	14	7	1	2	2	1			13	2	9	2				112		
Total	5	4	23	13	2	10	4	13	3	4	4	11	19	8	4	4	5	5	4	2	17	9	10	2	1	3			189	

* High winds, no sweeping done

** Rain, no sweeping done

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

	May				June				July					August				September					October				Pittraps	Sweeps	Total		
	6	13	21	29	5*	12	19	26	3*	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28					
<u>COLEOPTERA</u>																															
Anobiidae																/1															
Cerambycidae								1/																					1	1	
Chrysomelidae			/1																									1		1	
Coccinellidae					/1											/1													1	1	
Curculionidae	2/	1/							1/							/1	1/									/1		4	3	2	2
Histeridae														1/																7	
Melyridae	/11	/7	/3																								1			1	
Scarabaeidae				1/		1/								4/	4/	2/	2/	5/	10/	10/	9/		3/	2/					21	21	
Silphidae														1/															53	53	
Tenebrionidae	33/	5/	12/	16/	25/	9/	4/	9/	10/	7/	19/	19/	21/	18/	27/	7/	3/	8/	14/	2/	3/	7/	3/	3/	2/	2/		288			288
Unknown		/1																													
<u>DIPTERA</u>																															
Mycetophilidae	/2																														
Phoridae		/1																											2	2	
Pipunculidae	/2																												1	1	
																								/4	/2			8		8	

Table 5. continued

	May				June				July				August				September					October				Pittraps	Sweeps	Total		
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28				
Simuliidae														/1		/2													3	3
Tephritidae	/1																				/1			/1	/3				6	6
Unknown	/1	/6	/7		/1									/1	/1					/6		/2	/1	/1				27	27	
<u>HEMIPTERA</u>																														
Lygaeidae			1/		1/1					/1																	2	2	4	
Miridae		/1	/3																						/1			5	5	
Pentatomidae					/3	/1	/1													1/				2/		3	5	8		
Tingidae			/1																									1	1	
Unknown					/2	/3	/1					/2																8	8	
<u>HOMOPTERA</u>																														
Cicadellidae			/1	/32	/9	/6		/2	/3	/1	/23		/2	/2						/3	/3		/4					91	91	
Cicadidae					/1																							1	1	
Fulgoridae										/8	/7	/7	/6	/5				/2	/2	/3	/1		/2					43	43	
Psyllidae														/1														1	1	
Unknown					/13		/4	/4																				21	21	
<u>HYMENOPTERA</u>																														
Braconidae																				/1	/1							2	2	

Table 5.

	May				June				July				August				September				October				Pittraps	Sweeps	Total		
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28			
Chalcididae					/1																							1	1
Formicidae									/4					/1				/1										6	6
Mutillidae			2/	4/	4/	2/			2/	1/	1/		1/	1/			1/	2/				2/			1/		24		24
Pompilidae								1/																1/			2		2
Pteromalidae			/2															/1						/1				4	4
Sphecidae									/1																			1	1
Tiphiidae				1/																						1			1
Unknown	/1		/1		/2									/2				/1				/1		/1				8	8
<u>LEPIDOPTERA</u>																													
Nymphalidae																						/1						1	1
Pyralidae				/1																								1	1
Unknown														1/1				/1				/1		/5		1		7	8
<u>ORTHOPTERA</u>																													
Acrididae		/1			/5				/1		/2	/1	/1	/1			/1			/2		/1						15	15
Gryllacrididae								1/		1/	2/	1/	3/	2/	5/			1/	1/	7/	1/					27			27
Mantidae					1/	1/																				2			2

Table 5. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28			
<u>THYSANOPTERA</u>																													
Phaeothripidae					/1								/1															2	2
Thripidae												/1																1	1
<u>TRICHOPTERA</u>																													
Unknown					/1																							1	1
Pitfall Traps	33	7	16	22	29	13	5	12	14	8	21	21	27	28	32	14	9	20	25	13	10	14	6	4	3	4	410		
Sweeps	2	23	24	6		46	18	21		8	12	10	35	9	10	15	4	1	3	2	9	16		7	18	5		304	
Total	35	30	40	28	29	59	23	33	14	16	33	31	62	37	42	29	13	21	28	15	19	30	6	11	21	9			714

* High winds, no sweeping done

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

	May				June				July				August				September					October *				Pittraps	Sweeps	Total
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28		
<u>COLEOPTERA</u>																												
Anthicidae					/1	/1	/1	/3						/1													7	7
Anthribidae											/4																4	4
Carabidae	1/	5/			4/	3/	2/	7/	1/	17/	9/	30/	26/	35/	30/	9/	10/	5/	1/	2/	1/	2/		3/	1/	204		204
Cerambycidae									2/		1/	1/						/1								4	1	5
Chrysomelidae					/3	/1	/2	/2	/3	/1	/1	/2	/4	/7		/1				/4	/3						34	34
Cicindelidae																										1		1
Cleridae					/1				/1		/2			/2		/2											8	8
Coccinellidae		1/3							/1	/2			/1	/1	/1	/1			/1							1	11	12
Curculionidae	1/	5/1	4/	1/1	/2	/1		2/2	/3	/2	/1	/2	/2	/4	/4	/3		/2	/3	/1			1/1			14	35	49
Elaterridae	1/									1/																2		2
Helyridae					1/					/1	/1	/13	/11	/8	/5	/5		/2								1	46	47
Horrellidae								/1		/1																	2	2
Phalacridae																					/1						1	1
Scarabaeidae					3/	3/	6/	1/	5/					1/	1/			1/								21		21
Staphylinidae															1/			1/					1/			3		3

Table 6. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28			
Tenebrionidae	33/	37/	71/	58/	45/	63/	48/	53/	50/	46/	74/	76/	56/	50/	64/	43/	37/	10/	28/	25/	115/	19/	11/	6/	4/		1022	1	1023
<u>DIPTERA</u>																													
Acroceridae					/2	/1																						3	3
Bibionidae	/40		/2																									42	42
Conopidae														/1														1	1
Drosophilidae									/5	/2		/1	/3															11	11
Empididae					/1																							1	1
Leptogastridae											/1																	1	1
Mycetophilidae	/1																											1	1
Pipunculidae			/1	/1	/1																/1		/2					6	6
Sarcophagidae									/2		1/	/1															1	3	4
Sciaridae	/1																											1	1
Simuliidae		/6	/3	/5	/1																							15	15
Tephritidae				/1	/1	/5	/3	/1	/1					1/3	/17	1/0		/3	/3		/2	/4						54	54
Therevidae									/2																			2	2
Unknown	/1	/12	/11	/14	/14	/31	/4	/49	/42	/44		/1	13	/5	/2	/3		/6	/17	/16	/13	/4		/1			293	293	

Table 6. Continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total	
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28				
<u>HEMIPTERA</u>																														
Coreidae											/1																		1	1
Lygaeidae			1/	/1						/1				/2				/8	/5	/19	/11	/16		/1	1		64	65		
Miridae			/3	/4	/2			/4	/1	/8	/1	/7	/8	/2	/2	/1		/5	/10	/5	/3	/6		/1			73	73		
Nabidae											/1	/2															3	3		
Pentatomidae								/2		/5	/7	/4								/1							19	19		
Scutelleridae																		/1		/2							3	3		
Tingidae			/1		/1																						2	2		
Unknown										/2			/3	/1													6	6		
<u>HOMOPTERA</u>																														
Aphididae			/1		/1	/1				/1																		4	4	
Cercopidae														/1													1	1		
Cicadellidae	/1	/6		/7	/14			/28	/46	/78	/31	/46	/64	/37	/14	/18		/10	/13	/3	/6		/1			423	423			
Fulgoridae														/3	/1												4	4		
Membracidae										/1	/3		/1					/1								6	6			
Psyllidae					/1					/2			/2					/9	/7							21	21			
Unknown										/2																	2	2		

Table 6. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28			
HYMENOPTERA																													
Anthophoridae														/1				/1		1/						1/	3	1	4
Apidae															/1						/2							3	3
Braconidae				/1	/1					/1		/2	/1							/2	/2			/10	/5			25	25
Chalcididae												/1																1	1
Encyrtidae												/2																2	2
Eucharitidae							/1																					1	1
Eupelmidae					/3																							3	3
Figitidae														/1														1	1
Formicidae	/1		/3												/58	/15		/1		/13	/4							95	95
Halictidae									/1																			1	1
Ichneumonidae					/1	/2				/1				/1	/3	/1	/3			/1		/1						14	14
Megachilidae										/1											/1							2	2
Mutillidae			1/				2/								1/												4		4
Perilampidae											/1																	1	1
Pompilidae					1/			2/		1/					1/				1/				2/	1/			9		9

Table 6. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total	
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28				
Pteromalidae					/2		/1				/2	/2	/6	/2						/12	/9	/7		/5		/1				
Sphecidae														1/	1/						2/				1/		5			5
Vespidae																		2/									2			2
Unknown			/2			/1		/2							/1						/3		/2					11		11
<u>LEPIDOPTERA</u>																														
Arctiidae				1/	1/				1/		1/																4			4
Noctuidae					1/						1/			2/													4			4
Nymphalidae					/1	/1																						2		2
Pterophoridae									/1		/1																	2		2
Pyralidae													/3	/1		/1												5		5
Unknown					3/1				1/																		4	1		5
<u>ORTHOPTERA</u>																														
Acrididae				2/	/3	1/2	/1		/5	/19	/6	/9	/5	/9	/11	/4	/2		1/	/1	/1		/1			/1	4	80		84
Gryllacrididae	3/	1/				1/		5/1	2/	3/	7/	12/		14/	10/	7/	3/	4/	2/	4/	1/			1/	1/	81				81
Gryllidae									1/					19/					1/						1/	22				22

Table 6. continued

	May				June				July					August				September					October				Pittraps	Sweeps	Total
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28			
Mantidae									1/																		1		1
Tettigoniidae					/1								/2															3	3
Pitfall Traps	36	41	85	66	53	73	55	73	59	74	88	115	96	106	110	64	55	21	36	33	20	24	11	9	10	5	1418		
Sweeps	42	3	37	21	48	28	66	12	100	128	161	57	111	120	79	117	68		1	65	89	67	40	48		11		1519	
Total	78	44	122	87	101	101	121	85	159	202	249	172	207	226	189	181	123	21	37	98	109	91	51	57	10	16			2937

* Rain, no sweeping done

Table 7. Summarized Data for the White-Lined (Hyles lineata), Tomatato Hornworm (Manduca quinquemaculata), and Tobacco Hornworm (Manduca sexta)
Sphinx Moths Caught in the Black Light Trap at the Wupatki Visitor Center, 1978.

	May				June				July							August							September					October					
VCW	6	13	21	29	5	12	19	26	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	Total
<u>Hyles lineata</u>	14	24	48	9	11	10	9	1	35	11	62	2	73	29	73	120	44	30	49	5	5	2	5	4	7			2				684	
<u>Manduca</u>																																	
<u>quinquemaculata</u>		1															2			2			2									7	
<u>Manduca sexta</u>										4							4	1	8	1	2	4	5	1	2							32	
<u>Manduca**</u>	2		2	1	1	6	7	6	14		8	2	5	5	6	4				1			1									71	
Total	16	25	50	10	12	16	16	7	49	15	70	4	78	34	79	130	45	38	50	10	9	7	9	6	7			2				794	

* Black light found blown over

** Species identification of hornworm moths not possible due to poor condition

Table 8. Summarized Data for the White-Lined (Hyles lineata), Tomato Hornworm (Manduca quinquemaculata), and Tobacco Hornworm (Manduca sexta)
Sphinx Moths Caught in the Black Light Trap at the Sunset Visitor Center, 1978

	May				June				July							August							September					October					
	6	13	21	29	5	12	19	26	3	10	13	17	20	24	27	31	3	7	10	14	17	21	27	1	9	16	24	30	7	14	21	28	Total
<u>Hyles lineata</u>	8	11	17	8	12	9	14	6	9	15	22	64	14	185	52	279	102	97	62	13	14	12	4	3	5	5							1042
<u>Manduca</u>																																	
<u>quinquemaculata</u>											3	7					1	9	3	1	2	1	1									28	
<u>Manduca sexta</u>																																----	
<u>Manduca *</u>						9	6	6		4			2	2	1	16																46	
Total	8	11	17	8	12	9	23	12	15	19	25	71	16	187	53	295	103	106	65	14	16	13	5	3	5	5						1116	

* Species identification of hornworm moths not possible due to poor condition.

Table 9. Summarized Data for Darkling Beetles (Tenebrionidae: Coleoptera) Caught in Pitfall Traps at All Sites, 1978.

SITE 1	May <u>6 13 21 29</u>				June <u>5 12 19 26</u>				July <u>3 10 17 24 31</u>					August <u>7 14 21 27</u>				September <u>1 9 16 24 30</u>					October <u>7 14 21 28</u>				Total
<u>Edrotes</u>																											
<u>ventricosus</u>									2					1		1								1			5
<u>Eleodes</u>																											
<u>extricata</u>							1			5	2			2	1		6	1	1								19
<u>Eleodes</u>																											
<u>hispidabris</u>	2	2	1	1	1		1	1			1			2	1	1		2					1		1		18
<u>Eleodes</u>																											
<u>longicollis</u>		1					1								1				1	1				1			6
<u>Eusattus</u>																											
<u>reticulatus</u>							1																				1
<u>Stenomorpha</u>																											
<u>marginata</u>									1						1			1	1				2	1			7
<u>Stenomorpha</u>																											
<u>obovata</u>																	1										1
Unknown	1			3		1				1				2													8
Subtotal Site 1	3	3	1	4	1	1	2	2	3	7	3			5	3	3	9	1	4	2	1		3	1	2	1	65

Table 9. continued

SITE 2	May				June				July					August				September					October				Total
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28	
<u>Eleodes</u>																											
<u>extricata</u>		1												1													2
<u>Eleodes</u>																											
<u>hispidabris</u>																		1			1						2
<u>Eleodes</u>																											
<u>longicollis</u>	2		1							1								2			3						9
<u>Embaphion</u> spp.															1												1
<u>Glyptsida</u> sp.									1	1		3		1						1				1			8
<u>Gonasida</u>																											
<u>elata</u>															1												1
<u>Stenomorpha</u>																											
<u>marginata</u>										1				2				1	1	1							6
Unknown	2																										2
Subtotal Site 2	4	1	1						1	1	1	4		2	2	2		3	2	1	1	4		1			31

Table 9. continued

SITE 3	May				June				July					August				September					October				Total
	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28	
<u>Coelocnemis</u>																											
<u>magnum</u>																					1						1
<u>Eleodes</u>																											
<u>extricata</u>				1	2	1	1	2	4	1	7	10	12	15	15	3	2	5	3		1						85
<u>Eleodes</u>																											
<u>hispidabris</u>	24	3	7	3	4		1	4	4	3	6	7	5	3	5	2	1	2	3		1	3	3	1	1	1	97
<u>Eleodes</u>																											
<u>longicollis</u>	4		1		2		1	3	2	3	4		2			1		1	1		1		2	1		29	
<u>Eleodes</u> spp.*														4				1									5
<u>Embaphion</u> spp.	1										1		1	1				1	1		2				1	9	
<u>Eusattus</u>																											
<u>reticulatus</u>					3	1					1	2	1	1	1			2		1						13	
<u>Glyptsida</u> sp.																		1								1	
<u>Gonasida</u>																											
<u>elata</u>																		1								1	

Table 9. continued

	May				June				July					August				September					October				Total
SITE 3 (cont.)	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28	
<u>Stenomorpha</u>																											
<u>marginata</u>														1				1									2
Unknown	4	2	4	12	17	5												1									45
Subtotal Site 3	33	5	12	16	25	9	4	9	10	7	19	19	21	18	27	7	3	8	14	2	3	7	3	3	2	2	288
SITE 4																											
<u>Coelocnemis</u>																											
<u>magnum</u>																		2					1				3
<u>Eleodes</u>																											
<u>extricata</u>	15	14	24	22	19	19	15	7	18	11	9	11	12	11	4	5	3	1	2	1			1	1	1		226
<u>Eleodes</u>																											
<u>hispidabris**</u>	4	3	1		1	11	1	16	7	9	13	16	14	8	19	12	13	4	11	9	7	7	6	3	1		196
<u>Eleodes</u>																											
<u>longicollis</u>		6	4		1	8	2		3		3	2	1	3	1							1					35
<u>Eleodes</u>																											
<u>nigrina</u>								1																			1

Table 9. continued

	May				June				July					August				September					October				Total
SITE 4 (cont.)	6	13	21	29	5	12	19	26	3	10	17	24	31	7	14	21	27	1	9	16	24	30	7	14	21	28	
<u>Eleodes</u>																											
<u>obscura</u>	17	17	33	27	23	21	27	19	16	15	30	29	22	20	35	20	20	3	11	11	7	8	3	2	1		437
<u>Eleodes</u>																											
<u>obsoleta</u>							7		4	4	6	5	2	1		1		2	1								33
<u>Embaphion</u> spp.	1	2	5	4	1	3	1	2	2	3	7	6	3	3	5	1	1	2		2	1	2			1		58
<u>Eusattus</u>																											
<u>reticulatus</u>													1														1
<u>Neobaphion</u>																											
<u>planipennis</u>					2				4	5	6	1		3		4						1					26
<u>Stenomorpha</u>																											
<u>corrugans</u>									1	1																	2
<u>Zopherus</u>																											
<u>gracilis</u>					1		1							1						1							4
Subtotal Site 4	33	37	71	58	45	63	48	53	50	46	74	76	56	50	64	43	37	10	28	25	15	19	11	6	4	0	1022
Total All Sites	73	46	85	78	71	73	54	64	64	54	101	102	77	72	97	55	51	22	48	30	20	30	17	10	9	3	1406

*species unknown

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

Table 10. Summarized data for all Reptiles caught in pitfall traps at the four sites in 1978.*

Site 1: Cold Desert Shrub	May	June	July	Aug.	Sept.	Oct.	Total
<u>Cnemidophorus velox</u>					1		1
<u>Crotaphytus collaris</u>			1				1
<u>Crotaphytus wislizenii</u>					2		2
<u>Uta stansburiana</u>			9	5	16	5	35
Site 2: Juniper/Grassland							
<u>Cnemidophorus velox</u>					4	2	6
<u>Holbrookia maculata</u>	14	13	8		6	1	42
<u>Sceloporus undulatus</u>					3	2	5
Site 3: Grassland							
<u>Cnemidophorus velox</u>			1				1
<u>Crotaphytus collaris</u>		1			1		2
<u>Holbrookia maculata</u>	1				4		5
<u>Phrynosoma douglassi</u>		1					1
Site 4: Ponderosa Pine							
<u>Phrynosoma douglassi</u>			1	2	1		4
Total	15	15	20	7	38	10	105

*Those reptiles found alive were released and may have been captured in subsequent weeks.

Table 11. List of Insects Collected at Wupatki and
Sunset Crater National Monuments During 1978

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

List continued

Order/Family	Common Name
COLEOPTERA	
Lampyridae	Fireflies, lightning bugs
Lycidae	Net-winged beetles
Melyridae	Soft-winged flower beetles
Monommidae	Monommid beetles
Mordellidae	Tumbling flower beetles
Nitidulidae	Sap beetles
Phalacridae	Shining flower beetles
Phenogodidae	Glow-worms
Pyrochroidae	Five-colored beetles
Scaphidiidae	Shining fungus beetles
Scarabaeidae	Scarab, June beetles
Scolytidae	Bark beetles
Silphidae	Carrion beetles
Staphylinidae	Rove beetles
Tenebrionidae	Darkling beetles
Trogostidae	Bark-gnawing beetles
DIPTERA	
Acroceridae	Small-headed flies
Asilidae	Robber flies
Bibionidae	March flies
Bombyliidae	Bee flies
Calliphoridae	Blow flies
Cecidomyiidae	Gall midges
Chironomidae	Midges

List continued

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

List continued

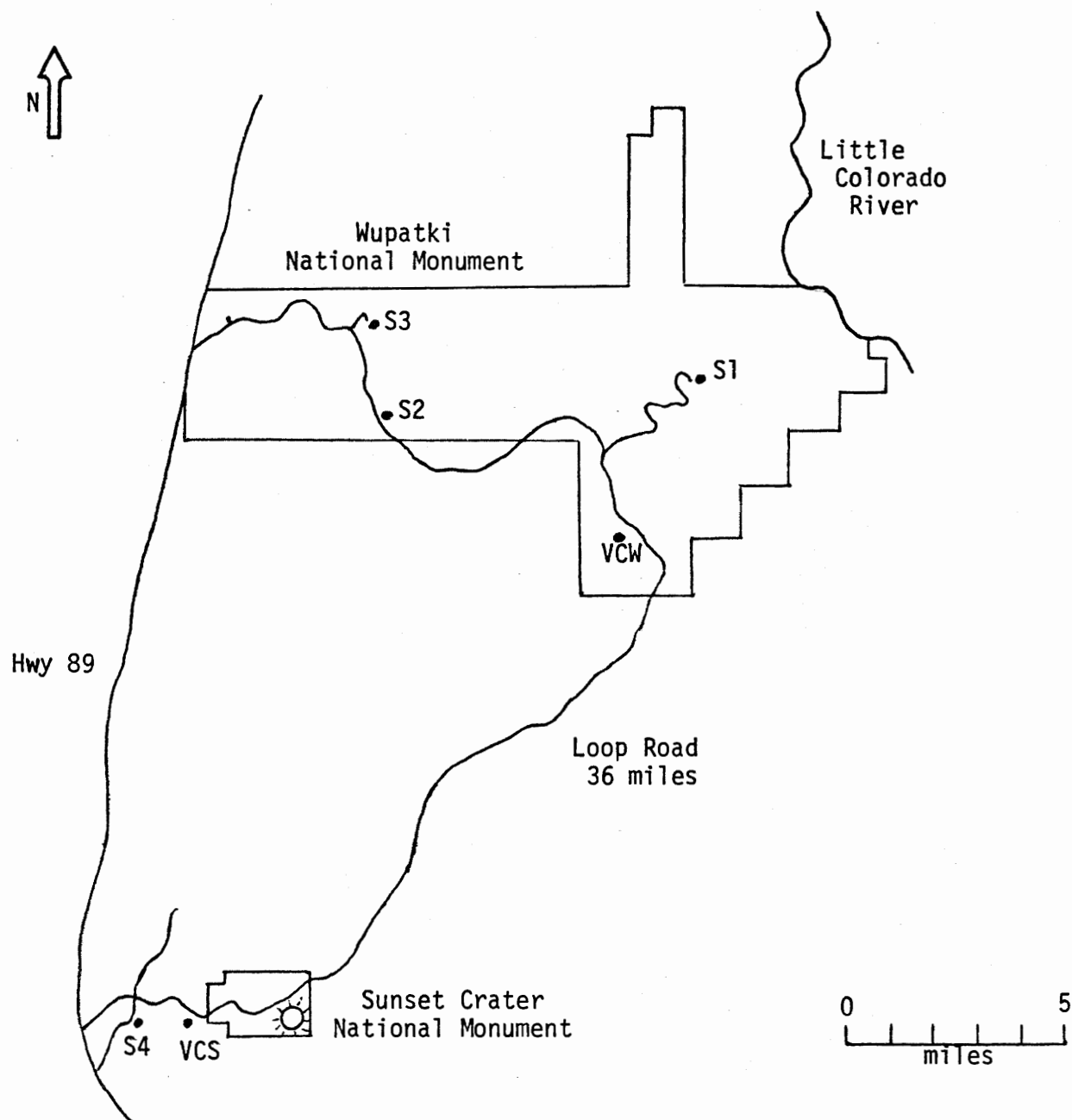
Order/Family	Common Name
HEMIPTERA	
Notonectidae	Backswimmers
Penatomidae	Stink bugs
Phymatidae	Ambush bugs
Reduviidae	Assassin bugs
Scutelleridae	Shield-backed bugs
Tingidae	Lace bugs
HOMOPTERA	
Aphididae	Aphids
Cercopidae	Froghoppers, spittlebugs
Cicadellidae	Leafhoppers
Cicadidae	Cicadas
Flatidae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

List continued

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

List continued

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



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.

