# NATURAL RESOURCE SURVEY AND ANALYSIS

# OF SUNSET CRATER AND WUPATKI NATIONAL MONUMENTS

Final Report

December, 1976

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I

# SUMMARY AND CONCLUSIONS

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December, 1976

## SUMMARY AND CONCLUSIONS

The area studied varies in elevation from roughly 1320 m near the Black Falls of the Little Colorado River in Wupatki National Monument to almost 2435 m at the crest of Sunset Crater in Sunset Crater National Monument. These areas were set aside for public use and enjoyment primarily because of their unique archaelogical and geological features. The Monuments and immediately surrounding area consist of an uplifted plateau, punctuated with scattered cinder cones and streaked by numerous lava flows. The nearby San Francisco Peaks tower to nearly 3870 m and form the most prominent landmark in this vast area.

It was in this general region of complex physiography that the classic early studies concerning the eco-geographical distributions of plants and animals were conducted by C. Hart Merriam. Indeed, the area was well chosen since within a fairly narrow latitudinal zone a wide variety of plant and animal life exists.

The studies described in this report were undertaken as a result of a cooperative agreement between the National Park Service and Northern Arizona University under terms of grant #950134.

Within the Monuments themselves exists a complex array of biotic assemblages from Cold Desert Shrub communities at lower elevations extending to well-developed coniferous forests at upper elevations. Our studies of the plant communities in the area have thus far resulted in the formal recognition and description of four major vegetational units. These are the Cold Desert Shrub, Grassland, Juniper/Grassland and Ponderosa Pine Forest. This classification scheme is tentative as the first and last named types require further

study to more satisfactorily assess their relationships. The Cold Desert Shrub community, for example, may require subdivision or at least qualification to reflect local fasciations which exist.

Where present in Sunset Crater National Monument, plant cover consists primarily of a forest of ponderosa pine (Pinus ponderosa) having scattered occurrences of shrubs such as cliffrose (Cowania mexicana) and apache plume (Fallugia paradoxa).

The plant communities of Wupatki National Monument are considerably more diverse and tend to be less continuously distributed. Grassland comprises about nine percent of the Monument and in various areas is dominated by galleta (Hilaria jamesii), New Mexico feathergrass (Stipa neomexicana), and black grama (Boutelous eriopoda). Other grasses occur in this community, but tend to be less important. In some areas the Grassland has significant densities of shrubs, especially rubber rabbitbrush (Chrysothamnus nauseosus) and broom snakeweed (Gutierrezia sarothrae). Perhaps these shrubs indicate overgrazing as both tend to be increasers on overgrazed rangelands.

Juniper/Grassland comprises 9 percent of Wupatki National Monument and tends to lie adjacent to the upper limits of Grassland sites. The only tree of importance in this community is one-seed juniper (Juniperus monosperma); a single pinyon pine (Pinus edulis) was found in this community. Snakeweed and rabbitbrush occur also in this community, their densities apparently somewhat related to soil type and, perhaps, intensity of grazing. A variety of grasses occurs in this community; galleta appears to be dominant.

The Cold Desert Shrub community is the most complex and largest of any in the Monument, comprising roughly 54 percent of the total. Elevationally this is the lowest community and it occurs from 1535 to 1320 m in the eastern part of the Monument. Soils in this region are very complex and topography is broken and cut by several major drainages.

Shrubs commonly occur on scattered hummocks separated by intervening empty areas of deep, black cinders. Normally several shrub species are found within a single hummock and such sites appear to provide microhabitats necessary for the establishment of certain herbs and grasses in this area. Four-wing saltbush (Atriplex canescens), broom snakeweed and apache plume (Fallugia paradoxa) are important components of the shrub community. Other important shrubs are several species of Ephedra and Brickellia. Herbs in this community are many and include globemallow (Sphaeralcea subhastata), prince's plume (Stanleya pinnata), buckwheats (Eriogonum spp.) and several spurges.

Grasses found in the Cold Desert Shrub community probably constitute less than 5 percent of ground cover and include galleta, threeawns (Aristida spp.) and bush muhly (Muhlenbergia porteri).

Floristically the Monuments are moderately rich with a total of 351 species of vascular plants being present in the area; this includes 13 species newly reported for the Monuments as a direct result of the past summer's fieldwork. In addition, there are at least seven plant species finding refuge in the Monuments which are on the U. S. Fish and Wildlife Service's Threatened or Endangered list.

The communities of birds and mammals inhabiting the above described habitats are highly varied. Birds and mammals appear to be responding somewhat differently to the various communities studied. The mammalian community occurring in the Cold Desert Shrub area was far and away the most diverse and had the greatest population densities of that in any area studied. Because of the great variety of shrubs, forbs and grasses there was a wide spectrum of food resources for the small mammals in this area. By all measures, then, this area had the richest mammalian fauna. The Juniper/Grassland was essentially similar to the Grassland as far as mammals were concerned except that the

presence of some trees allowed two additional species to exist in the Juniper/Grassland.

The Grassland had the fewest species of small, nocturnal mammals, just two; the fewest individuals; the lowest diversity; and the least biomass of any area studied.

The mammals of the Ponderosa Pine Forest were not formally studied during this phase of field work, but this habitat is notably "sterile" for small mammals. About the only species likely to be encountered here are the deer mouse (Peromyscus maniculatus) and the Mexican woodrat (Neotoma mexicana). The former species is notoriously "weedy" and seems almost always to be able to eke out an existence, even in extremely marginal habitats. The woodrat would only occur where rock piles or crevices provided shelter for den sites. In addition to these nocturnal rodents, the pine forest has Abert's squirrels (Sciurus aberti) and cliff chipmunks (Eutamias dorsalis). It would be worthwhile to assess densities and dynamics of populations of these two species at Sunset Crater National Monument.

The densities and numbers of avian species inhabiting the various plant communities in which they were studied were generally correlated with elevation, except that the Grassland site had only a single breeding species, the Horned Lark (Eremophila alpestris), occurring along the study transect.

The greatest avian diversity, as measured by the Shannon Index (H'), was found for the Juniper/Grassland site (H'=3.2371); this area was followed closely by the Ponderosa Pine community where H'=3.0256. Both communities had 12 species breeding along sample transects. Population density in the pine forest was greater with 62.7 pr./40 ha, while the Juniper/Grassland had 39.8 pr./40 ha. The Cold Desert Shrub had a somewhat lowered diversity (H'=2.0922) and just seven species bred along the transect line. Here densities were lowest of any site studied (28.5 pr./40 ha).

For both birds and mammals it appears that the most rigorous habitat is the grassland. Here there is little shelter from environmental stresses such as cold winds during winter and extreme heat during summer days. Further there is little in the way of vegetational diversity, e.g. foliage height diversity, to provide for foraging niche stratification among birds or floral diversity to allow for food resource partitioning (e.g. on the basis of seed size selection) of among small mammals.