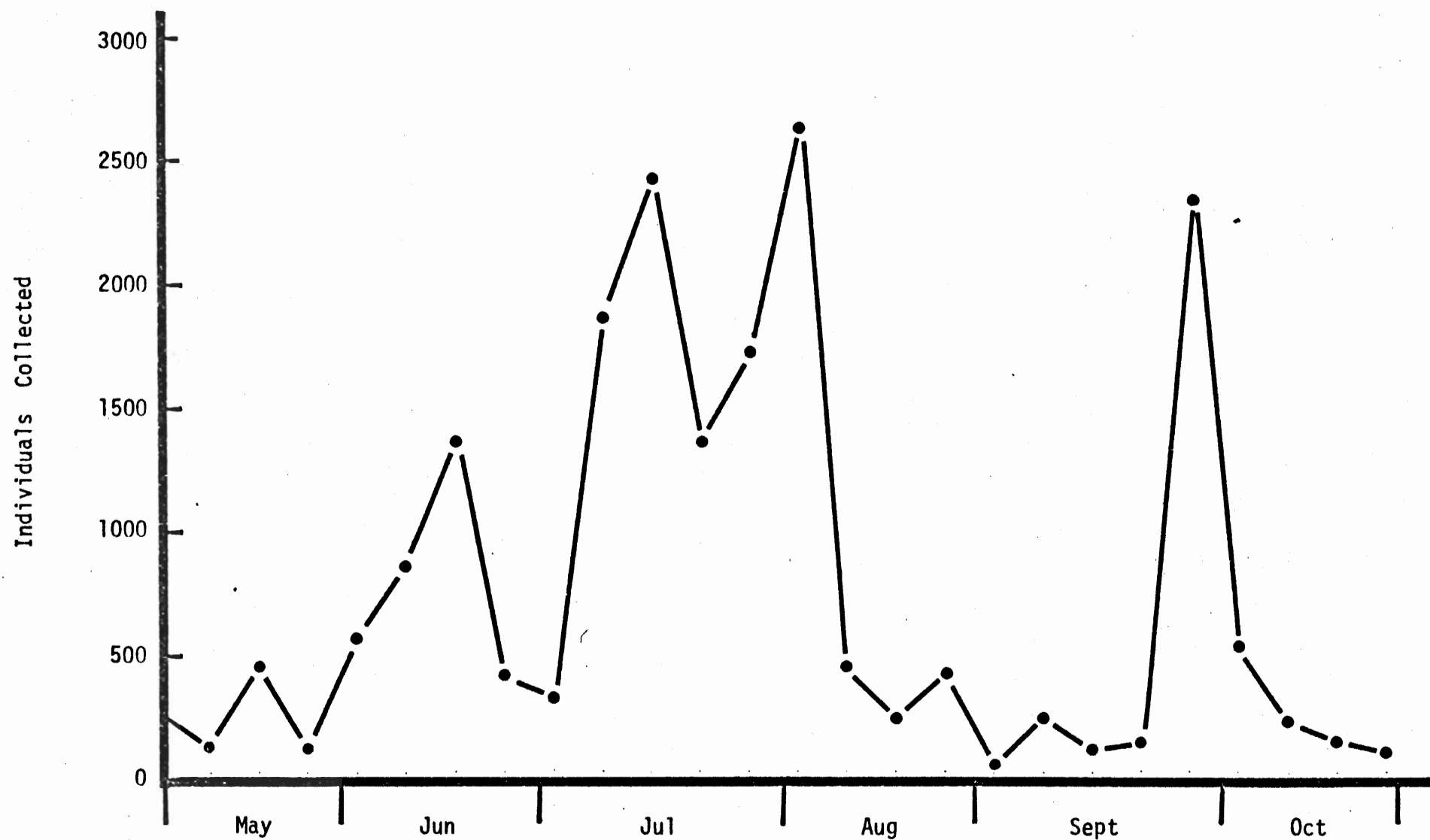


Figure 2. Weekly totals of all insects caught in the black light trap at Wupatki Visitor Center, 1978.

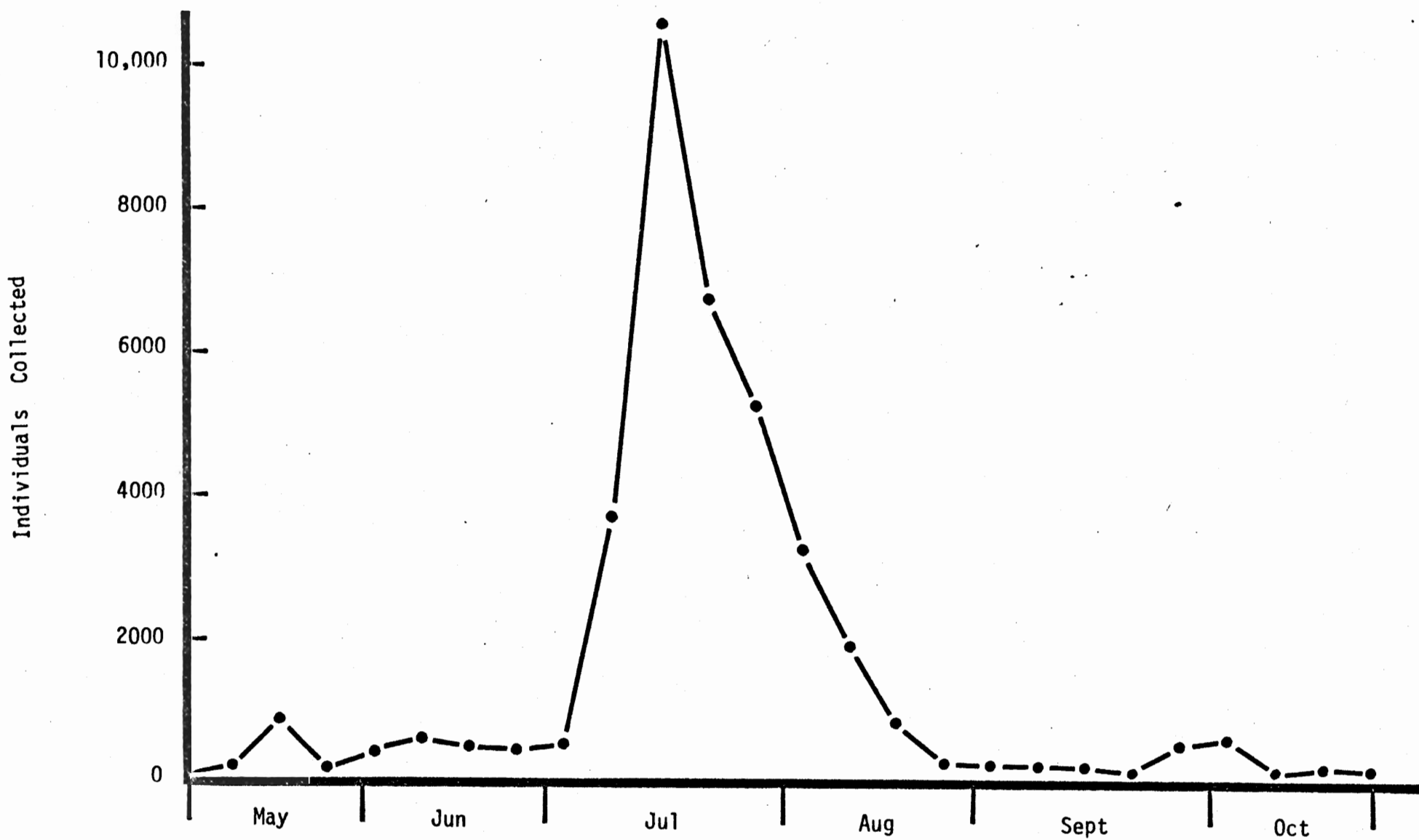


Figure 3. Weekly totals of all insects caught in the black light trap at Sunset Crater Visitor Center, 1978.

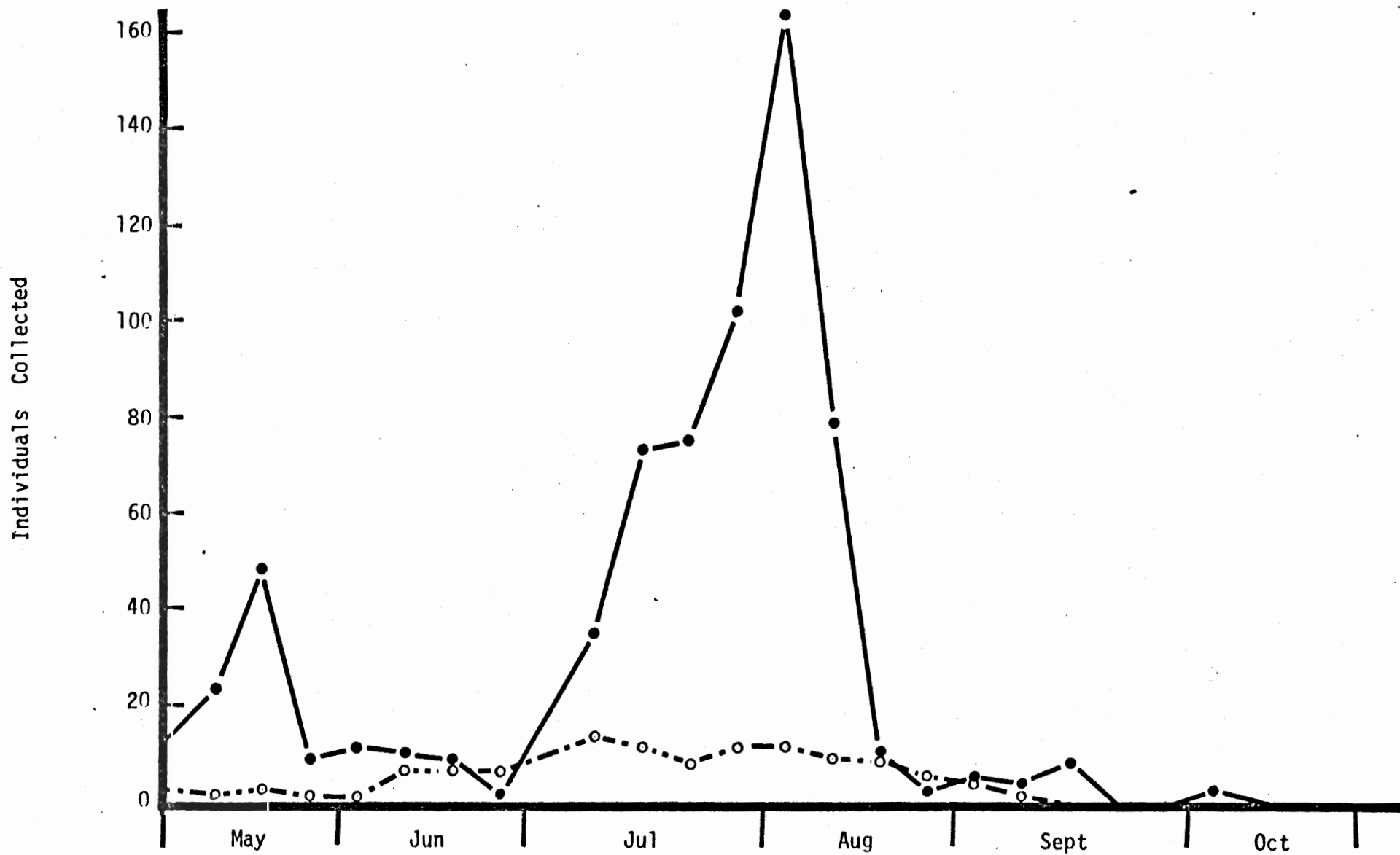


Figure 4. Weekly totals of the Sphinx moths *Hyles lineata* (solid line), *Manduca quinquemaculata*, and *M. sexta* (dashed line) caught in the black light trap at Wapatki Visitor Center, 1978.

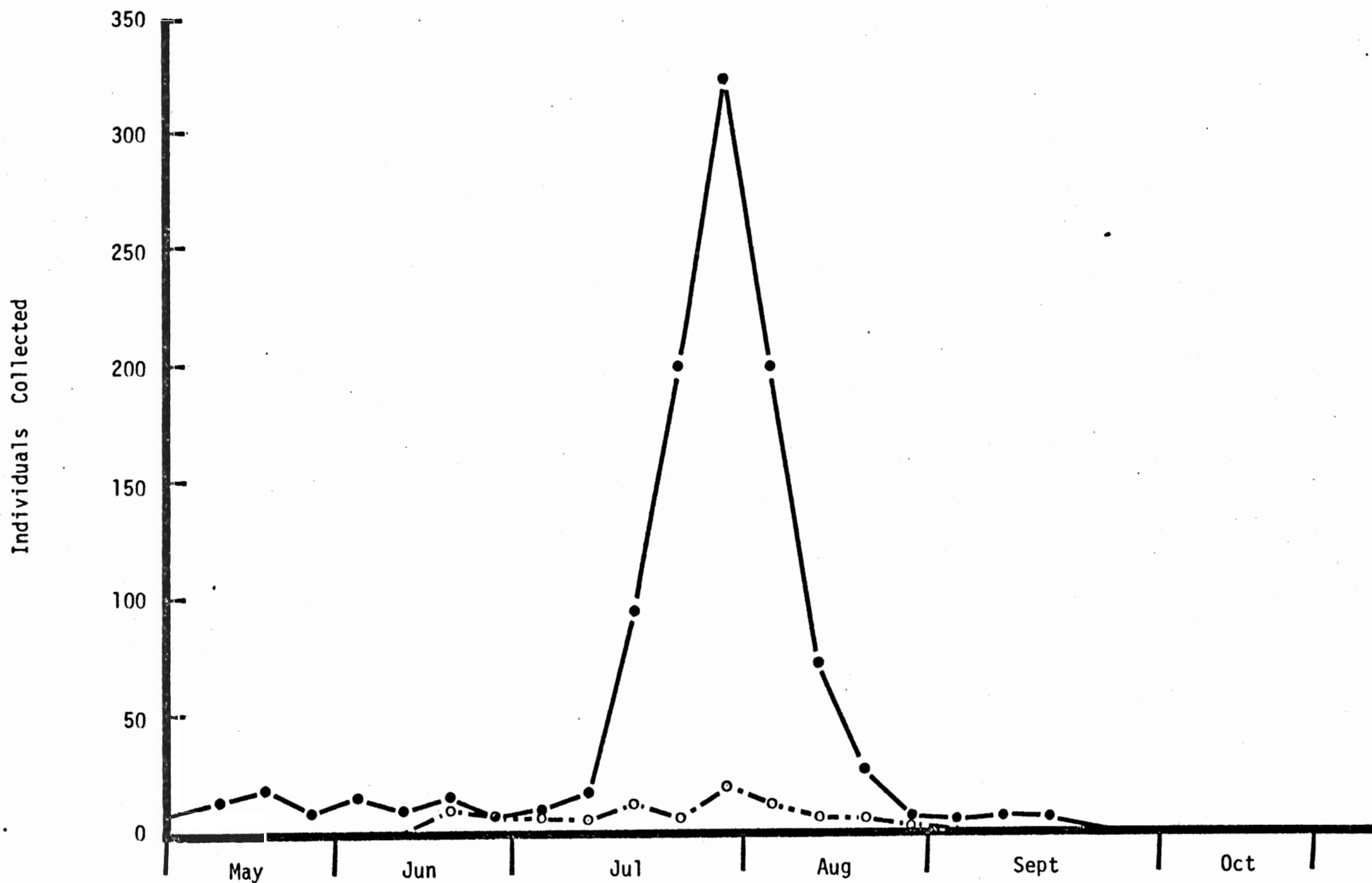


Figure 5. Weekly totals of the Sphinx moths *Hyles lineata* (solid line), *Manduca quinquemaculata*, and *M. sexta* (dashed line) caught in the black light trap at Sunset Crater Visitor Center, 1978.

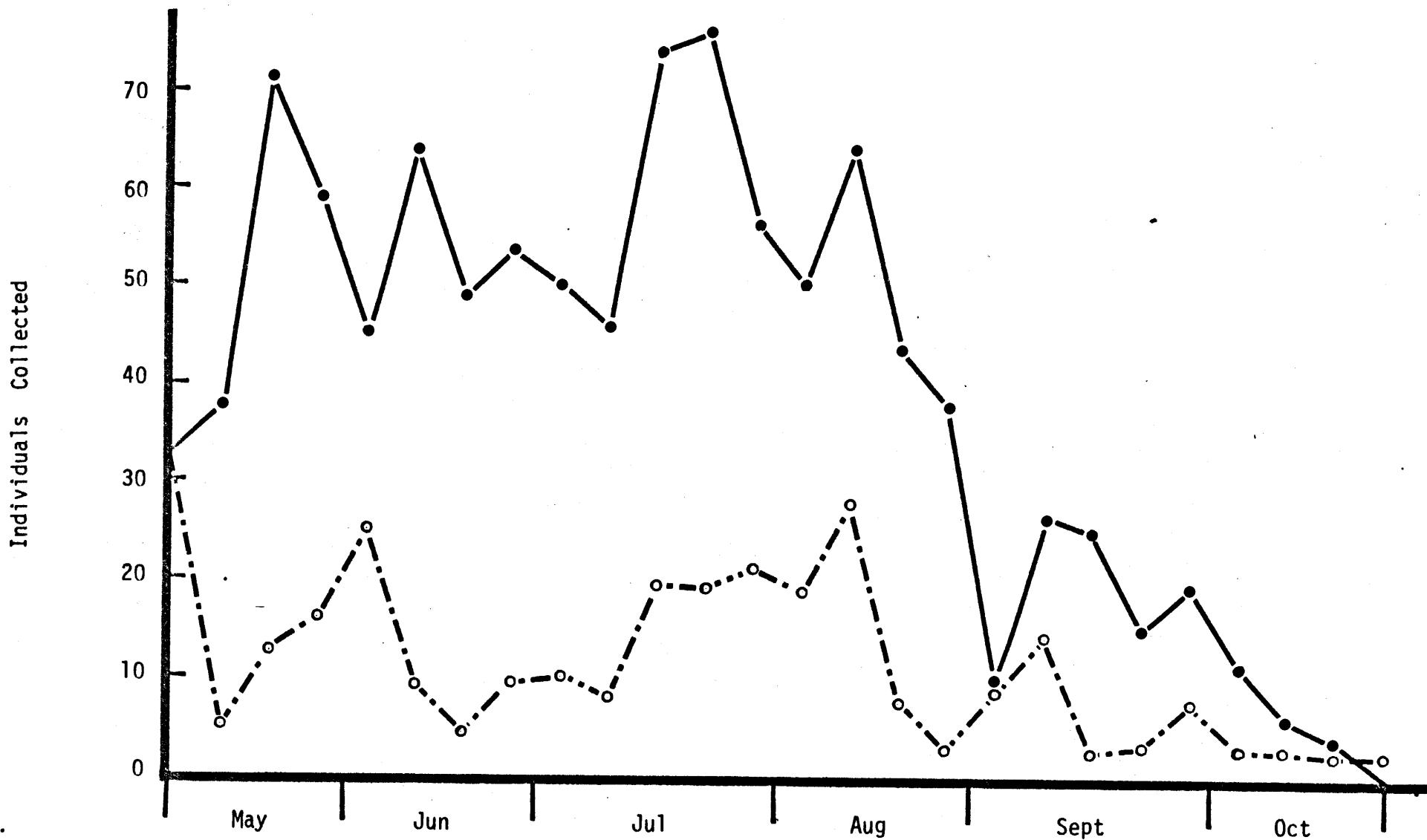


Figure 6. Weekly totals of darkling beetles (Coleoptera: Tenebrionidae) caught in pitfall traps at site 4 (solid line) and site 3 (dashed line) at Sunset Crater and Wupatki National Monuments, 1978.

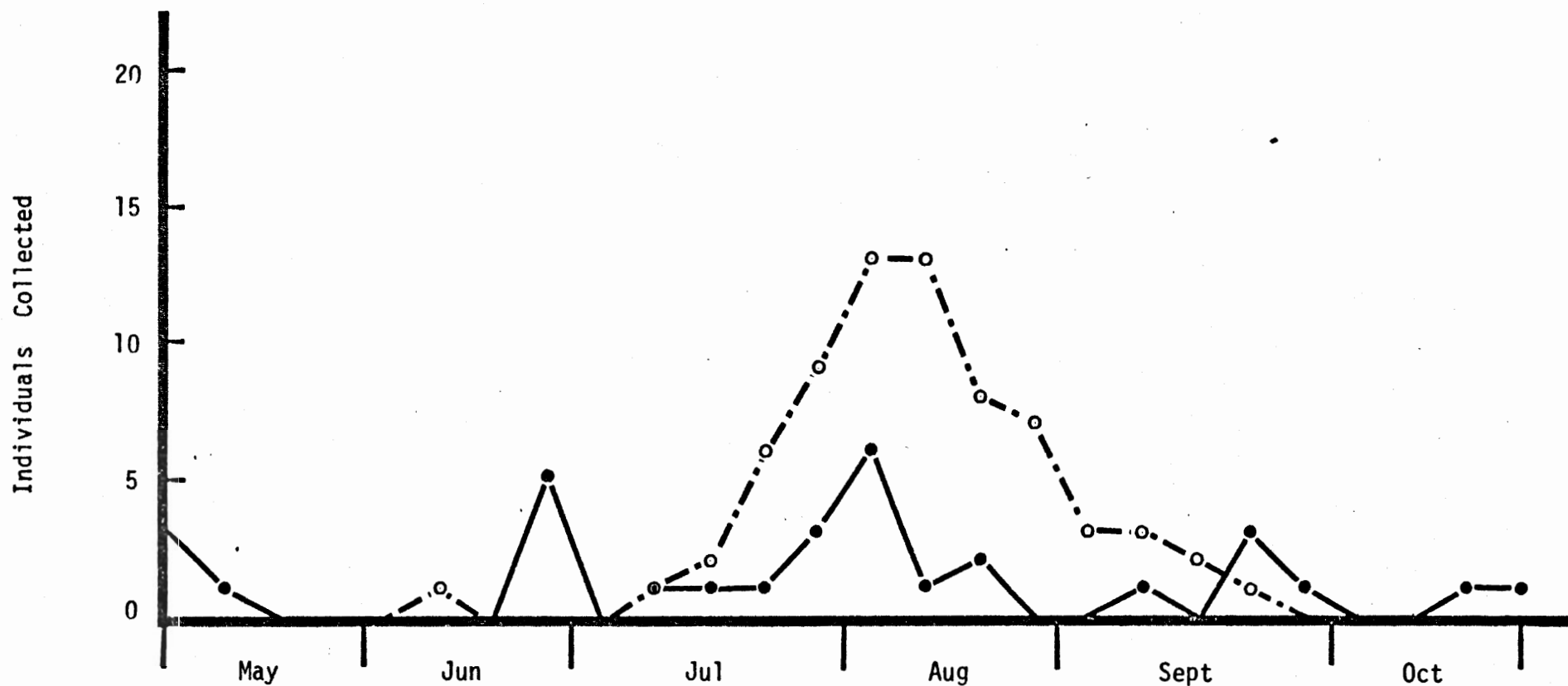


Figure 7. Weekly totals of Jerusalem crickets (dashed line), subfamily Stenopelmatinae, and camel crickets (solid line), subfamily Rhaphidophorinae, caught in pitfall traps at site 4 near Sunset Crater National Monument, 1978.

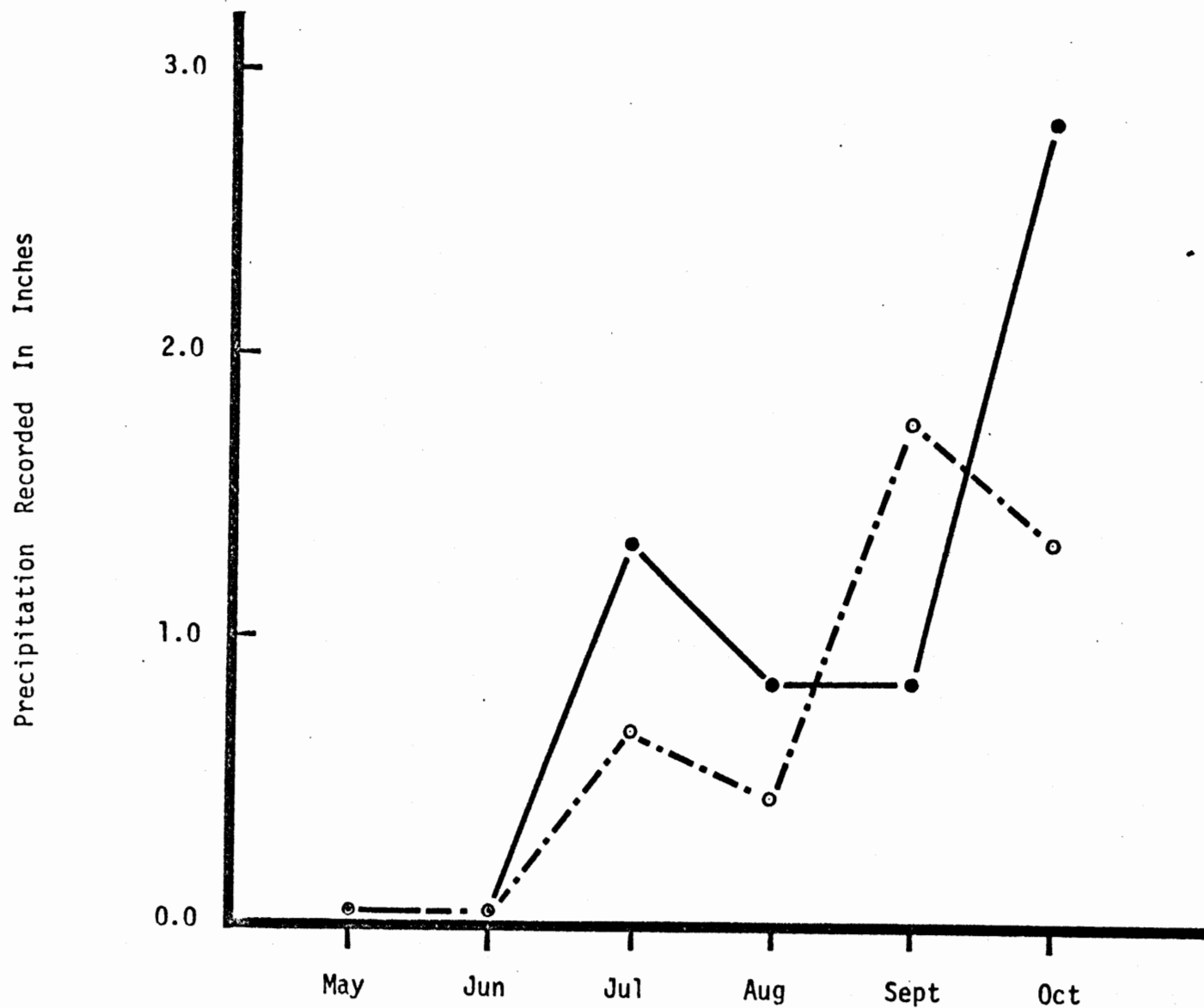


Figure 8. Monthly precipitation totals at Wupatki (dashed line) and Sunset Crater (solid line) National Monument Visitor Centers during 1978.

IV

AMPHIBIANS AND REPTILES

INTRODUCTION

Since 1976 members of the Northern Arizona University Department of Biological Sciences have been involved with a natural resource survey of Wupatki and Sunset Crater National Monuments. This project has been undertaken in an attempt to provide the National Park Service with useful information for future management planning on the monuments.

With the eruption of Sunset Crater in A.D. 1065 the landscape of Wupatki National Monument was altered dramatically. The unique geological features of the area have allowed for the evolution of a diverse flora capable of supporting a wide variety of animal populations.

In past years studies conducted by members of this department have focused on the arthropods, birds, mammals, flora in general, and impact of livestock grazing on the vegetation of the monuments. To date no study has been initiated to document the herpetofauna of the monument. Bateman (1976) compiled a checklist of reptiles and amphibians thought to occur on the monuments.

For management practices to be most effective all aspects of community organization must be considered. In this way management decisions can be based upon a sound understanding of ecological processes. By understanding ecological processes operating in a community land use can be maximized without endangering the fragile structure of the community itself.

In an attempt to more thoroughly understand the ecology of Wupatki National Monument a study was undertaken from July 1978 to September 1978 in which the reptilian communities of the monument were examined. Within this survey an attempt was made to determine: 1) the species of reptiles occupying each of the major vegetative zones, 2) the relative

abundances of species in each vegetative zone, and 3) the interrelationship of the herpetofauna to other biotic features of the monument, principally insects and plants.

METHODS AND MATERIALS

Three sites were chosen for the study of reptilian communities within the boundaries of Wupatki National Monument. At each site a pitfall trapping grid was established and operated at various times throughout the summer of 1978.

The three sites chosen for study were located in homogeneous areas representative of the three major vegetation types found in the monument. The first study site was located in Cold Desert Shrub habitat at an elevation of 4410 feet. The second study site was located in a Juniper/Grassland habitat near Arrowhead Tank at an elevation of 5400 feet. The third study area was situated in a Grassland plain 0.5 miles east of Lomaki Ruin at an elevation of 5360 feet. A detailed analysis of the vegetation and plant communities of Wupatki National Monument has been presented elsewhere (Green and Rominger, 1976; Green, 1978). The locations of the three study plots are indicated on the vegetation map prepared by D.M. Nelson as part of this final report.

At the Cold Desert Shrub and Juniper/Grassland sites 64 one-gallon cans were buried in an 8 X 8 quadrat with 15 m separating the rows and columns of traps. Thus each site represented a sampling area of 1.1ha (2.72 acres). The Grassland trapping grid was identical to the others with the exception that it was a 7 X 7 configuration sampling an area 0.81 ha (2.00 acres). A 12 in X 12 in cardboard lid was placed over each trap and supported above the trap by placing small stones underneath. This procedure prevented rain from entering the trap and allowed each trap

to be more effective in that reptiles would more readily seek its shelter and be captured.

The Cold Desert Shrub and Juniper/Grassland sites were examined for captures three times per week during July and once per week during August and September. Due to a paucity of captures at the Juniper/Grassland site, pitfall trapping was terminated at the end of July and a trapping grid was established at the Grassland site. The Grassland site was then examined for captures once per week through August and September. Table 1 indicates upon which each trapping grid was examined.

As each trap within a specific site was examined, any captured reptile was identified to species using Stebbins (1966), aged (juvenile or adult), and measured for snout-vent length (SVL) to the nearest millimeter (mm). Each reptile was then given a distinctive toe clip and released from the point of capture.

Approximately four individuals of each species were collected, preserved, and deposited in the Northern Arizona University Museum of Vertebrates.

Recognizing the limitations of pitfall trapping as a means of adequately sampling all reptiles in a particular habitat, additional observations were made by randomly visiting representative areas within each of the major vegetation types. Notes were kept as to each species observed and captures were made utilizing a car antenna with a slip noose of thread secured to one end. Lizards captured in this manner were identified, measured for SVL and released from the point of capture after being given a toe clip.

On the whole, equal time was spent in each of the vegetative types thereby reducing the probability of a significant time bias in the results.

In addition to trapping and making field observations, road kills were examined and, when possible, identified. This procedure was particularly useful in identifying some of the snakes occurring on the monument.

Several investigators working on this project made special efforts to secure further information on amphibians or reptiles of the monuments. Jon Peters, who was using pitfall traps to capture arthropods, added several valuable observations.

RESULTS

It is suggested that the results presented in this study be regarded as a foundation for further research. The ecological complexities of Wupatki National Monument make a comprehensive herpetological analysis difficult to accomplish during a single year. The total numbers of reptiles captured (including road kills) and identified by all sampling methods are presented in Table 2. From the absolute numbers of reptiles captured it is clear that the most diverse habitat in terms of numbers and species present is the Cold Desert Shrub. The Juniper/Grassland habitat, by contrast, appeared to support relatively low numbers of reptiles.

Tables 3-5 list the numbers and species of reptiles captured by sampling period at each of the three sites. Again, note the greater abundance of reptiles in the Cold Desert Shrub relative to the other habitats examined.

Due to the large numbers of Uta stansburiana captured on the Cold Desert Shrub grid these lizards were subdivided into juveniles (SVL 40 mm) and adults (SVL 40 mm) for the purpose of data compilation. This separation is nearly identical to that described by Porter (1972).

The low numbers of captures at the Juniper/Grassland grid (Table 4)

resulted in a termination of trapping at this site after the sampling period ending on 31 July. The Grassland grid was then established and examination of this grid commenced on 7 August.

Tables 6 and 7 present the range and mean SVL for all trapped reptiles on the Cold Desert Shrub and Grassland grids, respectively. No such table was prepared for the Juniper/Grassland grid because of the low numbers of captures in that particular habitat. Tables 8-10 provide the same data (range, mean SVL) for all noosed reptiles in each of the major vegetative zones.

Finally, Table 11 shows the Shannon-Wiener Diversity Index (H') for each habitat. The formula for calculating the diversity index is given by:

$$H' = - \sum_{i=1}^s (p_i) (\log_2 p_i)$$

where: s = number of species in the community under study.

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

Larger values of H' are indicative of a more diverse community.

Jon Peters, Table 11 this section, recorded the presence of Phrynosoma douglassi in his insect pitfall traps near Bonito Park, Sunset Crater and at his Grassland Site. In addition, several individuals representing Sceloporus undulatus were observed at Sunset Crater National Monument by personnel working on this project. The species is widespread throughout the Ponderosa Pine forest and at lower elevations surrounding Flagstaff. The Short-horned Lizard (P. douglassi) extends upwards on the San Francisco Peaks to about 10,300 feet (Lowe 1964).

The only amphibian species recorded during this study period was Bufo punctatus, the Red-spotted Toad. Several individuals of this species were observed calling at the Wupatki sewage ponds by Bateman and others

who were mist netting for bats on the evening of 5 July 1978. Anurans are probably more numerous than suggested by this isolated observation; they are just not apparent most of the year, spending much of their time underground.

DISCUSSION

Trapping and noosing data (Table 2) indicate there is a significant variation in the numbers of reptiles present within each of the major vegetation types. The Cold Desert Shrub exhibited the most diverse herpetofauna and the Juniper/Grassland had the fewest reptiles, both in terms of species present and actual numbers.

The Cold Desert Shrub community yielded over 64 % of all captures made on the monument. Since this vegetation type is the most complex of those on the monument it seems reasonable that it would be capable of supporting a wide array of reptiles. In all, 12 species of reptiles were observed in this habitat in differing abundances as indicated in Table 2. The most numerous reptile in the Cold Desert Shrub was Uta stansburiana, accounting for 55.79 % of all captures recorded. Of the captured Uta, 53.77 % were classified as juveniles. These juveniles were very numerous, even in early July when the study was begun. Uta is active year around at Joshua Tree National Monument in California (Bateman, personal observation) and the first hatchlings appear in July at that locale (Stephens 1962). Data from the reptile can traps and insect pitfall traps indicate that the species is active from at least July through October at Wupatki National Monument. Surely Uta is active earlier in the Spring at Wupatki, but no individuals were trapped at this time.

Cnemidophorus tigris and Holbrookia maculata were the next most numerous species in the Cold Desert Shrub, accounting for 14.74 % and 12.63 % of the captures, respectively. Members of the genus Cnemidophorus

are probably the most unusual reptiles occupying the monument due to the fact that some members reproduce parthenogenetically while others are biparental. Cnemidophorus tigris fits the latter category and was most numerous in the Cold Desert Shrub during July and early August. These animals are known to favor dry, sandy regions with sparse cover (Leviton 1971 and others); their abundance in early summer could be related to higher environmental temperatures during this part of the year.

Holbrookia maculata is a widely occurring lizard which is found in many types of habitats ranging from streambanks to short-grass prairie. Its presence is to be expected in areas where there are exposed patches of sand or gravel. The absence of the Lesser Earless Lizard from can traps placed in the Juniper/Grassland to capture lizards is difficult to explain. Throughout the entire month of July not a single lizard of this species was captured on the grid, but traps set in similar habitat for the purpose of collecting insects took eight individuals of this species during July and over the May through October period of insect sampling this was the most common lizard found in the insect pitfalls placed in the Juniper/Grassland. This contradictory finding just points out the problems in sampling one encounters even in such homogenous vegetation as the Juniper/Grassland. Perhaps the occurrence of this lizard in the Juniper/Grassland is extremely "patchy", its occurrence being determined by such locally variable factors as substrate texture, canopy structure, slope exposure and other environment variables acting singly or in combination.

Stebbins (1966) describes the habitat of Cnemidophorus velox as, "chiefly in the mountains in pinon-juniper woodland, oak woodland, and lower edges of ponderosa pine forests. At lower elevations frequents broadleaf streamside woodland of permanent and semipermanent streams."

The occurrence at Wupatki of this species in all three of the major habitats, Cold Desert Shrub, Grassland, and Juniper/Grassland, make it one of the most ecologically ubiquitous lizards and points to the conclusion that its distribution is more catholic than is suggested by the above quote. Bateman (personal observation) has found it to be very diverse in its choice of habitats in another northern Arizona locality, near the confluence of the Little Colorado River and Chevelon Creek in Navajo County. There the Plateau Whiptail occurs in several plant associations of a "bushy" or "grassy" nature and is even found in association with thickets of tamarix and camelthorn along the Little Colorado River.

The two species of Crotaphytus were observed only in the Cold Desert Shrub area, although they perhaps occur locally in other parts of the monument. These are large, attractive lizards and bold predators upon other smaller lizards and large arthropods. They are among the most spectacular reptiles on the monument, reaching SVL of five inches and being brilliantly colored, particularly when in breeding condition.

Large adults of Crotaphytus collaris may be strikingly colored in green with a yellow head set off by two bold black "collars." The males are vividly colored beneath with a variety of greenish, bluish and orangish hues, often with darker markings being found on the chest, belly and groin. Females are generally less brilliantly marked than males, but in breeding season develop orange markings on the body and throat which are seen to fade soon after oviposition. Collared Lizards are usually found on or near larger rocks, boulders or massive outcrops from which vantage points they search for their lizard or large arthropod prey. They are very

wary once "warmed up" and can dash off at high speed when approached, often running bipedally. Sometimes they take the easy way out and simply seek shelter beneath the jumbled rockpiles upon which they frequently bask.

The Leopard Lizard (C. wislizeni) although somewhat larger than the related Collared Lizard, is usually less obvious, since it normally is more of a ground dweller and tends to wait for prey from beneath the shade of some shrub. As the common name implies, the body is generally some shade of brownish or tan flecked with large spots, leopard fashion. The males are not so spectacular in color as the preceding species, but females are boldly streaked and spotted with salmon-orange during the breeding season. This species is not dependent upon the occurrence of rocks and outcrops in its habitat, therefore it may be found in areas of very flat terrain.

The Shannon-Wiener Diversity Index for the Cold Desert Shrub was 2.00, making it the most diverse of the three habitats studied (Table 11).

As is evidenced in Table 2 the Grassland plant community supported the next most abundant community of reptiles. In this community only three species of lizards were encountered; they accounted for 25.6 % of all captures recorded as a direct part of this survey. Holbrookia maculata was the most abundant species in the Grassland, making up 58.67 % of the captures there. As reported earlier, H. maculata is capable of occupying a wide variety of ecological situations and its occurrence in the Grassland is probably related to the amount of vegetative cover. Ditmars (1920) and numerous other authors have categorized H. maculata as a plains or short grass prairie lizard. Thus its distribution and abundance on the monument will probably be limited to areas with suitable grassland cover. It is interesting to compare the relative abundance of H. maculata

in Grassland with its abundance in the Cold Desert Shrub (Table 2). The vegetation differences are striking between these two communities and it would be a worthwhile undertaking to document the extent to which vegetation limits the abundance of H. maculata on the monument. When data from the insect pitfall traps are included (Table 12), this becomes the most abundant species in two of the three plant communities on the monument.

Cnemidophorus velox was captured in appreciable numbers in the Grassland and, in one way, represents the most unusual species found on the monument. As mentioned previously, some members of the genus Cnemidophorus reproduce parthenogenetically. Cnemidophorus velox represents such a species and males are unknown. Parthenogenesis is extremely rare in vertebrates and parthenogenetic species have been referred to as "weedy" animal counterparts to the plants adapted to disclimax or disturbed habitats (Wright and Lowe 1968). Perhaps the invasion of C. velox into the somewhat "atypical" habitats it occupies at Wupatki and other areas in northern Arizona is a reflection of the ecological disturbance caused in these habitats by activities of man, such as livestock grazing.

Table 2 shows that Cnemidophorus tigris is relatively abundant in the Cold Desert Shrub and absent from the Grassland. Again, such differences are accounted for on the basis of habitat preferences. Stebbins (1966) indicates that C. tigris prefers arid to semiarid habitats in which plant cover is scarce and there are, thus, open areas between plants for running. Thus this species is ideally suited for the Cold Desert Shrub and may not be capable of living in a relatively more uniformly vegetated area like the Grassland.

Although the Shannon-Wiener Diversity Index for the Grassland is slightly less than that for the Juniper/Grassland it is the investigator's opinion that this is an artifact of the low numbers of captures in the Juniper/Grassland. From observations made in both habitats the Grassland seemed much more alive in terms of reptilian activity. The only reptile present in appreciable numbers on the Juniper/Grassland lizard grid was Sceloporus undulatus, a lizard known for its close association with trees and rock outcroppings. Although S. undulatus was found predominantly in the Juniper/Grassland it was also located on the periphery of the Cold Desert Shrub where it (CDS) and the Juniper/Grassland overlapped. The apparent absence of S. undulatus from the rocky outcroppings of the Grassland community could be related to its food habits. Toliver et al. (1975) describe the diet of S. undulatus as consisting of a wide variety of invertebrates with termites providing a major food item. Thus S. undulatus may be restricting its range to areas of available food. In the Juniper/Grassland resources are scarce, as indicated by the lack of vegetative ground cover and litter. Here S. undulatus may survive because of the availability of termites found in association with juniper. In the other habitats it is possible that competition for resources is more and S.undulatus is unable to hold its own.