In summary, Sunset Crater and Wupatki National Monuments not only provide unique archaelogical and geological settings for man's enjoyment, but they contain an interesting series of biotic assemblages. Though much biological investigation remains to be done in this area we are beginning to find out more about how these ecosystems function and are interrelated.

It is to be expected that with further field work in this area additional species will continue to be added to the flora and fauna for the Monuments. Also with more work our understanding and appreciation of the interesting biotic assemblages will be enhanced and it will be possible for those charged with administering these lands to make more informed and wiser management decisions.

It must be mentioned in summation that though these monuments were originally set aside for the preservation and display of unique geologic features and works of early man in North America, the natural communities preserved within their boundaries are also very real resources and ones which, if lost or poorly managed, will not be easily regained.

II

# PLANT COMMUNITIES OF SUNSET CRATER AND WUPATKI NATIONAL MONUMENTS

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December, 1976

# INTRODUCTION

Wupatki and Sunset Crater National Monuments in northern Arizona are currently being studied to gather basic biological data for future management planning by Park Service personnel. Wupatki National Monument, about 30 miles northeast of Flagstaff on U. S. Highway 89, encompasses 56 square miles or about 36,000 acres, with elevation ranging from 4280 feet along the Little Colorado River in the northeast corner to 5720 feet in the southwest corner near U. S. Highway 89. Sunset Crater National Monument, about 15 miles northeast of Flagstaff, is a much smaller area, including only 7.5 square miles or about 3000 acres, with an elevational range between 7000 and 8000 feet.

To many, Wupatki and Sunset Crater National Monuments appear solely to be of archeologic and geologic significance. But also the area within these two monuments is of great botanical interest. The fine, black volcanic ash which provided a water holding mulch over much of this area not only made agriculture possible but simultaneously stimulated a peculiar mosaic of vegetational responses closely correlated to soil substrate and depth of cinder cover. The prevailing southwesterly winds concentrated the ash from Sunset Crater over much of the land now included in Wupatki National Monument. The drifting ash provided numerous microhabitats suitable to a wide variety of plant species. The result is a varied flora which includes a few endemics and several species of limited distribution.

Recent disturbances by man and grazing animals have contributed to an alteration of the native grassland community resulting in subsequent invasion by juniper and rabbitbrush populations. This affords another dimension of

botanical interest and concern.

During the spring and summer of 1976, an intensive study of the flora and vegetation was undertaken as part of an overall biological survey of Wupatki and Sunset Crater National Monuments under Grant #950134 awarded to Northern Arizona University by the National Park Service.

The botanists involved in this biological survey have gathered information and data to accomplish the following goals:

1) preparation of an up-to-date species list of all vascular plants known to occur within the two monuments (Appendix A)
2) identification of the major plant communities present
3) extensive vegetation measurement to determine the relative importance of the species within each community
4) preparation of a vegetation map outlining the major plant communities (Appendix 1)
5) preparation of voucher specimens of major species of each community
6) observation of the phenology of the major species of each community
7) preparation of a list of species collected during this study which are new records for the monuments
8) preparation of a list of the Endangered and Threatened species of plants growing within the two monuments

Many botanists have contributed to our present knowledge of the flora of Wupatki and Sunset Crater Monuments. Those making collections of major importance include:

David Jones-Custodian of Wupatki in late 1930's and early 1940's.

Alfred F. Whiting-Ethnobotanist affiliated with the Museum of Northern Arizona during summers of the mid 1930's and early 1940's.

A. A. Nichol-Special Report on the Vegetation of Wupatki and Sunset Crater National Monuments, 1939.

Delzie Demaree-Itinerant botanist and educator; prolific collector on and adjacent to the Navajo and Hopi Indian Reservations in late 1950's and early 1960's.

C. F. Deaver-Curator Emeritus and Founder of the Deaver Herbarium at Northern Arizona University, 1930's-1960's.

W. B. McDougall-Curator of Botany, Museum of Northern Arizona, 1955-1976; author of Seed Plants of Wupatki and Sunset Crater National Monuments, 1962.

W. A. Eggler-Tulane University; study of plant succession on Sunset Crater, 1965.

D. J. McMillan-Northern Arizona University student collector during summer 1976.

J. M. Rominger-Coordinator of Vegetation Survey for NPS study, 1976-1977.

L. T. Green-Vegetation Technician for NPS study, 1976-1977.

Numerous other collectors have made valuable contributions to the current revised species list of plants for Wupatki and Sunset Crater National Monuments (Appendix A). This updated list is a modification of McDougall (1962) compiled from an examination of collections housed in the herbaria at the Museum of Northern Arizona, The Deaver Herbarium of Northern Arizona University, and at Wupatki and Sunset Crater National Monuments, plus additional collections made during the summer of 1976.

A total of 351 species of vascular plants have been reported for Wupatki and Sunset Crater National Monuments. This represents an addition of 83 taxa to the total reported in McDougall (1962).

# METHODS

One phase of this survey was to obtain adequate quantitative vegetation measurements to provide information for a vegetation map of Wupatki National Monument. Cover, density and frequency were considered to be the minimum measurable quantitative parameters necessary in this vegetation mapping survey. Time involved, area sampled and data obtained to determine these measurements influenced the methods selected.

Wupatki National Monument can be conveniently subdivided into three very general plant communities. These are: 1) Juniper/Grassland, 2) Grassland, and 3) Cold Desert Shrub. Within each of these communities the floristic levels of grasses, herbs, shrubs and, in appropriate areas, trees were sampled. Sampling techniques utilized for each community were selected as the best methods to accurately sample that particular vegetation type with the minimum time requirement for maximum information. A species/ area curve, to determine minimal area to be sampled, was developed for each community. Species/area curve sample plots were established according to methods described in Aims and Methods of Vegetation Ecology (Mueller-Dombois and Heinz Ellenberg, 1974, pp. 48-52).

Four species/area curve sample plots were established, one each in the Juniper/Grassland and Grassland communities with two in the Cold Desert Shrub. The total area sampled was limited by the time involved. The locations for these sample plots were arbitrarily selected from topographic maps. Photographs of the general area were taken for each sample plot and a permanent marker of a rock cairn was erected. Locations for each sample plot are marked on the vegetation maps that are part of this report (Appendix 1).

From the information obtained, a species/area curve was drawn by plotting the species number against size of sample area. Then a minimal area value was projected. This minimal area value is defined as the point in the curve where a ten percent increase in sample area yields only a ten percent or less increase in new species to the total number recorded in the sample. This minimal area value is the smallest area that should be sampled to record an adequate representation of the community. It also gives a predictive value of the area required to get a valid sample of the vegetation.

Sampling areas were selected within each community to serve as representative areas for that community. Locations for these sampling areas were either selected from U. S. Geological Survey topographic maps or placed along already existing bird survey transects. The community was then visually surveyed from aerial photos and from the ground to determine if the sample area was truly representative. Time and manpower available necessitated this type of general survey.