In the Juniper/Grassland much time was spent in the vicinity of Arrowhead Tank, a site of heavy grazing in past years. Grass, or any other type of ground cover was extremely scarce and this could in part account for the paucity of reptiles observed in this community. With suitable ground cover it is likely that this community would be capable of supporting more reptiles.

In summary, each of the major vegetative zones of Wupatki National Monument has a group of reptilian species more or less characteristic of that particular habitat. That cattle grazing has altered these habitats is well documented and this has probably contributed to the distributions of reptiles as they now occur on the monument. There does not appear to be any intrinsic biological reason why each of the major habitats could not support a larger and more diverse herpetofauna if available cover were present. The reduction of suitable grass cover in certain areas of the monument could be leading to the elimination of certain reptilian species from the monument, although data to support this generalization at this time are weak.

For proper management decisions to be made concerning the future of the monument it is essential that all aspects of community organization be examined. In the case of reptiles, it is important that management consider the impact changes may have on insect populations. Most of the reptiles present on the monument are insectivorous and if the insect populations become unstable the effects may be serious at the higher trophic levels (i.e. reptiles, birds, mammals).

This study has not uncovered any rare or endangered reptiles on the monument, but Cnemidophorus velox with its unusual mode of reproduction is restricted in distribution to small areas of Arizona, New Mexico, and smaller portions of Colorado and Utah. Those in charge of management of the monument should keep this in mind to ensure that its range is not reduced further in the future. Overgrazing on the monument should be kept to a minimum and if possible overgrazed areas should be allowed to return to a more "normal" condition by deferment of grazing. This practice could have nothing but beneficial results for the reptilian fauna of the monument.

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Table 1. Dates of sampling during 1978 for each reptile trapping grid
(- indicates grid not in operation).

Sampling Period	Cold Desert Shrub	Juniper/ Grassland	Grassland
1	3 July	3 July	-
2	5 July	5 July	-
3	10 July	10 July	-
4	12 July	12 July	-
5	14 July	14 July	-
6	17 July	17 July	-
7	21 July	21 July	-
8	24 July	24 July	-
9	26 July	26 July	-
10	28 July	28 July	-
11	31 July	31 July	-
12	7 August	-	7 August
13	14 August	-	14 August
14	21 August	-	21 August
15	4 September	-	4 September
16	11 September	-	11 September
17	18 September	-	18 September
18	25 September	-	25 September

Table 2. Total number of all reptiles identified by all sampling methods, exclusive of insect pitfall traps. Includes trapped, noosed and road killed * individuals, together with the major vegetation type in which each occurred.

<u>Family/</u> <u>Species</u>	<u>Common</u> <u>Name</u>	<u>Habitat</u>		
		Cold Desert Shrub	Juniper/Grassland	Grassland
Iguanidae				
<u>Holbrookia maculata</u>	Lesser Earless Lizard	24		44
<u>Crotaphytus wislizeni</u>	Leopard Lizard	13		
<u>Crotaphytus collaris</u>	Collared Lizard	3		
<u>Sceloporus magister</u>	Desert Spiny Lizard	3		
<u>Sceloporus undulatus</u>	Eastern Fence Lizard	8	14	
<u>Uta stansburiana</u>	Side-blotched Lizard	106	6	
<u>Urosaurus ornatus</u>	Tree Lizard	2		
<u>Phrynosoma douglassi</u>	Short-horned Lizard			15
Teiidae				
<u>Cnemidophorus tigris</u>	Western Whiptail	28		
<u>Cnemidophorus velox</u>	Plateau Whiptail	3	8	16
Colubridae				
<u>Pituophis melanoleucus</u>	Gopher Snake	3*		
<u>Lampropeltis getulus</u>	Common Kingsnake	1		
Crotalidae				
<u>Crotalus viridis</u>	Western Rattlesnake	3 (1*)		
		197	28	75

Table 3. Numbers of reptiles trapped on the Cold Desert Shrub grid during each sampling period (J= juvenile, snout-vent length ≤ 40.0 mm).

Date	<u>Holbrookia</u> <u>maculata</u>	<u>Crotaphytus</u> <u>wislizeni</u>	<u>Crotaphytus</u> <u>collaris</u>	<u>Sceloporus</u> <u>undulatus</u>	<u>Uta</u> <u>stansburiana</u>	<u>Uta</u> <u>stansburiana</u> (J.)	<u>Cnemidophorus</u> <u>tigris</u>	<u>Cnemidophorus</u> <u>velox</u>	Total
3 July	0	0	0	0	0	4	1	0	5
5 July	1	0	0	0	2	2	1	0	6
10 July	0	1	0	0	2	3	0	0	6
12 July	1	0	0	0	4	2	1	0	8
13 July	3	0	1	0	1	4	4	0	13
17 July	0	1	1	0	1	1	3	0	7
21 July	0	0	1(J)	0	1	2	2	0	6
24 July	0	0	0	0	0	1	0	0	1
26 July	0	0	0	0	3	3	1	0	7
28 July	0	1	0	0	0	2	0	0	3
31 July	0	0	0	0	0	2	0	0	2
7 August	0	1	0	0	2	4	2	2	11
14 August	0	0	0	0	5	4	1	0	10
21 August	0	0	0	1	1	3	0	1	6
4 September	0	0	0	0	1	3	0	0	4
11 September	3	0	0	0	1	0	0	0	4
18 September	2	0	0	0	2	3	0	0	7
25 September	2	0	0	0	2	0	0	0	4
Totals	12	4	3	1	28	43	16	3	110

Table 4. Numbers of reptiles trapped on the Juniper/Grassland grid during each sampling period.

Date	<u>Sceloporus</u> <u>undulatus</u>	<u>Uta</u> <u>stansburiana</u>	<u>Cnemidophorus</u> <u>velox</u>	<u>Totals</u>
3 July	0	0	0	0
5 July	0	0	0	0
10 July	1	0	0	1
12 July	0	0	0	0
14 July	0	0	0	0
17 July	0	1	1	2
21 July	1	0	0	1
24 July	0	0	0	0
26 July	0	0	1	1
28 July	0	0	0	0
31 July	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Totals	2	1	2	5

Table 5. Numbers of reptiles trapped on the Grassland grid during each sampling period.

Date	<u>Holbrookia</u> <u>maculata</u>	<u>Phrynosoma</u> <u>douglassi</u>	<u>Cnemidophorus</u> <u>velox</u>	<u>Totals</u>
7 August	4	1	3	8
14 August	4	0	0	4
21 August	3	0	0	3
4 September	3	2	1	6
11 September	2	0	1	3
18 September	1	0	0	1
25 September	<u>2</u>	<u>0</u>	<u>1</u>	<u>3</u>
Totals	19	3	6	28

Table 6. Mean and range of Snout-Vent Length (SVL) for reptiles trapped on the Cold Desert Shrub grid.

Species	n	SVL Range (mm)	Mean SVL (mm)	Standard Deviation
<u>Holbrookia</u> <u>maculata</u>	12	48-57	52.58	2.75
<u>Crotaphytus</u> <u>wislizeni</u>	4	98-103	100.75	2.22
<u>Crotaphytus</u> <u>collaris</u>	3	100-108	102.67	4.62
<u>Sceloporus</u> <u>undulatus</u>	1	-	59.00	-
<u>Uta</u> <u>stansburiana</u>				
Adult	28	40-62	47.54	5.33
Juvenile	43	16-36	25.09	5.42
<u>Cnemidophorus</u> <u>tigris</u>	16	83-122	97.81	10.58
<u>Cnemidophorus</u> <u>velox</u>	3	62-93	73.33	-

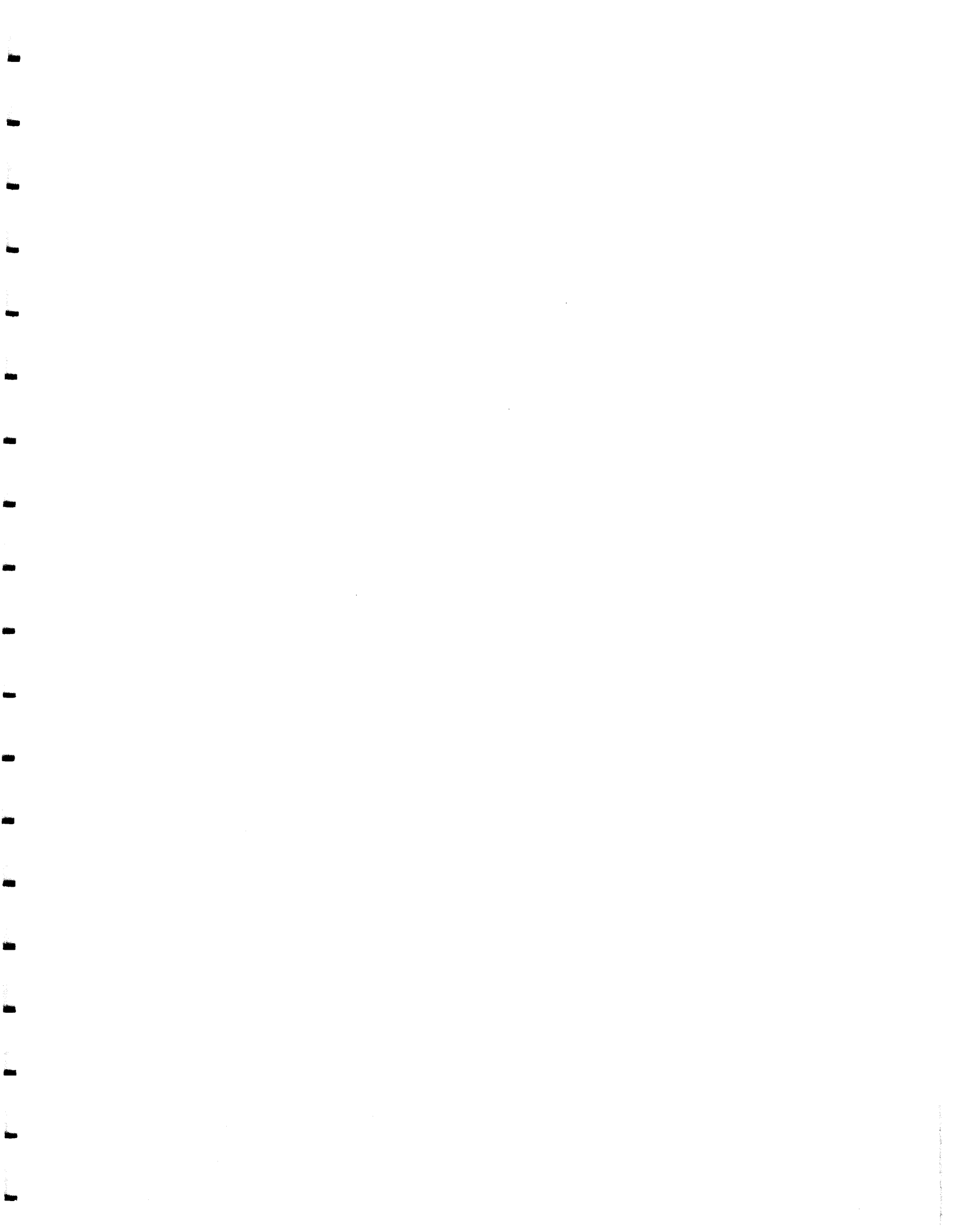


Table 7. Mean and range of Snout-Vent Length (SVL) for reptiles trapped on the Grassland grid.

Species	n	SVL Range (mm)	Mean SVL (mm)	Standard Deviation
<u>Holbrookia</u> <u>maculata</u>	19	44-56	51.68	3.73
<u>Phrynosoma</u> <u>douglasi</u>	3	62-78	65.66	-
<u>Cnemidophorus</u> <u>velox</u>	6	35-78	58.83	-

Table 8. Mean and range of Snout-Vent Length (SVL) for reptiles noosed and observed in the Cold Desert Shrub (* indicates no capture made and no measurements taken).

Species	n	SVL Range (mm)	Mean SVL (mm)	Standard Deviation
<u>Holbrookia</u> <u>maculata</u>	12	43-59	50.75	5.10
<u>Crotaphytus</u> <u>wislizeni</u>	9	94-107	100.56	5.17
<u>Sceloporus</u> <u>magister</u>	3*			
<u>Sceloporus</u> <u>undulatus</u>	7	50-66	57.43	5.59
<u>Uta</u> <u>stansburiana</u>				
Adults	21	40-61	51.33	6.92
Juveniles	14	18-37	27.14	5.71
<u>Urosaurus</u> <u>ornatus</u>	2*			
<u>Cnemidophorus</u> <u>tigris</u>	12	83-98	91.33	5.65

Table 9. Range and mean Snout-Vent Length (SVL) for reptiles noosed and observed in the Juniper/Grassland habitat.

Species	n	SVL Range (mm)	Mean SVL (mm)	Standard Deviation
<u>Sceloporus</u> <u>undulatus</u>	12	52-73	62.08	6.54
<u>Uta</u> <u>stansburiana</u>	5	50-62	55.80	4.55
<u>Cnemidophorus</u> <u>velox</u>	6	52-68	60.00	5.25

Table 10. Range and mean Snout-Vent Length (SVL) for reptiles noosed and observed in the Grassland habitat.

Species	n	SVL Range (mm)	Mean SVL (mm)	Standard Deviation
<u>Holbrookia</u> <u>maculata</u>	25	45-68	52.48	5.36
<u>Phrynosoma</u> <u>douglasi</u>	12	63-72	67.00	3.44
<u>Cnemidophorus</u> <u>velox</u>	10	62-81	70.00	6.29

Table 11. Shannon-Wiener Diversity Indices (H') for communities of reptiles existing in each of the three major habitat types

<u>Cold Desert Shrub</u>	<u>Juniper/Grassland</u>	<u>Grassland</u>
2.0012	1.4474	1.3494

Table 12. Supplementary reptile captures based upon lizards taken in insect pitfall traps by J. Peters.

Site/ Species	Month						Total
	May	June	July	Aug.	Sept.	Oct.	
Cold Desert Shrub (Site 1)							
<u>Cnemidophorus velox</u>					1		1
<u>Crotaphytus collaris</u>			1				1
<u>Crotaphytus wislizeni</u>					2		2
<u>Uta stansburiana</u>			9	5	16	5	35
Juniper/Grassland (Site 2)							
<u>Cnemidophorus velox</u>					4	2	6
<u>Holbrookia maculata</u>	14	13	8		6	1	42
<u>Sceloporus undulatus</u>					3	2	5
Grassland (Site 3)							
<u>Cnemidophorus velox</u>			1				1
<u>Crotaphytus collaris</u>		1			1		2
<u>Holbrookia maculata</u>	1				4		5
<u>Phrynosoma douglassi</u>		1					1
Ponderosa Pine (Site 4)							
<u>Phrynosoma douglassi</u>			1	2	1		4
Total	15	15	20	7	38	10	105

INTRODUCTION

The presence, amount, seasonal availability and quality of water can have a direct impact as limiting factors for the presence or absence of animal populations in a given region.

The dry climatic conditions, including limited, seasonal precipitation, low humidities and high summer temperatures, inconsistencies in vegetational types, and the porous cinder ground cover of Sunset Crater and Wupatki National Monuments seem to point to the fact that surface water is not generally available to the animal populations at the monuments.

Most of the permanent water sources within the confines of the monument boundaries or nearby have been established and maintained artificially as livestock or wildlife watering sites. While it is known that the presence of stock watering sites allows the continuation of seasonal domestic grazing, the importance of these sites to avian and mammalian populations living in or migrating through the area has not been previously investigated.

This study was undertaken in Summer 1978 to assess the importance of available open water to avian and mammalian populations occurring at Sunset Crater and Wupatki National Monuments.

Only three permanent watering sites are presently available for animal use within the boundary of Wupatki National Monument and none occur within the boundary of Sunset Crater. Two of the sites at Wupatki National Monument are sewage ponds, available only for avian and small mammal use, as a seven foot fence surrounds the ponds. The third site, Cottonwood Spring, was originally built as a sheep

watering tank, but is open to use by all animals. Three other sites were chosen for study since they occur within habitats representative of the monuments and because of their presence near monument boundaries. Coyote Spring is found within 0.5 mile south of Cottonwood Spring on Arizona State land and is found in Cold Desert Shrub habitat. Cinder Trick tank was chosen because of its location in Juniper/Grassland habitat which is characteristic of a large area in the northwest portion of Wupatki National Monument proper that lacks any permanent water. The Bonito campground watering site is found in close proximity to Sunset Crater Monument and also is found in Ponderosa Pine habitat.

The results reported herein describe the type of avian and mammalian utilization of watering sites found within the habitats characteristic of Sunset Crater and Wupatki National Monuments.

DESCRIPTION OF WATERING SITES STUDIED

Bonito Campground Wildlife Watering Site

The Bonito campground watering site is located on Coconino National Forest land in Bonito campground opposite Sunset Crater Visitor Center. This watering source, constructed in 1972, is dependent upon waste water from campground wash basins. The flow is intermittent, particularly during campground closures. The water system is of gravity flow type, with no valves regulating the input into the 21 X 41 inch wildlife guzzler of 10 gallon capacity.

Cinder Trick Tank

Cinder Trick tank is located on Coconino National Forest land along Sunset Crater-Wupatki Loop road. The tank was constructed

in 1962 by the United States Forest Service with a tank capacity of 61,000 gallons and the original apron approximately 100 X 50 feet. The tank and apron underwent maintenance in 1976 by the Youth Conservation Corps with a reduction in the apron size to the present 70 X 40 feet. The 24 X 90 inch 50 gallon guzzler is controlled by a float valve and the water is usually permanent, pending adequate precipitation.

Coyote Spring Stock Tank

Coyote Spring stock tank is located on Arizona State land along Sunset Crater-Wupatki Loop road approximately 0.5 mile from the southern entrance to Wupatki National Monument. The date of construction was unavailable. The flow results from a tap into an underground spring leading to a circular metal two foot deep stock tank. The observable flow was sparse and partly depends on percolation resulting from seasonal precipitation.

Cottonwood Spring Sheep Trough

Cottonwood Spring sheep trough is located within the boundary of Wupatki National Monument 0.25 mile northwest of the southern entrance. The date of construction was unavailable. The flow results from a tapped underground spring leading into four connected one foot deep watering troughs. The observable flow seemed to be fairly constant with a slight increase after periods of precipitation.

Heiser Sewage Ponds

Heiser sewage ponds are located at the Heiser residential units and function as sewage storage ponds for the units. The two adjacent ponds were constructed in 1977 and are surrounded by a seven foot

chain link fence topped with barb wire.

Wupatki Sewage Ponds

The Wupatki sewage ponds are located opposite the highway from Wupatki headquarters. The two adjacent ponds are approximately 65 X 82 feet and were surrounded by a four foot fence until July/August, 1978 when a seven foot chain link fence was constructed while the sewage ponds underwent relining.

METHODS AND MATERIALS

Two techniques were employed in this study to monitor watering site usage: direct observation and mist netting for bat species after dusk. The direct observation method involved sitting near each site and recording any direct usage by birds and mammals. One "usage" is defined as one visit and drink per bird or mammal. Observation days were picked at random and most sittings were made for 3 hours beginning at sunrise. A total of 86 hours of observation time was spent using this technique.

Two to three Japanese mist nets were set up at each watering site when attempting to monitor bat usage. Mist net nights averaged 5 hours. Bats are drawn to watering sites for a variety of reasons, with drinking and feeding being the two most important. The capture of bats by mist net involves many variables: differential probability of avoiding the mist net as to species, sex and age; and the size, location and number of watering sites in a given area. These make the mist net technique only partially reliable at best (Cockrum and Cross, 1963).

RESULTS AND DISCUSSION

Sixty-six avian species representing 23 families (Appendix I) and 15 mammal species representing four families (Table 7) were observed near to or utilizing the six watering sites during the course of this study. Utilization of each watering site varied as to species diversity which is to be expected because of the differential habitat needs of the species.

Bonito Campground Wildlife Watering Site

Thirty-one avian species (47% of the total avian species) were observed on seven observation days (Table 1), with the number of avian species per observation date varying from 11 to 17.

The pattern of avian utilization of a watering site is dependent upon many factors: the differential water requirement according to species and age; whether the species is a permanent resident or migrant; and whether there has been sufficient precipitation in the area to necessitate a visit to the watering site. The porous nature of the cinder ground cover characteristic of the Sunset Crater area allows few chances for formation of temporary pools and thus increases the importance of the Bonito watering site for bird populations.

Three species, the Steller's Jay, Western Bluebird, and Clark's Nutcracker, were observed in direct usage on all observation dates, while 10 species directly utilized the site on four or more of the dates. Usage by juveniles was found within both the Western Bluebird and Robin populations. The usage by Robins on August 16 consisted almost entirely of juvenile birds.

The Mourning Dove, a resident breeding species, heavily utilized

the site as a watering source and resting area during the summer until declining temperatures caused them to move south. Upwards of 100 dove were observed on June 29 and July 18, while only one was seen on September 11 and none on October 1.

Some species, the Pine Siskin, White-crowned and Chipping Sparrows, Solitary Vireo, Olive Warbler and the Red Crossbill, are wanderers and most probably utilized this watering site on their movements through the area. The Sharp-shinned Hawk was observed on two dates, both times seemingly following Pinon Jay flocks and actively hunting prey.

There were seven mammal species observed at the Bonito site (Table 8). Direct usage by the three rodent species was relatively low compared to the relative frequency of sightings and activity. The September 11 and October 1 usages by the Abert's Squirrel and Cliff Chipmunk consisted mainly of juvenile animals. The four bat species captured are characteristic of the habitat found at Sunset Crater. Bat numbers were never very high and activity markedly decreased on the September 21 and 26 mist netting attempts.

Cinder Trick Tank

Twenty-eight avian species (42% of total avian species) were observed on seven observation days (Table 2), with the numbers of avian species per observation date varying from two to 12. No one avian species was observed on all seven observation dates, but six species were observed on at least four dates. Direct usage was never very high, except on the following occasions. The Mourning Dove was very abundant on June 30 and July 10, then decreased in numbers during

August and was not observed on the September 15 and October observation dates. Robin usage was heavy on August 30, September 15, and October 4 with large aggregations of Robins in the near vicinity of the tank on all three dates.

The general trend of avian usage at Cinder Trick tank was one of inconsistency, with many of the species observed only once and many observed on dates months apart. Some of these species were wanderers such as the Black-headed Grosbeak, Bullock's Oriole, Yellow-headed Blackbird, Yellow-rumped Warbler, and Cassin's Finch which points to the speculation that this site is important as a stop-over site for species moving through the Juniper/Grassland area. The effect of local precipitation on avian usage of Cinder Trick tank can be seen by the October 25 results. Rain fell on October 24 and only two species were seen on October 25 with neither drinking at the site.

Two bat species were captured on four mist netting attempts (Table 9). Very few individual bats were observed flying about the site and no more than one species or two individuals were captured on any one night. On most observation dates, tracks of mule deer and coyote were seen all about the site, indicating usage by these two mammals. This indicated usage by mammals and the importance of this site to birds moving through the area suggest that the development of a watering site in the Juniper/Grassland habitat within Wupatki National Monument might be justified in the maintenance of larger animal populations.

Coyote Spring Stock Tank

Twelve avian species (18% of total avian species) were observed on two observation dates in July (Table 3). The Mourning Dove and House Finch used this site heavily on both dates. Two mist net nights yielded no bat captures, with very few bats seen flying. Evidence of other mammalian usage in the form of tracks or droppings was not found in the vicinity of the site. Observations were discontinued at this site due to its close proximity to Cottonwood Sheep trough, less than one mile, its location in the Cold Desert Shrub habitat characteristic of the Cottonwood site, and the need to better distribute observations among the other watering sites. Undoubtedly a greater number of birds and mammals would have been recorded if observations had been continued at Coyote Spring.

Cottonwood Spring Sheep Trough

Twenty-four avian species (35% of total avian species) were observed on five observation dates (Table 4), with the number of species per observation date varying from one to 11. Direct usage was never high on any observation date, with only the House Finch utilizing the site on more than two of the dates; it was also the only species using this watering site in any sizable numbers. The Western Tanager, Yellow-headed Blackbird, Wilson's Warbler, Ruby-crowned Kinglet, Hairy Woodpecker, and Common Flicker that visited this site are not typical residents of the Cold Desert Shrub habitat. The presence of the large cottonwood tree close to the watering site was no doubt a big factor in drawing these species as they moved through the Wupatki area. The relatively low usage by the avian species normally associated

with the Cold Desert Shrub habitat reflects not only their low water requirements but also the nearness of Wupatki and Heiser sewage ponds and Coyote Spring stock tank. The Loggerhead Shrike and Common Raven are two species that obtain their water requirement through their food sources, while birds such as the Black-throated Sparrow, Bendire's Thrasher and Say's Phoebe are thought to be opportunists which will drink when water is available but can go through long periods without drinking.

One Coyote and one White-tailed Antelope Ground Squirrel were observed utilizing the Cottonwood Spring watering site. Four Mule Deer were scared away as they neared the site by my presence on July 11 as I was mist netting for bats. I can only speculate that the deer were attempting to water that night. Three mist netting excursions yielded no bat captures, though bats were observed flying about.

This site, constructed mainly for sheep and cattle watering, despite having a relatively low observed direct usage rate, is important for its permanent water. The presence of the cottonwood tree in an otherwise treeless habitat makes it attractive as a stop-over for migrating and wandering avian species.

Heiser Sewage Ponds

Nine avian species (14% of total avian species) were observed on two observation dates (Table 5) with only three of these directly using the sewage ponds as a water source. Both the Mourning Dove and Brown-headed Cowbird were observed in large numbers at the ponds on July 12.

The seven foot fence surrounding the ponds successfully keeps out all large mammals. Three bat species were captured on July 12 and none on August 21, a windy night on which many bats were observed flying and drinking from the ponds.

Heiser sewage ponds are found in the Cold Desert Shrub habitat as are the Wupatki sewage ponds and are less than one year old. This young age of the ponds and the few observation periods probably both had an effect on the amount of usage observed.

Wupatki Sewage Ponds

Twenty-two avian species (33% of total) were observed on five observation dates (Table 6), with species number per observation varying from five to 11. The pattern of usage was inconsistent as to species visitation, but showed a general trend of heavier usage earlier in the summer decreasing with the coming of fall.

The ponds were important to populations of Mourning Dove and Common Nighthawk, both of which utilized the ponds heavily in July before usage sharply dropped off in August. No data are available on the distances Nighthawks will travel for water, but I observed at least 45 individuals at the ponds on July 6 at one time, so in all probability the ponds drew Nighthawks from a large surrounding area. A 1966 study in Arizona found Mourning Doves traveling four to 12 miles for water (Gubanich, 1966), revealing the potential for the ponds to support the dove populations found over a large area.

Ducks have been sighted on the ponds in previous years. This observation coupled with the presence of wandering White-crowned Sparrow, Killdeer, and Water Pipit points to the fact that these ponds,

with the largest area of open waters of the six sites studied, can serve as an occasional stop-over for migrating waterfowl and other species. On two occasions a Prairie Falcon was observed diving at birds at the ponds edge, the ponds providing hunting opportunities for the falcon.

One deer was seen drinking from the ponds on July 5 before the chain link fence was erected in August/September. This fence successfully excludes most mammals except for bats and small rodents. Five species of bats were captured on four nights of mist netting (Table 10). Two additional species were captured at the ponds during the previous summer on June 17, 1977, but were not recorded during this study. Bat activity at the six watering sites was highest at the Wupatki sewage ponds; this fact points to the importance of these ponds to local bat populations. The high of 48 individual bats captured on July 5 subsequently decreased when only 17 were caught on both July 25 and August 25. No bats were caught on October 26, and no more than three individuals were observed at any time. The bats used the ponds for at least two reasons: feeding and drinking. Pipistrellus hesperus was observed or captured during every night of mist netting and usually was active from before sunset until not over two hours after dusk. Myotis californicus was the most abundant bat, according to mist net captures on July 5 and 25, but its activity decreased on August 25 and October 26. One captured female Myotis californicus was originally caught and banded on July 29, 1963 at Heiser Springs, less than one mile from the sewage ponds. This 15 year time span points to the consistent usage of these ponds by some bats.

The water of the ponds consists entirely of sewage wastes, but the quality of the water did not seem to outwardly prevent or impair any animal from using the ponds as a water source.

CONCLUSIONS

Each of the six watering sites observed during this study had its direct usage defined by the local habitat situation, weather conditions and the animal species occurring near the sites. Earlier studies by Lynn Beatty (1978) have shown that avian diversities are quite high in the habitat types where the observed water sites were located, a fact confirmed by this study. No doubt an increase in diversity and numbers of both avian and mammalian species would have been noted with more observation periods. Lynn Beatty earlier suggested that available moisture may be the factor limiting the breeding bird populations. The six watering sites seem to be very important to some species during the summer when water availability is crucial. Their use by many juvenile birds would seem to point this out. The maintenance of large summer populations of Mourning Dove, Common Nighthawk, and the several bat species is dependent upon the availability of a watering source. All the sites are important to migrating and wandering avian species during the late summer and fall.

Though this study did not encompass observations during the winter and spring seasons, one would expect a probable decrease in usage during the winter as fewer birds are present during cold weather and moisture is generally more readily available.

The presence of Mule Deer, Coyotes and squirrels at the sites reveals at least some usage by these mammals. One might expect an

increase in winter utilization of the water sites by Mule Deer as increased snows force deer populations out of the higher mountainous regions of the San Francisco Peaks.

Bats were observed flying about all water sites and appeared in large numbers at the sewage ponds. This available water is especially critical to bat populations which require free water in the diet because of their small size and high pulmo-cutaneous losses. Bat populations are particularly susceptible to environmental changes and the maintenance of permanent watering sources is an important factor in the maintenance of a stable environment.

RECOMMENDATIONS

With a part of the philosophy of a national monument being to preserve and protect the natural landscape including the biota of the area, it is recommended that the three present watering sites, Cottonwood Spring sheep trough, Heiser and Wupatki sewage ponds, on Wupatki National Monument proper be preserved and maintained in their present state. The erection of the seven foot fence at the Wupatki sewage ponds this past summer leaves only the Cottonwood site open for usage by large mammals.

It is also recommended that the feasibility of further development of natural watering sources be pursued in the three habitat types found in the Monument to provide permanent watering sources for wildlife populations. This action would help to reduce the significance of water as a potential limiting factor for breeding birds and would also make water more readily available for the maintenance of resident populations of large mammals. Some possible avenues might be the

development of natural springs or the installation of guzzlers like Cinder Trick tank involving a minimum of habitat alteration. Man, whose actions past and present, have influenced the landscape at the Monument, has a responsibility to reverse this trend. Maintaining and increasing the populations of natural inhabitants might result from development of more watering sites. Such development would not only increase faunal carrying capacity and diversity on the Monument, but should also increase visitor pleasure by providing an increased opportunity for wildlife observation.

With no watering sites on Sunset Crater National Monument at present, but several sites in the near vicinity, it is suggested that maintenance of the Bonito Campground wildlife watering site be continued and that possibility for development of any natural springs in the area be pursued.

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Table 1. Avian utilization at Bonito Campground water site. Numbers indicate observed usages per hour. + indicates species present but no usage was observed.

Common name	June 29	July 7	July 18	July 28	Aug. 16	Sept. 11	Oct. 1
Sharp-shinned Hawk					+	+	+
Mourning Dove	19.6	17	15	30	3	+	
Common Nighthawk		+	+	+			
Broad-tailed Hummingbird	+		+				
Common Flicker	0.8	1.5	2.67		1.25	0.67	1.67
Yellow-bellied Sapsucker							0.33
Williamson's Sapsucker					0.25	1	2.3
Hairy Woodpecker	0.2	0.5		+	0.5		
Violet-green Swallow	+	+		+			
Steller's Jay	0.6	1.5	5.6	1	11.25	17.3	6
Piñon Jay	0.2	1.5	0.33		12	29.7	16
Clark's Nutcracker	3.2	5	17	3	14.5	11	13.67
Mountain Chickadee	0.2	1				+	0.33
White-breasted Nuthatch		+		+			0.33
Red-breasted Nuthatch		+					
Pygmy Nuthatch	0.2	+	0.33		4	1	17
Robin	2	4.5	0.67	1	40.5		1.3
Western Bluebird	2	7	24.8	7	3.25	1.3	10.33
Townsend's Solitaire			1.3		0.75	0.3	5
Solitary Vireo		0.5					

Table 1. Avian utilization at Bonito Campground water site. (cont.)

<u>Common Name</u>	June 29	July 7	July 18	July 28	Aug. 16	Sept. 11	Oct. 1
Olive Warbler					+		
Yellow-rumped Warbler	0.6		0.33			23.67	
Grace's Warbler	0.2		+		+		
Western Tanager	+	1.5	2.67		1		
Hepatic Tanager		0.5				0.33	
Dark-eyed Junco	0.2					2.3	1.3
Red Crossbill			1.67	1			
Lesser Goldfinch			8.3	1	1.5	5.67	4.3
Chipping Sparrow					0.25		
Pine Siskin							1.67
White-crowned Sparrow							0.33
Total number species per date	<u>16</u>	<u>17</u>	<u>16</u>	<u>11</u>	<u>17</u>	<u>14</u>	<u>17</u>

Table 2. Avian utilization at Cinder Trick Tank. Format follows Table 1.

Common Name	June 30	July 10	Aug. 8	Aug. 30	Sept. 15	Oct. 4	Oct. 25
Cooper's Hawk							+
American Kestrel	+						
Mourning Dove	19	3.3	+	+			
Common Nighthawk		+					
Common Flicker						8	
Yellow-bellied Sapsucker						+	
Williamson's Sapsucker				1		6	
Hairy Woodpecker				0.33	+		
Violet-green Swallow				+			
Cassin's Kingbird			+				
Scrub Jay				0.67	0.33	0.67	
Piñon Jay	2.5		+	1.67		+	
Common Raven	+	+					
Plain Titmouse	+		+	+	+	+	
Mockingbird	0.5						
Sage Thrasher					+	9.33	
Robin			+	14.33	7.5	36.7	+
Townsend's Solitaire				+		8	
Black-tailed Gnatcatcher					+		
Yellow-rumped Warbler						0.33	

Table 2. Avian utilization at Cinder Trick Tank (cont.).

<u>Common Name</u>	June 30	July 10	Aug. 8	Aug. 30	Sept. 15	Oct. 4	Oct. 25
Bullock's Oriole	+					.	
Yellow-headed Blackbird				+			
Brown-headed Cowbird	0.5		+			+	
Cassin's Finch	0.5						
House Finch		+	2	+		0.67	
Black-headed Grosbeak			1				
Lark Sparrow			+				
Chipping Sparrow		0.3		1.33	2	6	
Total number species per date	<u>9</u>	<u>5</u>	<u>9</u>	<u>12</u>	<u>7</u>	<u>13</u>	<u>2</u>

Table 3. Avian utilization of Coyote Springs water site. Format follows Table 1.

<u>Common Name</u>	July 1	July 11
Mourning Dove	9.5	13
Common Nighthawk		+
Cassin's Kingbird	0.25	
Western Kingbird		0.5
Pinon Jay	1	
Common Raven	+	
Mockingbird	1.25	1
Gray Vireo	+	
Scott's Oriole	0.25	1
Brown-headed Cowbird	1.75	6
House Finch	9.5	33
Black-throated Sparrow	0.5	5
Total species per date	<u>10</u>	<u>8</u>

Table 4. Avian utilization at Cottonwood Spring water site. Format follows Table 1.

<u>Common Name</u>	July 5	July 11	Aug. 8	Sept. 6	Sept. 25
Mourning Dove	0.75	+	+		
Common Nighthawk		+			
Broad-tailed Hummingbird			+		
Common Flicker					+
Hairy Woodpecker			0.33		
Western Kingbird		+			
Say's Phoebe	0.25	+	0.67		
Violet-green Swallow		+			
Piñon Jay			+		
Common Raven		+	+		
Mockingbird	0.5				
Bendire's Thrasher	+		+		
Ruby-crowned Kinglet					+
Loggerhead Shrike	+	+	+		
Wilson's Warbler					+
Yellow-headed Blackbird					+
Brown-headed Cowbird	0.25				
Scott's Oriole	0.25		+		
Western Tanager					+
House Finch	12	8.5	4	+	

Table 4. Avian utilization of Cottonwood Spring water site (cont.).

<u>Common Name</u>	July 5	July 11	Aug. 8	Sept. 6	Sept. 25
Lesser Goldfinch					0.5
Black-throated Sparrow		2	2		
Sage Sparrow	0.25				
Total number species per date	<u>9</u>	<u>9</u>	<u>11</u>	<u>1</u>	<u>6</u>

Table 5. Avian utilization at Heiser Sewage Pond water site. Format follows Table 1.

<u>Common Name</u>	July 12	Sept. 27
Mourning Dove	30	
Poor-will	+	
Common Nighthawk	+	
Horned Lark	+	
Violet-green Swallow	+	
Western Meadowlark		+
Brown-headed Cowbird	12.3	+
House Finch		+
Black-throated Sparrow	0.33	
Total number species per date	<u>7</u>	<u>3</u>

Table 6. Avian utilization at Wupatki Sewage Ponds water site. Format follows Table 1.

<u>Common Name</u>	<u>July 6</u>	<u>July 25</u>	<u>Aug. 16</u>	<u>Aug. 25</u>	<u>Oct. 11</u>
Prairie Falcon		+	+		.
Killdeer		0.25			
Mourning Dove	many	8.25	12.5		
Common Nighthawk	many	34	4	1.5	
Say's Phoebe	+	3		+	0.5
Horned Lark	+	0.5			
Cliff Swallow		0.5			
Rough-winged Swallow			1.5		
Common Raven			0.5		+
Mockingbird	+		0.5	+	
Bendire's Thrasher		+			
Sage Thrasher					6.5
Townsend's Solitaire					0.5
Black-tailed Gnatcatcher					+
Water Pipit				+	
Loggerhead Shrike			+	+	+
Brewer's Blackbird					3
Brown-headed Cowbird	18	1.75			
House Finch	9	1	+		3

Table 6. Avian utilization at Wupatki Sewage Ponds water site (cont.).

<u>Common Name</u>	July 6	July 25	Aug. 16	Aug. 25	Oct. 11
Sage Sparrow	0.5				.
Black-throated Sparrow		+			
White-crowned Sparrow					1
Total number species per date	<u>8</u>	<u>11</u>	<u>7</u>	<u>5</u>	<u>9</u>

Table 7. Mammals observed utilizing water sites. X indicates presence of mammal species either due to direct observation or capture by mist net.

Order/ Family/ Species	Bonito Park	Cinder Trick Tank	Cottonwood Springs	Coyote Springs	Wupatki Sewage Ponds	Heiser Sewage Ponds
Chiroptera						
Vespertilionidae						
<u>Myotis californicus</u>					X	X
<u>Myotis evotis</u>	X					
<u>Myotis yumanensis</u>					X	X
<u>Myotis thysanodes</u>		X			X	
<u>Eptesicus fuscus</u>	X					
<u>Pipistrellus hesperus</u>					X	
<u>Antrozous pallidus</u>	X				X	
<u>Plecotus townsendii</u>					X	
<u>Lasiurus cinereus</u>					X	
Rodentia						
Sciuridae						
<u>Ammospermophilus leucurus</u>			X			
<u>Eutamias dorsalis</u>						
<u>Spermophilus variegatus</u>	X					
<u>Sciurus aberti</u>	X					
Carnivora						
Canidae						
<u>Canis latrans</u>			X			

Table 7. Mammals observed utilizing water sites (cont.).

Order/ Family/ Species	Bonito Park	Cinder Trick Tank	Cottonwood Springs	Coyote Springs	Wupatki Sewage Ponds	Heiser Sewage Ponds
Artiodactyla						
Cervidae						
<u>Odocoileus hemionus</u>			X		X	

Table 8. Mammals observed at Bonito Park water site. The numbers of bats represent the total number and sex of individuals captured. The number of rodents is expressed as direct usage per hour.

Order/Family/Species	June 29	July 7	July 18	July 23	July 28	Aug. 16	Sept. 11	Sept. 21	Sept. 26	Oct. 1
Chiroptera										
Vespertilionidae										
<u>Myotis evotis</u>		5 ♀ 1 ♂			3 ♂					
<u>Antrozous pallidus</u>				1 ♀						
<u>Myotis thysanodes</u>				1 ♂						
<u>Eptesicus fuscus</u>				2 ♂						
								Mist netting unsuccessful	Mist netting unsuccessful	
Rodentia										
Sciuridae										
<u>Sciurus aberti</u>	0.2		0.33			0.25	1			2.33
<u>Spermophilus variegatus</u>	0.2									
<u>Eutamias dorsalis</u>			0.67			1.5	1			0.67

Table 9. Mammal utilization of Cinder Trick Tank, Cottonwood Springs, and Heiser Sewage Ponds. The numbers of bats represent the total number and sex of individuals captured. The carnivore and rodent numbers are expressed as direct usage per hour.

Order/Family/Species	Cinder Trick Tank				September 26
	July 10	July 23	September 21		
Chiroptera					
Vespertilionidae					
<u>Myotis thysanodes</u>			1 ♀		Mist netting unsuccessful
<u>Antrozous pallidus</u>	2 ♀	1 ♀			
Order/Family/Species	Cottonwood Springs				September 26
	July 5	July 11	August 8	September 21	
Carnivora					
Canidae					
<u>Canis latrans</u>	0.25	Mist netting unsuccessful		Mist netting unsuccessful	Mist netting unsuccessful
Rodentia					
Sciuridae					
<u>Ammospermophilus leucurus</u>			0.33		

Table 9. Mammal utilization of Cinder Trick Tank, Cottonwood Springs, and Heiser Sewage Ponds (cont).

Order/Family/Species	<u>Heiser Sewage Ponds</u>	
	July 12	August 21
Chiroptera		
Vespertilionidae		
<u>Myotis californicus</u>	2	Mist netting unsuccessful
<u>Pipistrellus hesperus</u>	2	
<u>Antrozous pallidus</u>	8	

Table 10. Mammals observed utilizing Wupatki Sewage Pond. The numbers of bats represent the total number and sex of individuals captured. The artiodactyl number represents the number of deer observed at the site on July 5.

Order/Family/Species	July 17 ¹ 1977	July 5 1978	July 25 1978	August 25 1978	October 26 1978
Chiroptera					
Vespertilionidae					Mist netting unsuccessful
<u>Myotis californicus</u>	6♀ 1♂	21♀* 5♂	5♀ 1♂		
<u>Myotis yumanensis</u>	3♂	5♂	4♂	3♂	
<u>Myotis thysanodes</u>	1♀ 1♀	1♀		1♀ 1♂	
<u>Pipistrellus hesperus</u>	5♀	3♂	4♀	3♂	
<u>Antrozous pallidus</u>	7♂	9♀ 3♂	1♂ 1♂	5♂ 2♂	
<u>Plecotus townsendii</u>	5♀ 4♂	1♀	1♀	1♂	
<u>Lasiurus cinereus</u>	1♀				
Artiodactyla					
Cervidae					
<u>Odocoileus hemionus</u>		1			

* Myotis californicus♀ was originally captured and banded on July 29, 1963 at Heiser Springs.
1. Netting conducted by G.C. Bateman, M.M. Bateman, L.T. Green, and J.H. Witham.