Five transects of nested plots, 1 square meter (m) for grasses, 10 square m for herbs and 20 square m for shrubs, were established in Wupatki National Monument. One transect of nested plots was established on Coconino National Forest adjacent to Sunset Crater National Monument to sample the Ponderosa Pine community. Three of the five transects in Wupatki National Monument were located within the Juniper/Grassland community with the other two transects in the Grassland community. The complexity of the Cold Desert Shrub was such as to preclude the use of this nested plot technique during the 1976 field season. The shrubs were sampled by the point-centered quarter method, but the herbs and the grasses were not measured. Data obtained from these point-centered quarter measurements have not been analyzed and are not included in the report. The beginning point for each established transect and direction of travel is indicated on the enclosed vegetation maps (Appendix 1).

To be able to stay within the community being sampled, an azimuth was selected and followed which set the direction of survey for the transect. Actual field observations and topographic maps for the area were utilized to select this azimuth. When available, established bird transects were used as the direction of survey. Once the transect direction was determined and the starting point set, an initial 10 m transect line was established. Additional 10 m transects were established at 100 m intervals along the selected azimuths. Areas surveyed along pre-established bird transects had nested plots set at every fifth stake, or approximately every 150 m.

After the establishment of the 10 m transect line, a 2 m wide belt to either the left or right side of the line was randomly selected by the toss of a coin. This set the 20 square m area for the sampling of shrubs (Figure 1). The 2 m belt was then subdivided into 1 m belts and either the left or right area randomly selected by the toss of a coin. This 10 square m was then surveyed for herbs (Figure 1). Within this 1 m belt, a 1 square m quadrat was established at the beginning of the belt. This quadrat was used to sample the grasses (Figure 1). The area selected for sampling both the grasses and herbs had the variable range of right right, right left, left left, or left right with a right or left range for the shrub sample area (Figure 1).

Within each of the respective sample areas of grasses, herbs, and shrubs, individual plant crown diameters were measured by species. Crown diameter was considered to include any living or dead foliage or stems sufficient in area and/or density to reduce or stop the impact of a falling raindrop on the soil below the plant considered. This measurement allowed data collection to determine cover, frequency and density per species per floristic level deemed as the minimal quantitative measurements necessary. A minimum of ten such nested plots per transect was established with only one exception.

To measure tree density, cover, and frequency in the Juniper/Grassland, the point-centered quarter method (Cottam and Curtis, 1956) was used. This method was modified in that crown diameters were measured for each tree instead of diameter breast height. These quarter point samples were run in conjunction with nested plot transects. The beginning point of the 10 m transect line and the midpoint (50 m) between these beginning points were the locations for quarter point samples. This would allow a minimum of 20 sample points per transect and provided enough distance between quarter point samples to prevent remeasurement of the same tree. When following established bird transects, a quarter point sample was taken at every fifth stake (5, 10, 15, etc.) and another read two stakes beyond this fifth stake (7, 12, 17, etc.). Again this allowed sufficient spacing to prevent duplications in measurements. At each quarter point sample, the distance to and the diameter of the nearest tree in each quarter was measured by species. In all cases, the first two diameter measurements were parallel with the 10 m transect line and the second two diameters were measured perpendicular to the transect line.

In order to determine flowering and seed set time for dominant species, four 1 m square plots were established in each of the three general plant communities. The plots were established at 100 m intervals bisecting established mammal trapping grids for each community. These permanent plots were placed so that two sample areas were within the grid and two were outside the grid. A photograph was taken of each plot and a sketch map was drawn showing the location of each species in the plot. Photographs were taken once a month from June through September.

# RESULTS

Juniper/Grassland species/area curve sample Plot #1 was conducted on the Coconino National Forest adjacent to Wupatki National Monument and will not be included in this report. Juniper/Grassland Plot #2 was established on 3 July, 1976, and was located in the NW1/4, SW1/4 of Section 16, T25N, R9E. Grassland Plot #3 was sampled on 4-5 July, 1976, and was in the SE1/4, NW1/4 of Section 13, T25N, R8E. Cold Desert Shrub Plot #4, sampling an area with nearly void interspaces, was established on 15 July, 1976. It was located in the SW1/4, NW1/4 of Section 7, T25N, R10E. Cold Desert Shrub Plot #5, primarily sampling areas with herbaceous covered interspaces, was established on 17 July, 1976 and was located in the SW1/4, NE1/4 of Section 13, T25N, R9E. The results of the species/area curve sample plots are summarized in Table 1.

Minimal area values are the same for three plots and doubled for the one Cold Desert Shrub Plot #4. As can be seen, the overall minimal area values and the various minimal area values for the grasses, herbs and shrubs indicate a rather large sample size. To meet these requirements, either large nested plots or numerous smaller area plots were necessary. The total number of species recorded for each community remained fairly constant varying from 26 to 29.

Juniper/Grassland transect # G-30 was established on 22-23 July, 1976 with the beginning point located in the NW1/4, SE1/4, SW1/4, SE1/4 of Section 31, T25N, R10E. This transect represents the Juniper/Grassland community on top of Woodhouse Mesa. Juniper/Grassland transect # G-32/33 was established on 24-25 July, 1976, and the beginning point was located in the SE1/4, SE1/4, SE1/4, NW1/4 of Section 18, T25N, R9E. This transect sampled the main area of the

community west of Forest Road 545. Juniper/Grassland transect # G-34 was established on 12 August, 1976, with the beginning point located in the NE1/4, NW1/4, NW1/4, SW1/4 of Section 17, T25N, R9E and follows the established bird transect. This transect sampled the community east of Forest Road 545. Tables 2-10 represent the computer analysis of data gathered from these transects.

Grassland transect # G-31 was established on 23 July, 1976. The beginning point was located in the NE1/4, NW1/4, NE1/4, NW1/4 of Section 31, T25N, R10E. This transect sampled the grassland belt that borders the northeastern rim of Woodhouse Mesa. Grassland transect # G-50 was established on 17 August, 1976, and followed the established bird transect. The beginning point is the SW1/4, SW1/4, SE1/4, NW1/4 of Section 5, T25N, R9E. Tables 11-16 show the calculated results.

Ponderosa Pine transect # G-70 was established on 10 August, 1976, and followed the bird survey transect located in the NE1/4, SE1/4, NW1/4, NE1/4 of Section 19, T23N, R9E. Results of the data gathered are in tables 17-19.

Point-centered quarter samples were taken in the Juniper/Grassland community simultaneously with the nested plot sample transects to determine tree density, average crown diameter, average distance between trees, and average crown cover. This data evaluation is preliminary for this report with a complete computer analysis pending. The initial results for the point-centered quarter samples are seen in Table 20. Point-centered quarter samples were also conducted in Ponderosa Pine community but due to the lack of complete analysis are not submitted in this report.