APPENDIX I

Checklist of Birds Observed at
Sunset Crater and Wupatki Water Sites During Study

Order/Family/Common Name	Species
Falconiformes	
Accipitridae - Hawks and Eagles	
Sharp-shinned Hawk	<u>Accipiter striatus</u>
Cooper's Hawk	<u>Accipiter cooperii</u>
Falconidae - Falcons	
Prairie Falcon	<u>Falco mexicanus</u>
American Kestrel	<u>Falco sparverius</u>
Charadriiformes	
Charadriidae	
Killdeer	<u>Charadrius vociferus</u>
Columbiformes	
Columbidae - Pigeons and Doves	
Mourning Dove	<u>Zenaidura macroura</u>
Caprimulgiformes - Gatsuckers	
Caprimulgidae	
Poor-will	<u>Phalaenoptilus nuttalli</u>
Common Nighthawk	<u>Chordeiles minor</u>
Apodiformes	
Trochilidae - Hummingbirds	
Broad-tailed Hummingbird	<u>Selasphorus platycercus</u>
Piciformes - Woodpeckers	
Picidae	
Common Flicker	<u>Colaptes auratus</u>
Yellow-bellied Sapsucker	<u>Sphyrapicus varius</u>
Williamson's Sapsucker	<u>Sphyrapicus thyroideus</u>
Hairy Woodpecker	<u>Dendrocopos villosus</u>

APPENDIX I (cont.)

Order/Family/Common Name	Species
Passeriformes	
Tyrannidae - Tyrant Flycatchers	
Western Kingbird	<u>Tyrannus verticalis</u>
Cassin's Kingbird	<u>Tyrannus vociferans</u>
Say's Phoebe	<u>Sayornis saya</u>
Alaudidae - Larks	
Horned Lark	<u>Eremophila alpestris</u>
Hirundinidae - Swallows	
Violet-green Swallow	<u>Tachycineta thalassina</u>
Cliff Swallow	<u>Petrochelidon pyrrhonota</u>
Rough-winged Swallow	<u>Stelgidopteryx ruficollis</u>
Corvidae - Jays, Magpies, Crows	
Steller's Jay	<u>Cyanocitta stelleri</u>
Scrub Jay	<u>Aphelocoma coerulescens</u>
Common Raven	<u>Corvus corax</u>
Piñon Jay	<u>Gymnorhinus cyanocephala</u>
Clark's Nutcracker	<u>Nucifraga columbiana</u>
Paridae	
Mountain Chickadee	<u>Parus gambeli</u>
Plain Titmouse	<u>Parus inornatus</u>
Sittidae - Nuthatches	
White-breasted Nuthatch	<u>Sitta carolinensis</u>
Red-breasted Nuthatch	<u>Sitta canadensis</u>
Pygmy Nuthatch	<u>Sitta pygmaea</u>
Mimidae - Mockingbirds, Thrashers	
Mockingbird	<u>Mimus polyglottos</u>
Bendire's Thrasher	<u>Toxostoma bendirei</u>
Sage Thrasher	<u>Oreoscoptes montanus</u>
Turdidae - Thrushes	
Robin	<u>Turdus migratorius</u>
Western Bluebird	<u>Sialia mexicana</u>
Townsend's Solitaire	<u>Myadestes townsendi</u>

APPENDIX I (cont.)

Order/Family/Common Name	Species
Sylviidae - Kinglets	
Black-tailed Gnatcatcher	<u>Polioptila melanura</u>
Ruby-crowned Kinglet	<u>Regulus calendula</u>
Motacillidae - Pipits and Wagtails	
Water Pipit	<u>Anthus spinoletta</u>
Laniidae - Shrikes	
Loggerhead Shrike	<u>Lanius ludovicianus</u>
Vireonidae - Vireos	
Gray Vireo	<u>Vireo vicinior</u>
Solitary Vireo	<u>Vireo solitarius</u>
Parulidae - Wood Warblers	
Olive Warbler	<u>Pencedramus taeniatus</u>
Yellow-rumped Warbler	<u>Dendroica coronata</u>
Grace's Warbler	<u>Dendroica graciae</u>
Wilson's Warbler	<u>Wilsonia pusilla</u>
Icteridae - Blackbirds, Orioles	
Western Meadowlark	<u>Sturnella neglecta</u>
Yellow-headed Blackbird	<u>Xanthocephalus xanthocephalus</u>
Scott's Oriole	<u>Icterus parisorum</u>
Bullock's Oriole	<u>Icterus bullockii</u>
Brewer's Blackbird	<u>Euphagus cyanocephalus</u>
Brown-headed Cowbird	<u>Molothrus ater</u>
Thraupidae - Tanagers	
Western Tanager	<u>Piranga ludoviciana</u>
Hepatic Tanager	<u>Piranga flava</u>
Fringillidae - Grosbeaks, Finches, Sparrows, Buntings	
Black-headed Grosbeak	<u>Pheucticus melanocephalus</u>
Cassin's Finch	<u>Carpodacus cassinii</u>
House Finch	<u>Carpodacus mexicanus</u>
Pine Siskin	<u>Spinus pinus</u>
Lesser Goldfinch	<u>Spinus psaltria</u>
Red Crossbill	<u>Loxia curvirostra</u>

APPENDIX I (cont.)

Order/Family/Common Name

Species

Fringillidae (cont.)

Lark Sparrow
Black-throated Sparrow
Sage Sparrow
Dark-eyed Junco
Chipping Sparrow
White-crowned Sparrow

Chondestes grammacus
Amphispiza bilineata
Amphispiza belli
Junco hyemalis
Spizella passerina
Zonotrichia leucophrys

Appendix II. Longevity Record for Myotis californicus.

A female Myotis californicus, banded by Terry A. Gustafson on 29 July 1963 (no. 67-45825) at Heiser Spring, Wupatki National Monument, Coconino Co., Arizona, was recaptured 5 July 1978. The bat was captured in a mist net placed over sewage ponds at monument headquarters, a distance of 2 km. by air from the original point of capture, and was released unharmed. Both bat and band were in good condition.

The 15-year minimum age of this individual constitutes a substantial extension of the known longevity for the species. The previous record was 3 years and 1 month (Cockrum, J. Arizona Acad. Sci., 8: 108-110. 1973)

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VI

STUDIES OF SELECTED
MAMMALIAN POPULATIONS
(AN ADDENDUM)

INTRODUCTION

Though the Final Report (Phase II) of the Natural Resource Survey and Analysis of Sunset Crater and Wupatki National Monuments was available in February, 1978, the study of small mammal populations at Wupatki was continued until June, 1978. This continued work has revealed additional information pertaining to the population dynamics of different rodent species inhabiting the major vegetation zones of Wupatki National Monument. This paper is written as an addendum to the final report in order to present this additional information.

METHODS AND MATERIALS

Please refer to the Methods and Materials section of the Final Report (Phase II), February, 1978.

RESULTS

Species Present

As indicated in Table 1, rodent trapping was conducted six times, once in December, 1977, and five times in 1978. Information regarding species composition numbers and sexes of individuals at each of the three trapping quadrats is provided in Tables 2, 3, 4, and Figures 1, 2, and 3. The Grassland quadrat was dominated by the silky pocket mouse (Perognathus flavus). Also occurring there was a low density population of deer mice (Peromyscus maniculatus),

and for the first time since this study was begun, a single pinon mouse (Peromyscus truei) was captured in the Grassland habitat.

Perognathus flavus was the dominant rodent in terms of density in the Juniper/Grassland community. This dominance was not nearly so pronounced as on the Grassland grid however, as significant populations of both Peromyscus maniculatus and P. truei were also present. A single western harvest mouse (Reithrodontomys megalotis) was also caught in this habitat.

The greatest species diversity was again found on the Cold Desert Shrub quadrat, though heteromyid inactivity reduced the number of species to four in both the January and February samples. During the winter sampling, while Perognathus amplus was inactive, Peromyscus truei was the dominant species. However, the Perognathus amplus population returned to dominance in the spring. Also occurring in moderate densities here were P. maniculatus, R. magalotis, Perognathus intermedius and Dipodomys ordii.

Population Densities and Recruitment

Lincoln Index Population density estimates, where available, generally corresponded closely with the actual number of animals caught. This indicates that a large segment of the resident rodent population was being successfully trapped. Where the samples were very small, Lincoln Index Population estimates were not calculated.

As illustrated in Figure 1, peaks in the P. flavus population occurred in December when forty-one individuals were captured, and again in April when forty-three individuals were captured. These population peaks are attributable to high rates of recruitment within the P. flavus population. In December, twenty-five of the forty-one animals captured were new and unmarked, giving a very high recruitment value of 60.9%. A recruitment value of 26.2% was found for the April sample, but it should be noted that recruitment levels were high in preceding samples as well, and thus, this 26.2% figure underestimates the number of new members comprising the sample.

Peak P. flavus populations were observed on the Juniper/Grassland quadrat in July and December, 1977, and in late March and April, 1978, (Figure 2). This spring peak in 1978 was characterized by high recruitment (63.% in April). Patterns of peak populations similar to those in the P. flavus population were observed in the P. truei and to a lesser extent in the P. maniculatus populations in the Juniper/Grassland community. Both species reached spring peaks similar to that seen in P. flavus and both of these peaks were characterized by high levels of recruitment (see Table 9a, 9b).

At the Cold Desert Shrub quadrat, the Arizona pocket mouse (P. amplus) population peaked in July, 1977 (Fig.3), and again in June, 1978, with a period of complete inactivity in the winter from early December, 1977 to mid-February, 1978.

The peak population observed in June was characterized by a high level of recruitment of 59.% (Table 10). Interestingly, P. truei and P. maniculatus populations exhibited extremely similar population trends, both peaking in December, 1977, as the dominant P. amplus population became inactive, and again in late March-early April.

Rodent Activity

The number of animals caught in a given number of trap-nights is used as a rough index of rodent activity. Percent trapping success for all species on each of the grids during each sampling period since December, 1977, is provided in Table 11. As would be expected, overall rodent activity dropped considerably during the winter months. At all three grids, rodent activity decreased to the lowest point in the January sample. This winter decrease in overall rodent activity is attributable mainly to the drop in heteromyid activity, particularly among the pocket mouse populations. As mentioned previously, the P. amplus population became completely inactive from early December to mid-February. Populations of Perognathus flavus at the Juniper/Grassland and Grassland grids both decreased significantly in January and February, though complete inactivity never occurred.

Overall rodent inactivity peaked on all three quadrats in the late April sample, with a mean trap success of 26.4%. This is considerably higher than the peak July, 1977, of 18.74%

Rodent Diversity

As in the report previous to this one, when based simply on the number of species per area, rodent diversity was found to be greatest in the Cold Desert Shrub community. Six different species, representing two families and four genera, were found. Three of these six species were unique to the Desert Shrub: Dipodomys ordii, P. amplus and P. intermedius. The Juniper/Grassland habitat produced four species, of two families, none of which was unique to this area. The lowest number of species was found at the Grassland grid, where P. flavus and P. maniculatus were commonly found and a single P. truei and captured.

The Shannon Index values (Table 12), which take into account such additional aspects as biomass, numbers and energy transfer, give a different picture. While the Grassland habitat exhibited an expected low value of 0.464, diversity at the Juniper/Grassland grid was greater than one might have expected based simply on the number of species present. A mean diversity value of 1.39 was found for the Juniper/Grassland, which compares closely to a mean value of 1.47 found at the Cold Desert Shrub. This is due to the fact that, while there are fewer species at the Juniper/Grassland study area, those present are all of significance in terms of numbers, biomass and energy transfer, at the Cold Desert Shrub more species are present, but several of these are less significant in their ecological impact.

DISCUSSION

While all three study areas are inhabited by rodent communities of considerable density and diversity, the already observable increase in vegetation within the recently constructed grazing exclosures indicates that cattle may be having a significant impact on consumer populations. The greater biomass and species diversity of plants within these exclosures undoubtedly provide a more ample food resource base for both herbivorous and granivorous rodents. It is probable that the exclusion of domestic livestock from the monument would result in significant increases in the densities of other herbivorous mammals such as lagomorphs and pronghorns. Ultimately, this might be expressed as an increase in diversity and density of species at higher trophic levels as well.

LITERATURE CITED

Bateman, G.G. 1978. Natural Resource Survey and Analysis of Sunset Crater and Wupatki National Monuments. Final Report (Phase II). Prepared for the Office of Natural Resources Management, Southwest Region, National Park Service.

Table 1. Dates of live-trapping, December, 1977 through June, 1978 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	Desert Shrub
1	3 Dec.	3 Dec.	3 Dec.
2	28 Jan.	28 Jan.	28 Jan.
3	18 Feb.	18 Feb.	18 Feb.
4	31 March	31 March	31 March
5	28 April	28 April	28 April
6	13 June	13 June	13 June

Table 2. Total numbers of individuals present on the Grassland Grid during each of the sampling periods. ♂ = male ♀ = female unk = undetermined.

Sampling Period	<u>Perognathus flavus</u> ♂/♀/unk. total		<u>Peromyscus maniculatus</u> ♂/♀/unk. total		<u>Peromyscus truei</u> ♂/♀/unk. total		Totals
1	18/23/0	41	1/0/0	1	0/1/0	1	43
2	7/3/0	10	0/1/0	1			11
3	16/9/2	27	0/1/0	1			28
4	18/18/1	37	3/5/0	8			45
5	25/17/1	43	2/0/0	2			45
6	8/11/0	19	0/1/0	1			20
Totals		177		14		1	192

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

Sampling Period	<u>Perognathus flavus</u> ♂/♀/unk total	<u>Peromyscus truei</u> ♂/♀/unk total	<u>Peromyscus maniculatus</u> ♂/♀/unk total	<u>Reithrodontomys megalotis</u> ♂/♀/unk total	Totals
1	4/9/2 15	3/2/0 5	1/0/0 1		21
2	5/4/0 9	2/1/0 3	3/0/0 3		15
3	2/0/0 2	1/1/0 2	2/1/0 3		7
4	10/16/1 27	2/3/0 5	5/6/0 11		43
5	13/13/1 27	8/4/1 13	10/7/1 18	1/0/0 1	69
6	7/4/1 12	2/4/0 6	3/1/0 4		22
Totals	92	34	40	1	177

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

Sampling Period	<u>Perognathus</u> <u>amplus</u> ♂/♀/unk total	<u>Perognathus</u> <u>intermedius</u> ♂/♀/unk total	<u>Peromyscus</u> <u>truei</u> ♂/♀/unk total	<u>Peromyscus</u> <u>maniculatus</u> ♂/♀/unk total	<u>Dipodomys</u> <u>ordii</u> ♂/♀/unk total	<u>Reithrodontomys</u> <u>megalotis</u> ♂/♀/unk total	Total
1		0/1/0 1	11/9/1 21	4/2/0 6	0/1/0 1	1/0/0 1	30
2			4/6/0 10	2/1/0 3	1/0/0 1	1/0/0 1	15
3			6/5/0 12	4/2/0 6	2/0/0 2	1/0/0 1	21
4	15/4/0 19	1/1/0 2	9/6/0 15	5/3/0 8	1/1/1 3		47
5	11/16/1 28	3/1/0 4	3/7/0 10	5/2/0 7	2/4/0 6		55
6	23/21/1 45	1/1/0 2	5/2/1 8	3/1/0 4	3/3/0 6	0/1/0 1	66
Totals	92	9	76	34	19	4	234

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

A = Population Estimate

B = Standard Error

Sampling Period	<u>Perognathus flavus</u>		<u>Peromyscus maniculatus</u>	
	A	B	A	B
1	50	$\pm$ 9.8	*	
2		*	*	
3	34.5	$\pm$ 9.8	*	
4	45.5	$\pm$ 6.2	12.5	$\pm$ 6.8
5	47.1	$\pm$ 8.2	*	
6	26	$\pm$ 7.5	*	

*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 quadrat.

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	15.0	± 3.1	5.0	± 0.0	*	
2	15.0	± 8.2	3.0	± 2.4	4.0	± 2.8
3	*		2.0	± 1.4	3.0	± 1.2
4	29.1	± 3.5	6.0	± 2.4	11.5	± 2.1
5	28.5	± 4.1	21.3	± 9.7	20.6	± 4.9
6	13.3	± 3.4	*		6.0	± 4.2

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

Sampling Period	A = population estimate		B = standard error			
	<u>Perognathus</u>	<u>Perognathus</u>	<u>Peromyscus</u>	<u>Peromyscus</u>	<u>Dipodomys</u>	<u>Reithrodontomys</u>
	<u>amplus</u>	<u>intermedius</u>	<u>truei</u>	<u>maniculatus</u>	<u>ordii</u>	<u>megalogotis</u>
	A B	A B	A B	A B	A B	A B
1	*	*	21.8 ± 2.7	8.0 ± 4.0	*	*
2	*	*	10.0 ± 2.5	3.0 ± 0.0	*	*
3	*	*	16.6 ± 8.0	6.0 ± 2.4	2.0 ± 0.0	*
4	22.5 ± 4.5	2.0 ± 0.0	16.5 ± 3.6	8.4 ± 1.5	4.0 ± 2.8	*
5	38.0 ± 8.2	*	11.2 ± 3.0	7.5 ± 1.7	7.5 ± 4.1	*
6	60.0 ± 11.5	2.0 ± 0.0	*	6.0 ± 4.2	7.5 ± 3.0	*

* 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/Total # captured captured	Percent Unmarked
1	25/41	60.9
2	7/10	70.0
3	11/27	40.7
4	10/37	27.0
5	11/42	26.2
6	6/18	33.3

Table 9. Per cent new individuals captured per sampling period within the Perognathus flavus population of the Juniper/Grassland quadrat.

Sampling Periods	number unmarked individuals/Totals # captured captured	Percent Unmarked
1	3/15	20.0
2	4/9	44.4
3	0/2	0.0
4	17/27	63.0
5	4/27	14.8
6	1/12	8.3

Table 9a. Per cent new individuals within the Peromyscus maniculatus population at Juniper/Grassland quadrat.

Sampling Periods	number unmarked individuals/Total # captured captured	Percent Unmarked
1	0/1	0.0
2	1/3	33.0
3	0/3	0.0
4	8/11	72.7
5	10/17	58.8
6	1/4	25.0

Table 9b. Percent new individuals within the Peromyscus truei population at the Juniper/Grassland quadrat.

Sampling Period	# Individuals/ Unmarked	Total # Captured	Percent Unmarked
1	0/5		0.0
2	0/3		0.0
3	0/2		0.0
4	5/5		100.0
5	7/12		58.3
6	4/6		66.6

Table 10. Per cent new individuals captured per sampling period within the Perognathus amplus population at the Cold Desert Shrub quadrat.

Sampling Periods	number unmarked individuals /Totals # captured captured	Percent Unmarked
1	0/0	0.0
2	0/0	0.0
3	0/0	0.0
4	1/19	5.3
5	4/29	13.8
6	26/44	59.0

Table 11. 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	19.4	11.8	16.6	15.9
2	4.1	6.6	7.9	6.2
3	13.2	3.5	10.1	8.9
4	22.9	23.3	11.8	19.3
5	22.9	29.2	27.1	26.4
6	8.7	10.4	29.5	16.2
Mean per cent trap success	15.2	84.8	17.2	

Table 12. Shannon Diversity Indices for communities of nocturnal rodents existing in each of the three major plant communities.

	Grassland	Juniper/Grassland	Cold Desert Shrub
Winter (1st 3 sampling periods)	.321	1.22	1.38
Spring (last 3 sampling periods)	.606	1.57	1.56
Mean Value of H'	.464	1.39	1.47

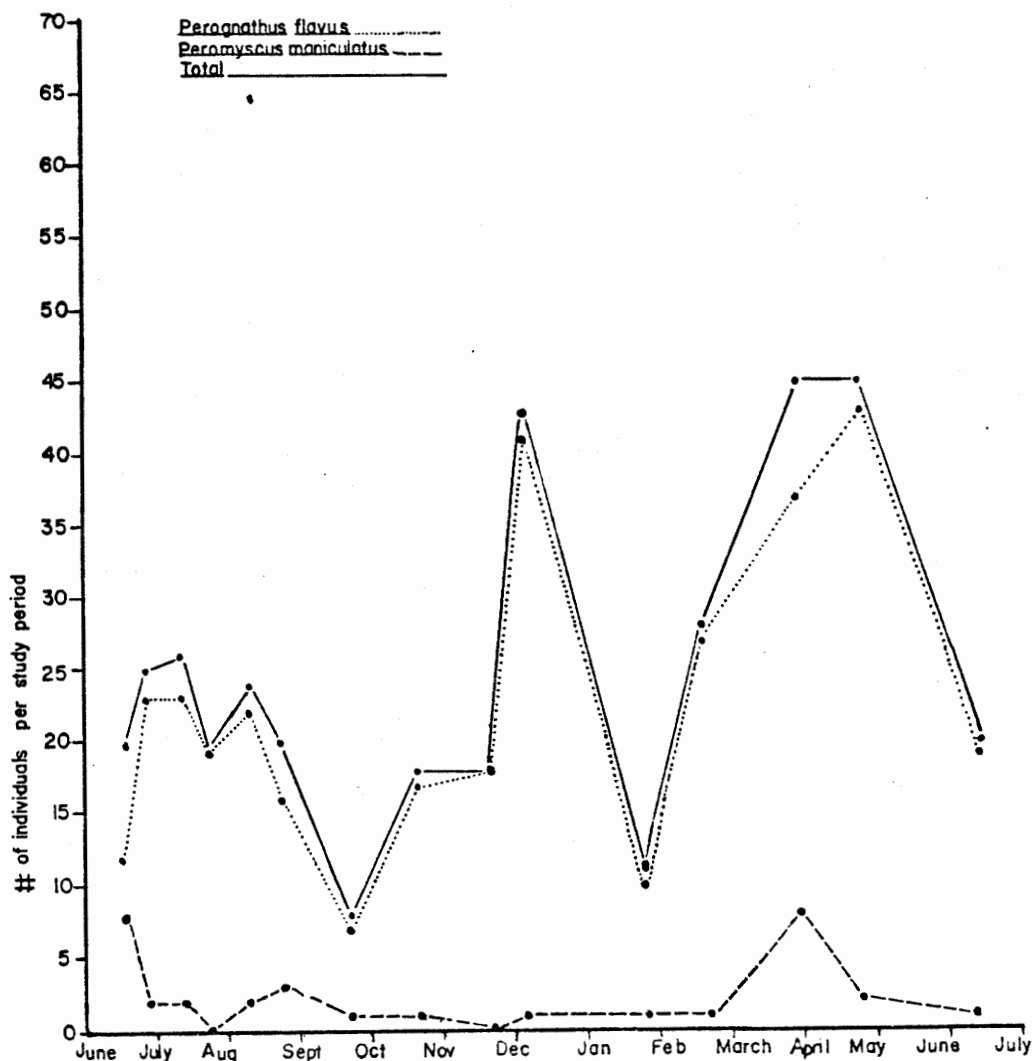


Figure 1. Total numbers of individuals trapped on the Grassland grid during each sampling period from June, 1977 to June, 1978. (Data from June/November, 1977, from Final Report-Phase II-Natural Resource Survey and Analysis of Sunset Crater and Wupatki National Monuments, February, 1978).