A checklist of the vascular flora of Wupatki and Sunset Crater National Monuments is included as Appendix A of this report. This updated list is a modification of McDougall (1962) compiled from an examination of collections

housed in the herbaria at the Museum of Northern Arizona, the Deaver Herbarium of Northern Arizona University, and at Wupatki and Sunset Crater National Monuments, plus additional collections made during the summer of 1976.

A total of 351 species of vascular plants are reported for Wupatki and Sunset Crater National Monuments. These are divided among 52 families and 198 genera. Wupatki includes 240 species and Sunset Crater has 166 species, with 55 species common to both monuments. These data are summarized below:

Taxa of Vascular Plants of Wupatki and Sunset Crater National Monuments

| | | |
|---|---|---|
| Families | Wupatki | 240 spp. |
| Genera | Sunset Crater | 166 spp. |
| Species | Common to both | 55 spp. |

Thirteen new records were collected during the summer of 1976. These species, newly reported for the monuments are:

| | | |
|---|---|---|
| Scleropogon brevifolius | (W) | W=Wupatki |
| Carex occidentalis | (S) | S=Sunset Crater |
| Salix laevigata | (W) | |
| Amaranthus albus | (W) | |
| Arenaria eastwoodiae | (W) | |
| Petrophytum caespitosum | (W) | |
| Euphorbia serpyllifolia | (W) | |
| Pediocactus simpsonii | (W) | |
| Nama dichotomum | (W) | |
| Baccharis wrightii | (W) | |
| Brickellia scabra | (W) | |
| Sanvitalia aberti | (W) | |
| Taraxacum officinale | (S) | |

The following species were first collected in 1976 for one of the monuments but had previously been reported for only the other monument. W=Wupatki; S=Sunset Crater.

| | |
|---|---|
| Pinus edulis | (W) |
| Lithospermum incisum | (S) |
| Verbascum thapsus | (W) |

## DISCUSSION

A minimum area value of 512 square m for the Juniper/Grassland, Grassland, and herbaceous covered interspaces of the Cold Desert Shrub was indicated by the species/area curve. The sample transect of nested plots, 1 square m for grasses, 10 square m for herbs, 20 square m for shrubs, yields a total area sampled of 310 square m with each ten samples. This value is 61 percent of the required minimum area and was judged to be sufficient for this initial survey. The method being used can be modified or more samples per transect taken to meet the minimal area requirement. If a minimum number of 20 samples are taken per transect, the minimal area requirement will be exceeded. The minimal area requirement of 1024 square m for the nearly void interspaces of the Cold Desert Shrub community will be met by doubling the values of each area in the nested plots. This will develop a total area of 62 square m per nested plot thus necessitating a minimum of 20 such nested plots per sample transect. It should be noted here that the minimum area values indicated for the grasses and herbs would be extremely difficult to fulfill. This would require more sampling than manpower and/or time would allow.

The total number of species recorded for each community is fairly constant. The number of grasses remains constant at six species for sample plots #2 (J/G), #3 (G), and #4 (CDS) with an increase to eight in sample plot #5 (CDS). This increase to eight species in the sample plot for the herbaceous covered interspace areas of the Cold Desert Shrub community could be interpreted as an indicator for another community classification. These areas could be classified as a Cold Desert Shrub Grassland. Additional studies and sampling are warranted in this area.

The herb values again are fairly consistent with 13, 17, 12, and 11 species recorded for sample plots #2 (J/G), 3 (G), 4 (CDS), and 5 (CDS) respectively. It is apparent that herbs comprise a significant element in the floral composition for the Grassland community. This is important with the consideration of the domestic livestock grazing taken place in this community. The high number of herbs could be an indicator that other vegetation competition has been decreased allowing an increase in herb establishment. On ranges where cattle grazing has existed, herbs do tend to become an important element in the floral composition with the reverse commonly encountered on sheep ranges. A comparison with a similar ungrazed or lightly grazed area would provide information useful in evaluating this idea.

The shrub numbers vary considerably from a low of three species in sample #3 (G) to a high of 11 species in sample plot #4 (CDS), five and eight species being intermediate for plots #2 (J/G) and #5 (CDS) respectively. The value of 11 shrubs found in the nearly void areas of the Cold Desert Shrub community indicates the importance of this floral element in the composition.

COMMUNITY DESCRIPTION

Three basic general communities can be recognized within the boundaries of Wupatki National Monument. These are, 1) Juniper/Grassland, 2) Grassland and 3) Cold Desert Shrub. The floristic composition of each has been described with emphasis on the dominant plants as indicated by the computer analysis.

There are many environmental factors that affect the composition of these communities. These factors have been briefly discussed in conjunction with the floristic description given for each community. Probably the single most important factor influencing the vegetation of this area is the soil composition.

Juniper/Grassland

The Juniper/Grassland community comprises approximately 1295 hectares (3200 acres) or roughly 9 percent of the monument. The major portion of this area occurs south and east of Citadel Sink with the remainder being found on top of Woodhouse Mesa (Appendix 1). The elevational range is from 1677 m (5500 feet) on the west to 1616 m (5300 feet) for the east edge. The average annual precipitation is 25 to 40 centimeters (10 to 16 inches), primarily in the form of rain from late July to September. Soils range from deep black to reddish brown cinders over sandy loam to a thin discontinuous cinder layer over gravelly loam with both sandstone and limestone outcrops common (SCS Soil Survey, 1971). The surface layer depth of the cinders dramatically affects the species composition and density in this community.

The dominant and only tree for this community is one-seed juniper (*Juniperus monosperma*) with only a single individual pinyon pine (*Pinus edulis*) found. This area being near the lower limits of the junipers' range is emphasized by the analysis of the point-centered quarter data. A west-east cline is noted with an increase from 10.54 m to 15.24 m mean distance between trees, a decrease from 90.01 trees to 43.06 trees per hectare (ha), a decrease in mean crown cover, 17.90 to 8.84 square m and another decrease in mean crown diameter from 4.77 to 3.36 m. This west-east cline is seen again with a decrease in percent crown cover from 16.11 to 3.8. The junipers on top of Woodhouse Mesa average 54.55 trees/ha with 14.5 square m average crown cover, 4.3 m average crown diameter, 13.54 m average distance between trees with a mean crown cover of 7.91 percent.

Broom snakeweed (*Gutierrezia sarothrae*) and rubber rabbitbrush (*Chrysothamnus nauseosus*)are the two dominant shrubs. The densities of these two shrubs vary with the soil type, snakeweed often found in small area-high density

"pockets" of light cinder cover in the limestone outcrops. The rabbitbrush becomes the dominant in the ecotone with the grassland. As indicated in Tables 3 and 4, shrubs make up less than 1 percent of the ground cover and appear to increase in frequency and density in a north and east direction. The cover value seems to be very low and is probably an underestimate. Two factors that could explain this are, 1) the information is based on only two sample transects and 2) the scattered patch like growth habit. A visual estimate would probably place the shrub cover in the area of 5 percent, but further sample transects will be necessary to verify this estimate. Other shrubs observed but not sampled were four-wing saltbush (Atriplex canescens) and apache plume (Fallugia paradoxa).

Rabbitbrush is the dominant shrub on top of Woodhouse Mesa contributing to an overall cover of 7.6 percent. Four-wing saltbush, green ephedra (Ephedra viridis) and apache plume are also shrub components of this area but were not actually sampled. This floristic element is an important part of this community and probably contributes a larger percent cover overall than calculated for rabbitbrush.

The herb component of this community is quite variable dependent upon the soil composition in particular. Rocky Mountain zinnia (Zinnia grandiflora), Russian thistle (Salsola kali) and spurge (Euphorbia revoluta) are all indicated as dominant from actual sample transect data by importance value. Other plants were sampled (for a complete listing refer to Tables 6 and 7). Less than one percent cover is indicated by the computer analysis, again based on only two sample transects. This figure is probably an underestimate with a visual estimate figuring approximately 5 to 7 percent ground cover.

It is extremely difficult to select two or three plants to be the dominant herbs for this community. The edaphic factors at play in this area are

exceptionally important and can change the herb composition and density within a meter of distance. Further sampling will be necessary before the important herbs can be selected.

Only one herb was actually sampled on top of Woodhouse Mesa, that being Rocky Mountain zinnia. Greenstem paperflower (Psilostrophe sparsiflora) is common but was not actually sampled. A cover value of less than 0.1 percent was computed.

The grass component varies considerably. Galleta (Hilaria jamesii) is obviously the dominant species as indicated by the computer analysis (Tables 9 and 10). Black grama (Bouteloua eriopoda), mesa dropseed (Sporobolus flexuosus) and Fendler threeawn (Aristida fendleriana) are other important grasses commonly associated with this community. These grasses replace each other according to the soil type, i.e. mesa dropseed is dominant in areas of sandstone outcrops with little cinder cover whereas Fendler threeawn and black grama are dominant on cindered limestone outcrops. The depth of cinders also plays a major role in determining which grass is present, with galleta being the best adapted for growth in all major soil types found and in the deep cinders. Cover values of 2.4 percent and 3.7 percent are influenced by the large areas of no plant cover that are quite common, especially west of Forest Road 545. An estimated value would be 15-20 percent cover for an overall average considering the large void spaces of very deep cinders. One important item to note from Tables 9 and 10 is that the density and frequency of all grasses except galleta are quite low and generally increase east of Forest Road 545.

Galleta again dominates the grasses of the Juniper/Grassland on top of Woodhouse Mesa. Black grama, Indian ricegrass (Oryzopsis hymenoides), and Fendler threeawn are the other major grass species here. A total of 2.7 percent ground cover is indicated from one transect.

An unusual area that occurs within this community is Hulls Canyon located approximately 2.8 kilometers (1.75 miles) south of Citadel Sink on the Monument boundary near Forest Road 545 (Appendix 1). This area could be classified as a Shrub Grassland dominated by four-wing saltbush and mesa dropseed with scattered low density black grama. No junipers are growing in this area and the four-wing saltbush plants have received heavy utilization. Sample transects will need to be measured to quantify the vegetation of Hulls Canyon.

Grassland

Approximately 37 percent of the Monument or 5059 ha (12500 acres), falls under this classification. The main area of the community is Antelope Prairie located west of the Doney Cliffs to East Mesa. The remainder of the community extends west to U. S. Highway 89. Elevation ranges from 1707 m (5600 feet) at the west boundary to 1555 m (5100 feet) at the edge of the Doney Cliffs on the east side with several mesas present near Citadel Sink. Annual precipitation varies from 15 to 40 centimeters (6 to 16 inches) mainly in the form of rain during the late summer months. Soils vary considerably, gravelly cindery loam with stoney basalt and limestone outcrops being typical (SCS Soil Survey 1971).

One-seed juniper is present in nearly all areas of this community in very low densities. The trees are generally small in height and crown diameter. These trees do not make up a significant part of this community having a crown cover of less than 0.1 percent.

The shrub element in the floristic composition appears to be dominated by rubber rabbitbrush. This plant is common throughout the entire community and varies from high density-large area populations to scattered occasional presence. Certain areas have an occurrence of rabbitbrush in sufficient densities to be considered as a subdivision of this community or a classification of a

Shrub Grassland. These areas might best be mapped as distinct areas but there was insufficient time to gather data to provide that information for this report. The presence of this shrub in such densities could also indicate overgrazing, the plant being quite common on overgrazed ranges in the Southwest.

Computer analysis of one sample transect indicates a 3.2 percent ground cover for shrubs in the community. One set of data is insufficient to accurately place a value for cover on any plant and an estimate of 10-15 percent in the "open" areas and 25-30 percent in the high density areas probably is more accurate. Other shrubs present but not sampled are four-wing saltbush and threadleaf groundsel (Senecio longilobus). These two shrubs occur in low density and generally replace rabbitbrush depending upon soil type. Winterfat (Eurotia lanata), an important forage plant for wildlife, occurs in very low density, primarily in the western areas of the community reaching the highest densities on the ungrazed area of the Monument on the west side of U. S. Highway 89. The grassland belt that borders the Juniper/Grassland community on top of Woodhouse Mesa has broom snakeweed and four-wing saltbush as its dominant shrub elements. A calculated cover value of slightly less than 1 percent is indicated in Table 11, possibly an underestimate being based on only one sample transect of five nested plots. Green ephedra and rubber rabbitbrush are also present but were not sampled.

The herb composition of this community is varied and complex. As was stated in the previous section, the edaphic factors cause abrupt and dramatic changes in composition and density within short distances. Table 14 indicates that Russian thistle, globemallow (Sphaeralcea subhastata), spurge (Euphorbia revoluta), and aster (Aster arenosus) are the dominant herbs based on importance values. The plants will change positions and others replace them

depending upon location within the grassland. For a complete list of species sampled, refer to Table 14. Ground cover for the area sampled is calculated to be 0.72 percent, probably a low value.

The grassland belt on top of Woodhouse Mesa has globemallow, Russian thistle, and aster as its major herb composition. The cover value is 0.44 percent.

Galleta again appears as the dominant grass in this community with a relative ground cover of 69 percent. New Mexico feathergrass (Stipa neomexicana) and black grama are the other major grasses found in the area sampled having relative ground cover values of 29 and 2 percent respectively. An overall value of 4.5 percent ground cover is figured (Table 16). Field observations indicate that 25-35 percent ground cover might be more accurate. The grasses occur in sufficient density to warrant such an estimate. The feathergrass and black grama have an apparent tendency to replace each other depending on soil type and location within the community. Both are of low densities and frequencies, with the feathergrass dominating the east area and the black grama occupying the west area in relatively high densities in certain areas. Indian ricegrass and Fendler threeawn were also noted but not sampled.