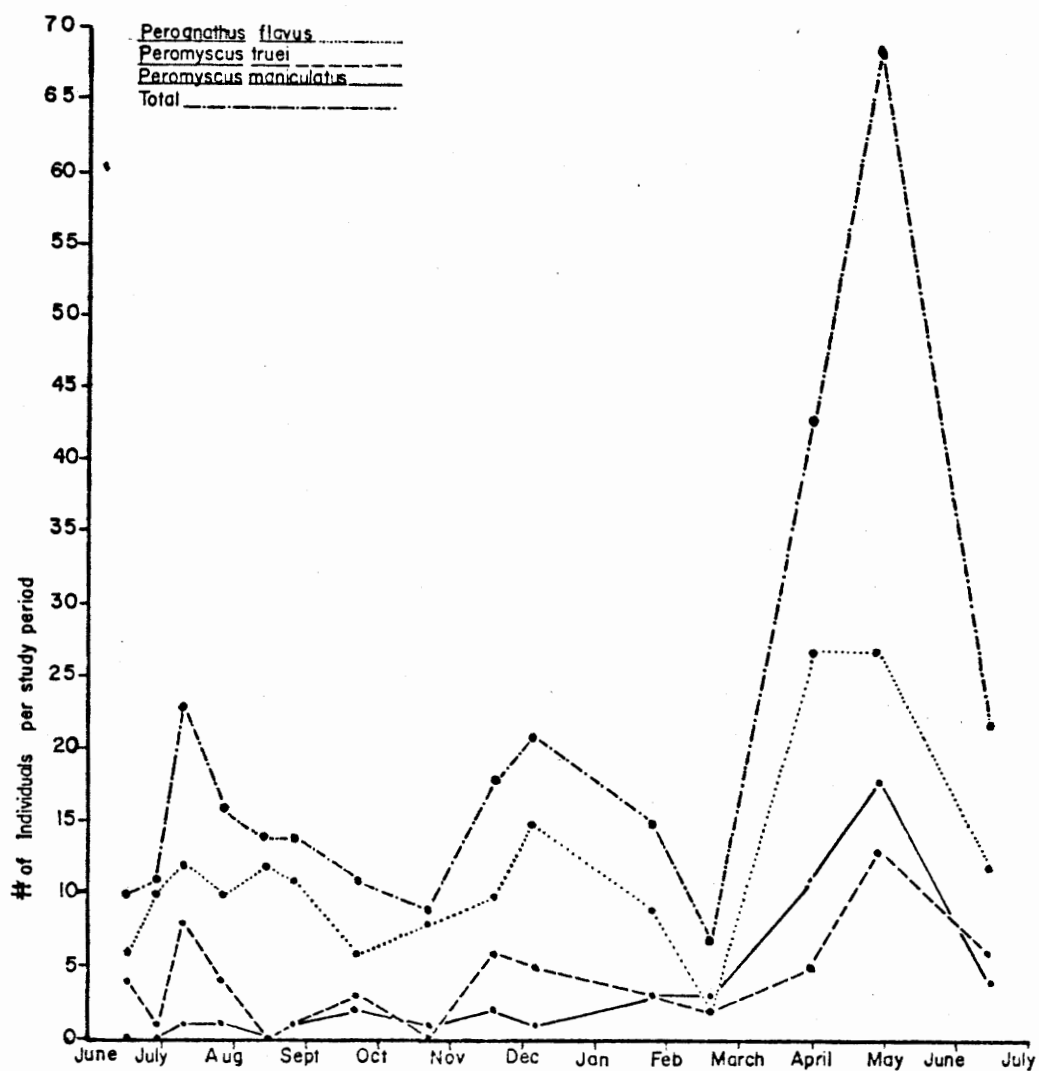


Figure 2. Total numbers of individuals trapped on the Juniper/Grassland grid during each sampling period from June, 1977 to June, 1978.

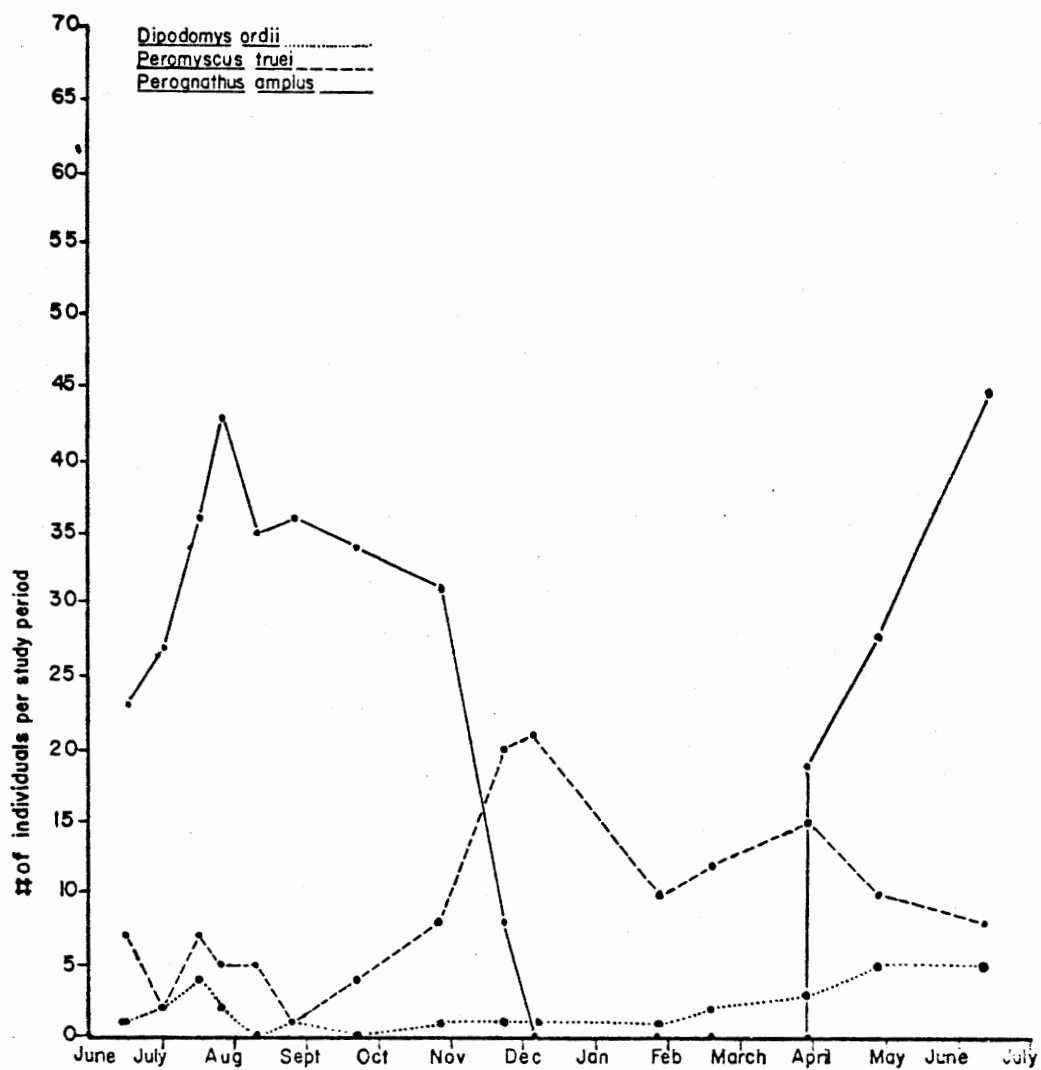


Figure 3A. Total numbers of individuals of selected species trapped on the Cold Desert Shrub grid during each sampling period from June, 1977 to June, 1978.

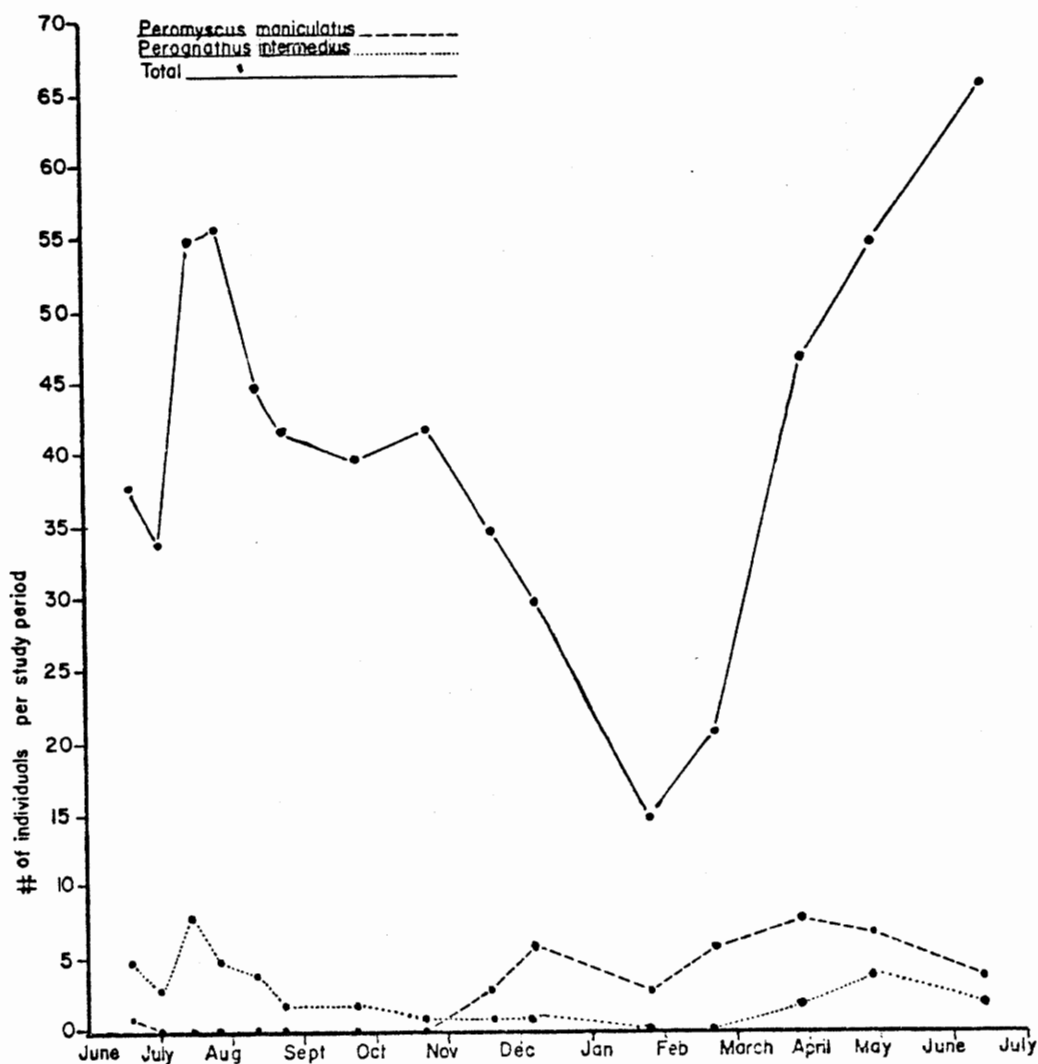


Figure 3B. Total numbers of individuals of selected species and grand total of all species trapped on the Cold Desert Shrub grid during each sampling period from June, 1977 to June, 1978.

VII

DIETS OF LIVESTOCK
ON
WUPATKI NATIONAL MONUMENT

INTRODUCTION

Cattle grazing is permitted on Wupatki National Monument from 15 November through 15 April. To determine the plants that comprise the winter diet of cattle foraging in the Grassland and Juniper/Grassland Communities, fecal samples were collected and analyzed. Analysis by microscopic examination of feces is based on the fact that plant cell walls are encased in cutin and undergo little or no digestion. Further, each species of plant has characteristic cuticular patterns which can be identified through microscopic comparisons with a reference collection of known plants. Microscopic fecal analysis has been utilized in studies determining dietary composition and food preferences of herbivores (Kufeld, 1973; Stewart, 1967; Todd and Hansen, 1973; and Ward and Keith, 1962), dietary overlap between different herbivore species (Constan, 1973; Hansen, Peden and Rice, 1973; and Hansen and Reid, 1975), and in general range management studies (Flinders and Hansen, 1975; Korschgen, 1962; Reppert, 1960; Schwartz and Nagy, 1976; and Stevens, 1966). The reliability of this technique for accuracy has been verified by numerous authors (Dearden, Pegan and Hansen, 1975; Sparks and Malechek, 1968; Storr, 1963; and Voth and Black, 1973).

METHODS AND MATERIALS

Cattle feces were collected biweekly from 1 February 1979 through 20 March 1979. Collections were taken from the center of large areas of each vegetative community to minimize the possibility

of collecting fecal materials transported between communities. Five samples were gathered from the Grassland Community in the vicinity of Cedar Canyon and Lomaki Ruin. Five fecal samples were also taken from the Juniper/Grassland Community between the monument boundary opposite Hulls Canyon at Forest Service Road 545 and South Mesa. Only fresh fecal materials were collected. These were placed in plastic bags and frozen until processed.

The fecal samples and plant samples to be used as reference were both prepared for mounting on microscope slides in the same manner. A combination of the techniques employed by Dusi (1949), Sparks and Malechek (1968) and Ward (1970) was followed. After being air dried, a small portion of the sample was pulverized using a mortar and pestle. This was then ground over a 60 mesh screen to ensure uniform particle size for a quantitative analysis. A small portion of the resulting powdered sample was placed on a microscope slide with 4 or 5 drops of Kleermount, a general all-purpose mounting medium. The sample fragments were then spread evenly over the slide, using a needle, and a cover slip was added. Two slides per fecal sample were prepared. Five fields per slide were located under a compound microscope at 100x magnification. The epidermal fragments were examined and compared to the reference collection at a magnification of 400x. The numbers of particles representing each plant species present in all 100x fields were recorded.

Those plants used in the reference collection representing the more abundant shrubs, herbs, and grasses found on the grazing areas of the monument are given in Table 1. Microscope slides for each of the

various parts, including stem, leaves, and seeds of the eighteen species of plants were prepared for use as reference materials.

RESULTS

Twenty microscope slides were prepared from the feces collected from February through March in the Grassland and Juniper/Grassland communities of Wupatki National Monument. Of the 100 fields searched, 1803 plant fragments were examined. An average of 5.28 plant species was identified per field and 6.6 plant species per fecal sample. Eleven forage plants were identified in the feces, including oneshrub, two herbs, seven grasses, and one tree. Ten species occurred in the samples from both the grassland and juniper/grassland, each community having only one unique foodplant species. Five hundred twenty two plant fragments (28.95%) were unidentifiable. Approximately 40% of those fragments had visible cuticular characteristics but could not be matched to a reference slide. Percent contribution to the diet by each of the food plants utilized by the cattle in the Grassland and Juniper/Grassland communities from February through March is given in Table 2.

To determine the average percent contribution of a plant species to the diet of the cattle over the total area of the Grassland and Juniper/Grassland communities of Wupatki, the percent contribution of the plant from each community was weighted in proportion to the area covered by that community. As reported in the Phase I Report (1976), the Grassland community comprises approximately 37% of Wupatki, the Juniper/Grassland Community approximately 9%. The percent dietary contribution of each foodplant, adjusted to represent the utilization

of each species over the total area of Wupatki under consideration, was used to rank the plant species in relative order of importance as forage for the cattle grazing on the monument from February through March. The adjusted percent dietary contribution of each foodplant is given in Table 3. The proportion of the diet composed of shrubs, herbs, grasses and trees from the Grassland and Juniper/Grassland communities and the adjusted proportion of each of these groups of plants from both communities are given in Table 4.

The percent contribution of each foodplant to the diet of the cattle grazing in the Grassland and Juniper/Grassland community was compared to the relative availability of each forage plant. Relative density and crown cover for each plant species in both communities was given in the Phase I Report (1976). However, as pointed out in the vegetational survey, the number of sample transects analyzed may not reflect the floral changes which occur in unique locales of the small areas of varying soil types as are common in the Wupatki vicinity. Any error in the estimated crown cover of each plant species due either to sampling error or vegetative changes since 1976, would proportionally have the greatest effect on those plants with the lowest percent cover. Hence, the percent crown cover values used to compare percent availability to percent dietary contribution of each plant species are reasonably accurate for those plants that comprise a major component of the floral community.

Those foodplants comprising a significant segment of the cattle's diet are considered by species in order of overall relative importance as a forage plant.

Hilaria jamesii (galleta)

Grassland

Hilaria jamesii, the dominant grass of the grasslands, comprised approximately 65% to 69% of all ground cover provided by the grasses present, or approximately 52.2% of all vegetative crown cover in this community (Phase I Report, 1976). The percent dietary contribution by this grass remained relatively consistent from February through March, averaging 16.7%. Those fecal samples containing the highest percent contribution by Hilaria, 21% and 17.6%, also showed the lowest percent contribution for Atriplex canescens, 8.7% and 0%, and Sporobolus airoides, 6.2% and 6.3% respectively. Though Hilaria was not used in proportion to its availability, it was a major foodplant in the Grassland Community from February through March, second only to Stipa neomexicana (17.7%).

Juniper/Grassland

Hilaria jamesii was also the dominant grass of the Juniper/Grassland community. It comprised approximately 76.4% of the crown cover provided by all grasses present in this community or approximately 49.3% cover relative to all vegetation, excluding that of the tree Juniperus monosperma (Phase I Report, 1976). The average percent dietary contribution by Hilaria from February through March was 15.5%. The fecal sample with the highest percent composition of Hilaria, 21.3%, also had the lowest percent composition of Sporobolus flexuosus, 6.9%, Sporobolus airoides, 0%, and Stipa neomexicana, 4.6%. Hilaria is the primary graze in the Juniper/Grassland community.

Hilaria jamesii was the dominant plant species in the Grassland and Juniper/Grassland communities of Wupatki, being well adapted for growth in all major soil types found within the monument and in deep cinders (Phase I Report, 1976). This grass comprised approximately 51.5% of all the vegetative crown cover, excluding Juniperus monosperma, for both floral communities (Phase I Report, 1976). The cattle which grazed in the Grassland and Juniper/Grassland communities from February through March were determined to have dietary contribution of 16.4% by Hilaria jamesii when adjusted for utilization in both grazed communities. Though there is a somewhat higher percent usage of Hilaria in the Grassland than in the Juniper/Grassland community, 16.7% to 15.5%, there is a greater utilization of this grass by the cattle in the Juniper/Grassland relative to its availability. Hilaria jamesii comprised a greater overall proportion of forage for the cattle which grazed in the Grassland and Juniper/Grassland communities from February through March than any other foodplant.

Stipa neomexicana (New Mexico feathergrass)

Grassland

From February through March Stipa neomexicana comprised approximately 17.7% of the diet of the cattle which grazed in the Grassland community. This was the highest contribution to the diet of any forage plant. The relative ground cover of S. neomexicana in the grassland was approximately 33.3%, its actual density varying with soil type (Phase I Report, 1976). The fecal sample with the greatest component of Stipa, 23.8%, also had the lowest percent composition of Hilaria jamesii, 11.9%, and Bouteloua eriopods, 0%.

Juniper/Grassland

Stipa neomexicana provided a fairly consistent percentage of the diet for the cattle in the Juniper/Grassland community from February through March, averaging 7.4%. However, the one fecal sample collected in late February was calculated to have a 15.9% dietary contribution by Stipa, 2.7 times more than the 5.8% average of the other four samples. That same fecal sample which had the highest volume of Stipa in the Juniper/grassland, also had the lowest percent composition of Bouteloua eriopoda, 4.8%, and the second lowest percent composition of Sporobolus flexuosus, 7.6%. The vegetational analysis in the Phase I Report (1976) did not record Stipa neomexicana in any of the 43 sample plots from the Juniper/Grassland community.

Stipa neomexicana constituted an adjusted average of 15.6% of the diet of the cattle in the Grassland and Juniper/Grassland communities of Wupatki from February through March. This grass ranked second only to Hilaria jamesii in importance as a forage plant. Even though the average percent contribution by Stipa in the juniper/grassland was considerably lower than that in the grassland, the value of this grass was reflected by its consistent presence in all the fecal samples from both communities.

Atriplex canescens (four-wing saltbush)

Grassland

Atriplex canescens occurred in low densities in the Grassland Community of Wupatki (Phase I Report - 1976). However, this shrub constituted an average of 13.9% of the forage of the cattle grazing in the grassland from February through March. The frequency of this foodplant in feces from the grassland is surpassed only by that of two

relatively abundant grasses, Stipa neomexicana, 17.7% and Hilaria jamesii, 16.7%. There was a steady decline (from 27% to 18.8% to 14.9% to 8.7% to 0%) in the contribution by Atriplex to the cattle's diet from early February to late March.

Juniper/Grassland

In the Juniper/Grassland Community Atriplex canescens was found at very low densities (Phase I Report - 1976), but again this shrub formed a significant component of the cattle's diet - 9.2%. In four of five fecal samples from the juniper/grassland, the average percent contribution by Atriplex was 3.9%, the remaining sample being composed of 31.6% Atriplex.