The abundance of Russian thistle in this grassland community is indicative of an overgrazed grassland, a result of heavy pressure by domestic livestock for many years. This community merits more intensive study and comparison with adjacent grasslands under jurisdiction of the U. S. Forest Service which have been deferred from grazing for several years. The results of such a comparative study of two grasslands separated by only a fence should give a much more accurate evaluation of the current status of the grassland community within Wupatki National Monument.

Cold Desert Shrub

The Cold Desert Shrub community is the largest, comprising approximately 7446 ha (18400 acres) or 54 percent of the total, and the most complex area of the Monument. This area occupies the entire east side from the Doney Cliffs on the west to the Little Colorado River on the east, north to the Township line between 25 and 26 North with a finger like extension to Crack-in-the-Rock ruins, and south to the Township line between 25 and 24 North. Elevations range from 1535 m (5000 feet) at the base of the Doney Cliffs to 1320 m (4300 feet) at the Little Colorado River. Annual precipitation averages 15 to 40 centimeters (6 to 10 inches), mostly from late summer rainstorms. Soils are described as complexes or as rough broken land and are strong determinants of the vegetational composition. The Soil Conservation Service Special Report (1971) describes large portions as "rough broken or hummocky mesas, hills, ledges and fans". Several major drainages cut the area on west to east directions to the Little Colorado, Deadman's Wash and Kana a Wash being the largest two, both crossing the area from Woodhouse Mesa to the Little Colorado River.

No actual sample transects were run in this community, primarily because of the complexity of the area and a lack of time. The mapped units and the dominant plants were determined from field observations. The unit boundaries are approximations based on wash drainages and other obvious landmarks, just as the dominant plant classifications are based on visual estimates.

The northwest corner, north of Doney Mountain Wash, is primarily an area dominated by randomly clumped shrub hummocks in deep black cinders with very little vegetation cover in the interspaces. Four-wing saltbush, apache plume and broom snakeweed are the important shrubs acting as islands of favorable habitats for both the herbs and grasses. The shrub cover constitutes an

estimated 10-15 percent. Commonly several shrubs occupy the same hummock, making accurate dominance measurements difficult. Other important shrubs are green ephedra, ephedra (Ephedra torreyana), and various species of flythicket (Brickellia spp.).

The herb level of composition is much more difficult to estimate. Globemallow, species of spurge, Tetraclea coulteri, buckwheat (Eriogonum spp.) and prince's plume (Stanleya pinnata) are probably important herb elements in terms of density and frequency. These species are commonly associated with the hummocks developed around the shrubs. Tetraclea coulteri and the spurge are the two common plants found in the open interspaces.

Galleta and threeawns are present and found in the open interspaces and appear to be the dominant grasses. Bush muhly (Muhlenbergia porteri) occurs frequently, growing up in the shrub hummocks. Grasses probably constitute less than 5 percent ground cover.

The area south of Doney Mountain Wash to Deadman's Wash and northeast for about 5 to 6.5 kilometers (three to four miles) could be classified as a Cold Desert Shrub Grassland. Shrub density and cover as well as diversity are decreased. Rubber rabbitbrush, four-wing saltbush, and apache plume are the important shrubs, associated with green ephedra, threadleaf groundsel and broom snakeweed in various densities. Important herbs are aster, globemallow, greenstem paperflower, and Russian thistle. The dominant grass is galleta with black grama, bush muhly, and Fendler threeawn in common association.

Along Deadman's Wash, south to the Monument boundary to approximately Kana a Wash and Wukoki Ruins is an area primarily dominated by hummocky shrub clumps in deep cinders. The major shrub elements are four-wing saltbush, apache plume, fringed sagebrush (Artemisia frigida) and ephedra species. Prince's plume, Russian thistle, buckwheat species and white horsenettle

(Solanum elaeagnifolium) are the important and common herbs. Grasses are primarily galleta, bush muhly, and threeawn species.

Northeast of this area for approximately 3.2 kilometers (two miles) and east to the park boundary is an area where four-wing saltbush, broom snakeweed, rubber rabbitbrush and ephedra species dominate the shrub element (Appendix 1). The herb composition is of low density and is primarily made up of prince's plume and Russian thistle. Galleta, alkali sacaton (Sporobolus airoides) and bush muhly are the common grasses. The area in the northern portions of this mapping unit is characterized by low density and frequency of shrubs with large, empty, gravelly-loam interspaces.

The area north to the Little Colorado River and northwest to approximately Doney Mountain Wash has shadscale (Atriplex confertifolia), ephedra species, rubber rabbitbrush, and four-wing saltbush commonly associated with it. Alkali sacaton is a common grass with galleta also present. Shrub density varies considerably, from open clumped areas to semi-herbaceous scattered populations.

One-seed juniper is of common occurrence throughout the community. The density and cover values do not approach significance with the area between the Doney Mountain Wash to Deadman's Wash south to approximately the Wukoki Ruins experiencing an "uncommon" occurrence. Junipers are also commonly found in and around the washes.

The complexity of this community created by the soil and topographic diversity presents a real challenge. More field observations and numerous sample transects will be necessary to accurately map and describe this complex community.

## Unique Areas

Certain areas within the boundaries of the Monument are unique and cannot

be placed in any particular community classification. These areas must be classed and described in context with their unique situation.

One such area is the cindery alluvial fan spreading northeast from Woodhouse Mesa. This area is dominated by apache plume, buckwheat species, four-wing saltbush and ephedra species varying with the distance from the mesa edge. Galleta, Indian ricegrass and sand bluestem (Andropogon hallii) are the common grasses in low density and frequency.

Another such area is the Doney Cliffs and Antelope Wash. These southeast facing limestone cliffs and the wash edges create a unique habitat, thus necessitating a different mapping unit. The two areas could, with additional data, be mapped as two separate units. Junipers are found throughout the wash both in the bottom and on the walls while the cliffs have few present except on the upper margins near the top. Common plants in association for these areas are ephedra species, broom snakeweed, four-wing saltbush, and apache plume. Grasses are black grama, New Mexico feathergrass, and scattered blue grama. Cacti such as hedgehog cactus (Echinocereus spp.) and pricklypear (Opuntia spp.) are common to occasional.

Ponderosa Pine

The area sampled for this community was adjacent to Sunset Crater National Monument and was established to sample this community type in conjunction with the bird survey transect. A degree of inaccuracy is expected with similar area sampling, therefore this data is to supplement the ornithological phase of this biological survey and is not intended to represent the Ponderosa Pine community of Sunset Crater National Monument.

The apparent dominant and only actual sampled shrub was apache plume with a 5.2 percent ground cover (Table 17). Few other shrubs were noted. The herb data analysis indicates beardlip or scarlet beardtongue (Penstemon barbatus) and skyrocket (Gilia aggregata) as the dominant herbs with many others present.

A cover value of less than 0.1 percent was calculated (Table 18). The common grasses were little bluestem (Andropogon scoparius), sand bluestem (Andropogon hallii) and blue grama (Bouteloua gracilis). A total cover value of 2.8 percent was calculated based on a single transect.

An analysis of plant families shows that two families, the Compositae and the Gramineae, include 30 percent of the total flora of both monuments combined. Table 21 summarizes the species total among the top ten families. These top ten include 60 percent of the total flora of both monuments combined. Table 22 ranks the top five families occurring in Wupatki National Monument. These five families include nearly one half of the species reported for Wupatki.

Within the boundaries of Wupatki and Sunset Crater National Monuments there are seven species of plants on the Endangered and Threatened species list compiled by the Fish and Wildlife Service of the Department of Interior. These species and their location and status are listed in Table 23.

During the summer of 1976, both the National Forest Service and the Bureau of Land Management funded studies to determine the distribution of Endangered and Threatened species of plants on federal lands under their respective jurisdictions in northern Arizona. A similar search for the occurrence and distribution of these species listed in Table 23 within Wupatki and Sunset Crater monuments should be included as part of the 1977 NPS vegetation studies.

Other plant records of special interest include the following:

Dalea whitingii - type locality at Black Falls of the Little Colorado along the eastern boundary of Wupatki National Monument.

Oenothera boothii - only collection for Arizona is from Wupatki National Monument.

Iva axillaris - first record for Arizona reported from Wupatki National Monument.

Penstemon clutei - type locality near Sunset Crater, endemic to this volcanic region.

Tables 24, 25, and 26 summarize the phenology of flowering period and onset of seeds of the major shrubs, herbs, and grasses growing in each of the three major plant communities of Wupatki National Monument as observed during the summer of 1976.

Voucher specimens of 120 different species of plants have been collected during the 1976 season, mostly from Wupatki National Monument. These specimens were collected in conjunction with the vegetation survey and represent plants encountered in determining species/area curves or along transect lines. These currently are housed at the Deaver Herbarium at Northern Arizona University.

## SUMMARY AND CONCLUSIONS

Minimal area requirements from the results of the species/area curve sample plots were presented and discussed and the numbers of species for each floral level per community recognized were compared.

Three general plant communities were recognized. These were 1) Juniper/Grassland, 2) Grassland and 3) Cold Desert Shrub with the possibility of a fourth community of Cold Desert Shrub Grassland being suggested. Influential environmental factors, primarily soil, were identified and incorporated into the community descriptions with respect to their effect on vegetation composition.

The Juniper/Grassland community, approximately 9 percent of the Monument, was interpreted to have; 1) one-seed juniper (Juniperus monosperma) as the dominant tree, 2) broom snakeweed (Gutierrezia sarothrae) and rubber rabbitbrush (Chrysothamnus nauseosus) as the dominant shrubs, 3) Rocky Mountain zinnia (Zinnia grandiflora) and Russian thistle (Salsola kali) as the dominant herbs,

and 4) galleta (Hilaria jamesii) and black grama (Bouteloua eriopoda) as the dominant grasses. Actual data analysis values for percent cover were considered to be underestimates, due to the low number of sample transects, and estimated percent cover values were presented. Hulls Canyon, characterized by four-wing saltbush (Atriplex canescens) and mesa dropseed (Sporobolus flexuosus), was discussed as a unique area within the community.

The Grassland community, estimated to be 37 percent of the Monument, with low density of one-seed junipers, was determined to have rubber rabbitbrush as the dominant shrub; in some areas this was of sufficient density to allow such areas to be mapped out as separate units. The herb composition of the community was estimated to be mainly Russian thistle and globemallow (Sphaeralcea subhastata) with the grasses dominated by galleta and New Mexico feathergrass (Stipa neomexicana) or black grama depending on the location in the community.

The Cold Desert Shrub community characteristics were based on field estimates. This area, 54 percent of the Monument, was subdivided into five areas based on the homogeneity of the floristic composition of the area. The idea that one of the five subdivisions could be classified as a Cold Desert Shrub Grassland was suggested.

Two general areas were classified as unique and described in considerable detail. No estimates for dominance were projected because of a lack of data.

A Ponderosa Pine community was recognized and sample transect data analysis was discussed but not assumed to be representative of Sunset Crater National Monument. Apache plume was the dominant shrub; beardlip (Penstemon barbatus) and skyrocket (Gilia aggregata) were the dominant herbs; and little bluestem (Andropogon scoparius) and sand bluestem (Andropogon hallii) were the dominant grasses.

It becomes obvious that further sampling and analysis of data are necessary to quantitatively determine the composition of the various plant communities

when the diversity and complexity of these communities are evaluated, especially the Cold Desert Shrub community. Presently there are insufficient transect data to accurately state the floristic composition of the communities. Additional information is also needed to determine if distinct communities exist within the three communities presently recognized.

(Field observations in the Juniper/Grassland and Grassland communities initially indicate a heavy utilization from grazing on the grasses found in these communities, probably a combination of domestic livestock and wildlife use which could develop serious competition for this resource.) The more palatable and desirable species, i.e. black grama, New Mexico feathergrass, and Indian ricegrass all have been noted to have poor seed vigor and seed production. Observations in August for the Grassland community east of East Mesa prompt the estimate that less than 25 percent of the New Mexico feathergrass plants had produced seedheads. Random selection of ten black grama plants in the Juniper/Grassland averaged a plant foliage height of less than four centimeters with less than 15 centimeter tall seed stalks of one to three spikes per plant. Black grama on the adjacent Coconino National Forest averaged 10 centimeters in plant foliage height with 4 to 5 spikes per plant. These and other observations, the heavy utilization of the four-wing saltbush in Hulls Canyon, indicate a strong necessity to further sample these communities and possibly compare the results to a "control" or ungrazed area to determine if floristic composition changes are taking place. Considering the sensitivity of these ecosystems, the unique soils and low annual precipitation, (any disturbance in floral composition would have serious effects on the entire system and would require a long time to correct.) With this in mind, it is imperative that quantitative analysis of the vegetation of Wupatki National Monument be continued.