The adjusted average of 13% of Atriplex canescens in the diet of the cattle which grazed in the Grassland and Juniper/Grassland Communities was considerably higher than the observed densities of this plant on the monument. The fecal samples from the end of March from both communities recorded no Atriplex. Atriplex canescens was the most heavily utilized foodplant in the Grassland and Juniper/Grassland Communities in relation to its actual abundance. Ranking third in order of value to the cattle as a foodplant, Atriplex canescens was the only shrub comprising a significant proportion of the diet of cattle in the areas studied.

Sporobolus airoides (alkali sacation)

Grassland

Averaging 9.9%, Sporobolus airoides comprised a significant proportion of the diet of the cattle which grazed in the Grassland Community from February through March. The greatest percent contribution

by this grass, 18.4%, was found in that fecal sample which had the least amounts of Bouteloua eriopoda, 0%, and Hilaria jamesii, 11.9%, and the greatest percentage of Stipa neomexicana, 23.8%.

Juniper/Grassland

The percent composition of Sporobolus airoides in the feces collected from the Juniper/Grassland Community from February through March averaged 7.1%. The highest relative abundance of this grass, 13.1%, was found in two fecal samples. One had the lowest percent composition of Bouteloua eriopoda, 4.8%, and the highest proportion of Stipa neomexicana, 15.9%. The other sample had the lowest percent contribution by Hilaria jamesii, 8.7%, and the next to lowest component of Bouteloua eriopoda, 7.1%.

Sporobolus airoides had an adjusted average dietary contribution of 9.4%. Ranking fourth, this was a relatively important foodplant for the cattle in both the Grassland and Juniper/Grassland Communities. The floral surveys for the Phase I Report (1976) did not locate Sporobolus airoides in any community of Wupatki other than the Cold Desert Shrub. However, during this study, Sporobolus airoides was collected from the grassland at Cedar Canyon. This grass, generally more common on arid, alkali soils, is often used as forage when other grasses are less available (Gould 1951).

Bouteloua eriopoda (Black grama)

Grassland

Comprising approximately 1.3% to 2% of the estimated ground cover provided by the grasses of the Grassland Community (Phase I

Report, 1976), Bouteloua eriopoda accounted for 7.3% of all forage consumed from February through March in the grassland. The fecal samples collected in March consisted of an average of 13.5% Bouteloua, while the previous three samples averaged only 3%. Those fecal samples with the highest percent composition of Bouteloua eriopoda, 13.8% and 13.1%, also had the highest percent composition of Hilaria jamesii, 21% and 17.6%, and the lowest percent composition of Sporobolus airoides, 6.2% and 6.3%, respectively.

Juniper/Grassland

Bouteloua eriopoda, averaging 9.5% of the diet of the cattle in the Juniper/Grassland Community, provided a fairly consistent and significant proportion of the forage taken from February through March. The relative ground cover furnished by Bouteloua eriopoda was 11.9%, making this second only to Hilaria jamesii as the dominant grass of the juniper/grassland (Phase I Report, 1976). The fecal samples with the highest percent contribution by Bouteloua eriopoda, 11.6%, also had the highest percent component of Aristida fendleriana, 5.6%. The samples with the second highest percent contribution by Bouteloua, 11.5%, also had the greatest proportion of Hilaria jamesii, 21.3%, and the lowest percent contributions by Stipa neomexicana, 4.6%, Sporobolus airoides, 0% and Sporobolus flexuosus, 6.9%.

Bouteloua eriopoda made an adjusted average dietary contribution of 7.8%. The adjusted percent crown cover equals 3.9% (Phase I Report, 1976). This highly palatable grass ranked fifth in importance as a forage plant from February through March in the Grassland and Juniper/Grassland Communities of Wupatki. Bouteloua eriopoda and

Stipa neomexicana tend to replace each other depending on soil type and location within the community - Bouteloua eriopoda dominating on cindereed limestone outcrops with Aristida fendleriana (Phase I Report, 1976).

Sporobolus flexuosus (mesa dropseed)

Grassland

Comprising 1.7% of the diet of the cattle grazing in the Grassland Community, Sporobolus flexuosus was only present in the fecal samples from March. This grass was not found in any of the fifteen grassland survey plots of the Phase I Report (1976) and was relatively unimportant in the diet of cattle in the Grassland area.

Juniper/Grassland

The relative ground cover of Sporobolus flexuosus in the Juniper/Grassland Community is 8.8% (Phase I Report, 1976), while the fecal samples examined contained 13.1% of Sporobolus flexuosus. The feces from the month of March showed twice as much of this grass as the average for the previous three samples, 18.7% to 9%. Sporobolus flexuosus was second only to Hilaria jamesii in terms of percent dietary contribution in the Juniper/Grassland from February through March. Though some feces showed relatively high proportions of both Sporobolus flexuosus and Bouteloua eriopoda, 12.6% to 11.6% and 17.6% to 11.2%, that sample with the highest proportion of Sporobolus flexuosus, 19.7%, had the next to lowest percent contribution by Bouteloua eriopoda, 7.1%. This sample exhibited the greatest departure from the combined average of Sporobolus flexuosus and Bouteloua eriopoda, thus having the most Sporobolus flexuosus relative to Bouteloua eriopoda.

Sporobolus flexuosus was of major importance as a forage plant in the Juniper/Grassland, but only of minor value in the Grassland. When adjusted to actual usage per area, Sporobolus flexuosus ranked sixth, providing only 4.0% of the combined forage from the Grassland and Juniper/Grassland Communities. Sporobolus flexuosus normally replaces Bouteloua eriopoda according to soil type, being dominant in areas of sandstone outcrops with little cinder cover (Phase I Report, 1976).

Other Forage plants

Grassland

The remaining 2.9% of the identifiable portion of the fecal material from the Grassland Community was comprised of two grasses, Aristida fendleriana and Oryzopsis hymenoides, and two herbs, Amsonia peeblesii and Euphorbia species. Each species of plant was represented in only a single fecal sample.

Juniper/Grassland

Those plant species which comprised the remaining 10.2% of the identified portion of the cattle's diet from the Juniper/Grassland Community consisted of two grasses, Aristida fendleriana and Oryzopsis hymenoides, one herb, Euphorbia species and the tree Juniperus monosperma. Oryzopsis hymenoides and Aristida fendleriana were both found to be present in the same three fecal samples.

Each of these grasses and herbs was present at very low densities in Wupatki, and formed a relatively minor part of the cattle's diet from both vegetative communities from February through March. Aristida fendleriana occurs in its highest density on cindered limestone

outcrops (Phase I Report, 1976), the same soil preference as the highly palatable Oryzopsis hymenoides (Gould 1951). Each of these grasses contributed an adjusted average of 1.5% to the cattle's diet. Amsonia peeblesii and Euphorbia species formed the only herb component in the cattle's diet, providing a combined adjusted average of 1.1%. Juniperus monosperma occurs in rather high densities in the Juniper/Grassland and regularly in the Grassland. However, this tree was represented in only one fecal sample.

The proportions of Hilaria jamesii and Bouteloua eriopoda in the diet of the cattle appeared to parallel one another as did the proportions of Stipa neomexicana and Sporobolus airoides. However, the proportions of Hilaria and Bouteloua eriopoda were opposite that of Stipa and Sporobolus airoides.

DISCUSSION

Each plant in the reference collection had from two to twenty different cell types. Though each plant had at least one clearly diagnostic cell structure, there were often several cells of one plant that closely resembled those of various other plants, this being especially true of the vascular transport cells which were often prominent in the fecal material. Though almost any plant cell is theoretically identifiable by its cuticular characteristics, many cells were sufficiently damaged by digestive activity or obscured by other plant fragments so as to make their identification nearly impossible.

The large proportion of unidentified fragments with discernible characteristics reflects in part, the problem of differentiating

between some cells of several plant species. In addition, several species of plants reported as locally common in the Phase I Report (1976) were not included in the reference collection. Consequently, any fragment in a fecal sample representing these species of plants remained unidentified. However, the combined total adjusted relative percent ground cover of the more common species of plants not in the reference collection comprised only a 2.1%, (Phase I Report, 1976).

The fecal samples collected actually represented only the last two months of a five month grazing season. Only one fecal sample per two week period from each the Grassland and Juniper/Grassland Communities was analyzed. Even though a short collection period and small sample size can introduce some degree of error into the data, the major proportion of error should lie with those plant species which make up a small percentage of the cattle's diet. General trends and average percent composition of the major dietary components should not be greatly affected.

In a dietary analysis, as one item increases percentagewise, others must automatically decrease. However, the relationships maintained between the proportions of different forage plants in the cattle's diet may indicate something about the relative abundance, distribution and palatability of each foodplant.

The soil conditions in the vicinity of Wupatki National Monument are rather variable. The depth of cinder cover, occurrences of sandstone and limestone outcroppings, and the patterns of precipitation and water drainage all contribute to create a mosaic of soil variations. The unique edaphic factors in this area can cause, within a short

distance, marked alterations in the vegetational composition of a community. The vegetation at each locale being composed of those plants which are best adapted to its specific soil conditions. Within the monument, patches or islands of vegetation surrounded by barren ground are common. As reported in the Phase I Report (1976) approximately 34% of the Grassland Community is devoid of any vegetation and in the Juniper/Grassland Community approximately 58% of the area lacks vegetative cover. Though Hilaria jamesii is the dominant grass in the monument, when it occurs in association with highly palatable foodplant species, it may not be utilized by the cattle until more preferred forage becomes scarce (Phase II Report, 1978). Consequently, a relatively high percent composition of Hilaria in the cattle's diet may signal a decrease in the overall availability of more palatable forage. However, some of the patches may form small reserves of desirable foodplant species within areas receiving a high degree of utilization by cattle.

All fecal samples collected from the Grassland Community, with the exception of the 27 February sample, contained relatively high and mixed proportions of several foodplants which are commonly found on different soil types. It is hypothesized that this is a direct result of movement between patches. The presence of Sporobolus flexuosus in both fecal samples from March may indicate that cattle in the Grassland have crossed from the Juniper/Grassland Community where this grass is relatively common, or, in their search for acceptable forage, have been to the more inaccessible areas of canyon walls and sandstone outcrops where there is little cinder cover and Sporobolus flexuosus is favored. These same two fecal samples also showed greater quantities of

Bouteloua eriopoda than any other sample. Since there is a tendency of Bouteloua eriopoda and Sporobolus flexuosus to replace each other according to soil types, this suggests that these fecal samples were comprised of plants gathered by widely-ranging animals. The high proportion of Hilaria jamesii in all samples suggests that the more desirable foodplants had already been severely reduced by February. These observations may indicate a substantial degree of forage selectivity and movement between vegetative patches from February through March. The slight increase of Hilaria towards the close of the grazing season is an indication of the continued reduction of desirable forage.

The fecal sample collected on 27 February from the Grassland Community contained 23.8% Stipa neomexicana. Though this is the highest percent composition of Stipa in any fecal sample, it is still well below the reported densities of this very desirable grass. It appears likely that this relatively abundant foodplant had been efficiently foraged upon earlier in the grazing season, consequently little remained in the latter part of the grazing season. Sporobolus airoides, a mildly palatable foodplant which is often found in association with Stipa, composed 18.4% of this fecal sample. This sample also had the lowest concentration of Hilaria, 11.9% and Bouteloua eriopoda, 0%, of any other sample from the grassland. The significance of the relative proportion of these foodplants in the cattle's diet is two-fold. First, the animal may have remained within a large patch for a considerable period of time foraging upon relatively high densities of Stipa and Sporobolus airoides. Confirmation of this may be the absence of Bouteloua, a highly desirable foodplant found on a different soil type. Second,

presuming that this animal remained within the patch, it may be inferred that the densities of Stipa, and to a lesser degree, Sporobolus airoides, had been drastically reduced within this patch. For even though the percent dietary composition of Hilaria in this sample is low, it would still be considered relatively high if in the presence of more palatable foodplants (Phase II Report, 1978). The high utilization of Hilaria, relative to its density and the utilization of other foodplant species may indicate that more preferred forage is becoming severely limited by the end of the grazing season.

The variety of foodplants that was encountered in each fecal sample from the Juniper/Grassland Community that are not usually found on similar soil types may reflect a greater degree of movement between patches than occurred in the Grassland, even though a lower proportion of Hilaria jamesii was consumed in the Juniper/Grassland. From the observed patterns of disproportionate forage consumption, it may be inferred that from February through March the overall availability of foodplants per unit area is less in the Juniper/Grassland than in the Grassland Community and that a higher proportion of the vegetation of the Juniper/Grassland is composed of more desirable forage than the Grassland.

The tendency of the dietary concentration of Bouteloua eriopoda and Hilaria jamesii to follow in parallel may be more the result of the replacement of Bouteloua by Stipa and the differences in their relative abundances rather than any direct association of Bouteloua eriopoda with Hilaria. Hilaria, in accompaniment with either Stipa or Bouteloua, occurs in higher proportion than eaten by the

cattle. The relative density of Bouteloua eriopoda is less than Stipa in their corresponding soil preference. Hence, the increase of Hilaria jamesii with Bouteloua would be an artifact of dealing with percentages in the dietary analysis.

Heavy utilization of low density forage plants is reflected as relatively high percent composition in the diet of the livestock. The fact that some highly palatable foodplants were found to be present in the cattle's diet at the close of the grazing season may be read not as an indication of the abundance of these plants, but as an indication of the strong foraging selectivity and movement between patches by the cattle. The relatively high dietary concentrations of Hilaria jamesii in the same fecal samples as the more palatable foodplants demonstrates the low availability of desirable forage. Bouteloua eriopoda, Stipa neomexicana and Oryzopsis hymenoides were all reported as receiving over 90% utilization in all areas of the monument in the Phase II Report (1978), while Hilaria jamesii was receiving only 10 to 20% utilization.

Amsonia peeblesii was listed as a threatened plant species in the Phase I Report (1976). Though found to be present in low concentration in only one fecal sample from the Grassland Community, observations in the area of Cedar Canyon where this fecal material was collected indicated that all Amsonia peeblesii present was consumed to ground level.

Under the vegetative conditions in the Juniper/Grassland and Grassland Communities of Wupatki which existed by February, after only three months of grazing, Atriplex canescens had reached a point of being a highly desirable forage. Those fecal samples with relatively

high proportions of Atriplex were probably the result of the location of one or more shrubs previously not found by foraging cattle. The rather high percent of Atriplex in these samples implies the subsequent virtual annihilation of the shrub. The lesser amounts of Atriplex present in the remainder of the feces most likely represent the remains of those shrubs foraged upon earlier in the grazing season. The lack of Atriplex in the fecal samples collected at the end of March from both communities suggest that this shrub was foraged to functional extinction by the close of the grazing season. High selectivity for this low density shrub was recorded in the Phase II Report (1978). "Field observations clearly indicate that over 90% of the four-wing saltbush plant in the Monument have received 100% utilization. This consistent extreme utilization has reduced the vigor of the adult plants and has reduced the crown diameter of the plant on the Monument . . . and the continuous overgrazing seriously inhibits maturation of the seedling/young plants If this present pattern of extreme utilization of adult plants continues, it can be predicted that the four-wing saltbush element of the flora . . . will be eliminated." Field observations of Atriplex canescens and the livestock dietary analysis for the 78-79 grazing season indicated that heavy utilization of this shrub was still occurring.

The results of this fecal analysis study further substantiated the effects of overgrazing by cattle on Wupatki National Monument and the prediction made in the Phase II Report (1978). "The continual heavy utilization of these more palatable . . . plant species . . . will eventually remove these . . . from competition. This removal of

competition will allow the continued increase in galleta (Hilaria jamesii) density and a deterioration of the range condition."

SUMMARY/CONCLUSION

By the close of the grazing season at Wupatki National Monument, desirable foodplants were generally still obtainable. However, the scarcity of preferred forage may be indicated by the relatively high consumption of the less desirable grass Hilaria jamesii. Though Hilaria was consumed in a greater proportion than any other foodplant on the monument, it was still utilized below its relative abundance. The observed densities of many of the more desirable foodplant species are relatively low, but when found in the cattle's diet these plants often comprised, either singularly or as a group, a significant component of that sample. This may be taken as evidence of a high degree of forage selectivity. The vegetational patchiness associated with the cinder cover of the area and the presence of plant fragments in single fecal samples from species not usually found to grow in association may indicate the cattle were effectively utilizing the entire grazing area of the monument to obtain a high proportion of the low density preferred forage.

The six major components in the cattle's diet in order of relative value as forage from February through March in the Grassland and Juniper/Grassland Communities of Wupatki National Monument were:

- 1) Hilaria jamesii, 2) Stipa neomexicana, 3) Atriplex canescens,
- 4) Sporobolus airoides, 5) Bouteloua eriopoda, and 6) Sporobolus flexuosus. Atriplex canescens received greater utilization relative to

its density than any other foodplant species. Hilaria, though consumed in the greatest quantities, actually received the lowest utilization relative to density of any foodplant. Grasses comprised the greatest component of the cattle's diet.

High foraging selectivity by cattle in areas receiving excessive utilization due to either too large of a herd or too long a grazing season, may cause the reduction of virtually all desirable foodplants from the area. Drastic reductions of more palatable plants each season may eventually result in the virtual elimination of such forage within certain areas. This would not only render the area less satisfactory for grazing cattle, but also may have serious ramifications on the natural wildlife populations. Depending on the degree of dietary overlap between the cattle and native herbivores, the reduction of forage by the end of the grazing season may be putting such additional stress on the native populations that population size is being limited well below the potential carrying capacity of the area.

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

tree

- a) Juniperus monosperma (one-seed juniper)

shrubs

- a) Artemisia frigida (fringed sagebrush)
b) Atriplex canescens (four-wing saltbush)
c) Chrysothamnus nauseosus (rubber rabbit brush)
d) Ephedra sp. (jointfir)
e) Fallugia paradoxa (Apache plume)

herbs

- a) Alhagi camelorum (camelthorn)
b) Amsonia peeblesii (amsonia)
c) Euphorbia sp. (spurge)
d) Psilostrophe sparsiflora (greenstem paperflower)

grasses

- a) Aristida fendleriana (Fendler three-awn)
b) Bouteloua eriopoda (black grama)
c) Hilaria jamesii (galleta)
d) Oryzopsis hymenoides (Indian ricegrass)
e) Sitanion hystrix (squirreltail)
f) Sporobolus airoides (alkali sacaton)
g) Sporobolus flexuosus (mesa dropseed)
h) Stipa neomexicana (New Mexico feathergrass)

Table 2. Percent contribution to the diet by each of the foodplants utilized by the cattle in the Grassland and Juniper/Grassland Communities from February through March, 1979.

	GRASSLAND						JUNIPER/GRASSLAND					
	Feb. 1	Feb. 13	Feb. 27	March 10	March 20	% of Total	Feb. 1	Feb. 13	Feb. 27	March 10	March 20	% of Total
<u>Hilaria jamesii</u>	16.9	15.3	11.9	21.0	17.6	16.7	16.7	21.3	16.6	14.4	8.7	15.5
<u>Stipa neomexicana</u>	10.6	14.7	23.8	17.9	22.2	17.7	5.6	4.6	15.9	8.0	4.9	7.4
<u>Atriplex canescens</u>	27.0	18.8	14.9	8.7	0	13.9	3.7	31.6	5.5	6.4	0	9.2
<u>Sporobolus flexuosus</u>	0	0	0	3.6	4.5	1.7	12.6	6.9	7.6	17.6	19.7	13.1
<u>Bouteloua eriopoda</u>	4.2	4.7	0	13.8	13.1	7.3	11.6	11.5	4.8	11.2	7.1	9.5
<u>Sporobolus airoides</u>	6.3	13.5	18.4	6.2	6.3	9.9	3.7	0	13.1	6.9	13.1	7.1
<u>Oryzopsis hymenoides</u>	0	0	0	0	5.1	1.0	8.8	0	0	5.9	2.2	3.8
<u>Aristida fendleriana</u>	0	0	5.4	0	0	1.0	5.6	0	0	4.8	5.5	3.4
<u>Euphorbia sp.</u>	0	0	0	2.1	0	.45	5.1	0	0	0	4.4	2.1
<u>Amsonia peeblesii</u>	2.1	0	0	0	0	.45	0	0	0	0	9	0
<u>Juniperus monosperma</u>	0	0	0	0	0	0	0	0	0	4.3	9	.9
unknown	32.8	32.9	25.6	26.7	31.3	29.8	26.5	24.1	36.6	20.7	34.4	28.1
total fragments	189	170	168	195	176	898	215	174	145	188	183	905

Table 3. The percent dietary contribution of each foodplant adjusted to represent the utilization of each species for the total combined area of the Grassland and Juniper/Grassland Communities. Each plant species is ranked in order of overall importance as forage.

	Feb. 1	Feb. 13	Feb. 27	March 10	March 20	Aver- age	Rank
<u>Hilaria jamesii</u>	16.9	16.5	12.8	19.7	16.0	16.4	1
<u>Stipa neomexicana</u>	9.6	12.7	22.3	16.0	18.8	15.6	2
<u>Atriplex canescens</u>	22.4	21.3	13.1	8.3	0	13.0	3
<u>Sporobolus airoides</u>	5.8	10.9	17.4	6.3	7.6	9.4	4
<u>Bouteloua eriopoda</u>	5.6	6.0	.9	13.3	11.9	7.8	5
<u>Sporobolus flexuosus</u>	2.5	1.4	1.5	6.3	7.5	4.0	6
<u>Oryzopsis hymenoides</u>	1.7	0	0	1.2	4.5	1.5	7
<u>Aristida fendleriana</u>	1.0	0	4.3	.9	1.1	1.5	8
<u>Euphorbia</u> sp.	1.0	0	0	1.7	.9	.7	9
<u>Amsonia peeblesii</u>	1.7	0	0	0	0	.3	10
<u>Juniperus monosperma</u>	0	0	0	.8	0	.2	11
unknown	31.6	31.2	27.8	25.5	31.9	29.5	

Table 4. The proportions of the diet by plant growth forms in each community and adjusted for utilization over the total area.

	Grassland	Juniper/Grassland	Adjusted
% Shrub	13.9	9.2	13.0
% Herb	.9	2.1	1.1
% Grass	55.3	59.8	56.2
% Tree	0	.9	.2
% Unknown	29.8	28.1	29.5