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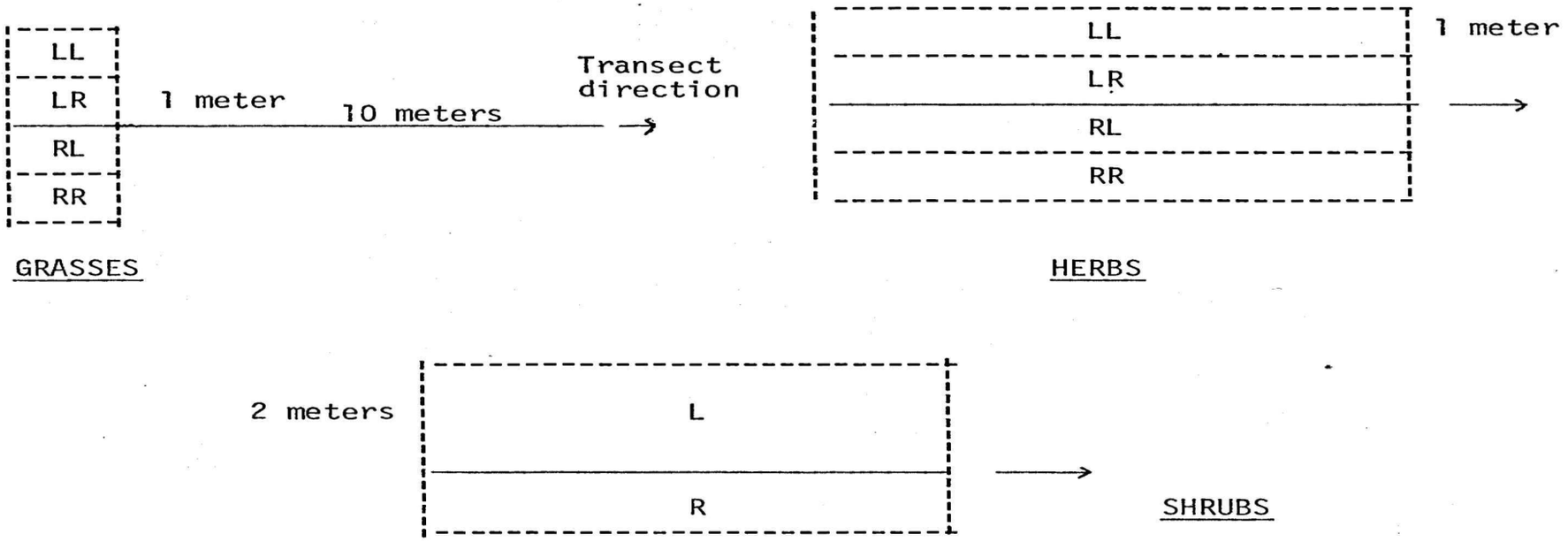


Fig. 1. The variable range and establishment of transect nested plots to sample the floristic levels of a community where L is left and R is right.

TABLE 1. Species/area curve sample plot data for each community. Areas are in square meters and are rounded off to the nearest square meter. Minimal areas for all species and for each floristic level are shown.

| Community Plot # | Total area sampled | Total # species | Minimal area | Minimal area for Grasses | Herbs | Shrubs |
|---|---|---|---|---|---|---|
| Juniper/Grassland #2 | 4096 | 26 | 512 | 512 | 287 | 164 |
| Grassland #3 | 16384 | 27 | 512 | 143 | 676 | 123 |
| Cold Desert Shrub #4 | 4096 | 29 | 1024 | 512 | 532 | 1024 |
| Cold Desert Shrub #5 | 4096 | 27 | 512 | 128 | 512 | 256 |

TABLE 2. Results of transect G-30.

Community: Juniper/Grassland
Veg. Type: Shrubs
Area Sampled: 12 plots each 20 square meters
Total Plants: 123
Total Cover: 183019 square centimeters
Percent Cover: 7.6

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Chrysothamnus nauseosus | 0.91 | 119 | 170781 | 85 | 97 | 93 | 1 |
| Ephedra viridis | 0.17 | 4 | 12237 | 15 | 3 | 7 | 2 |

TABLE 3. Results of transect G-32/33.

Community: Juniper/Grassland
Veg. Type: Shrubs
Area Sampled: 20 plots each 20 square meters
Total Plants: 9
Total Cover: 2999 square centimeters
Percent Cover: 0.08

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Gutierrezia sarothrae | 0.1 | 8 | 2888 | 66.6 | 89 | 96.3 | 1 |
| Chrysothamnus nauseosus | 0.05 | 1 | 111 | 33.3 | 11 | 3.7 | 2 |

TABLE 4. Results of transect G-34.

Community: Juniper/Grassland
Veg. Type: Shrubs
Area Sampled: 10 plots each 20 square meters
Total Plants: 56
Total Cover: 19140 square centimeters
Percent Cover: 0.96

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Gutierrezia sarothrae | 0.7 | 54 | 14484 | 87.5 | 96 | 76 | 1 |
| Atriplex canescens | 0.1 | 2 | 4656 | 12.5 | 4 | 24 | 2 |

TABLE 5. Results of transect G-30.

Community: Juniper/Grassland
Veg. Type: Herbs
Area Sampled: 12 plots each 10 square meters
Total Plants: 5
Total Cover: 503 square centimeters
Percent Cover: 0.04

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| *Zinnia grandiflora* | 0.17 | 5 | 503 | 100 | 100 | 100 | 1 |

TABLE 6. Results of transect G-32/33.

Community: Juniper/Grassland
Veg. Type: Herbs
Area Sampled: 20 plots each 10 square meters
Total Plants: 21
Total Cover: 380 square centimeters
Percent Cover: 0.02

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| *Zinnia grandiflora* | 0.15 | 17 | 237 | 43 | 81 | 62.0 | 1 |
| *Cryptantha pterocarya* | 0.10 | 2 | 49 | 29 | 9 | 13.0 | 2 |
| *Euphorbia revoluta* | 0.05 | 1 | 92 | 14 | 5 | 24.0 | 3 |
| *Aster arenosus* | 0.05 | 1 | 2 | 14 | 5 | 0.4 | 4 |

TABLE 7. Results of transect G-34.

Community: Juniper/Grassland
Veg. Type: Herbs
Area Sampled: 10 plots each 10 square meters
Total Plants: 137
Total Cover: 958 square centimeters
Percent Cover: 0.10

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Euphorbia revoluta | 0.6 | 66 | 122 | 25 | 48 | 13 | 1 |
| Salsola kali | 0.6 | 45 | 206 | 25 | 33 | 22 | 2 |
| Aster arenosus | 0.6 | 18 | 310 | 25 | 13 | 32 | 3 |
| Verbena gooddingii | 0.2 | 2 | 16 | 8 | 1 | 2 | 4 |
| Physalis fendleri | 0.1 | 1 | 45 | 4 | 0.7 | 5 | 5 |
| Evolvulus pilosus | 0.1 | 1 | 34 | 4 | 0.7 | 4 | 6 |
| Sphaeralcea subhastata | 0.1 | 3 | 218 | 4 | 2 | 23 | 7 |
| Hoffmanseggia jamesii | 0.1 | 1 | 6 | 4 | 0.7 | 1 | 8 |

TABLE 8. Results of transect G-30.

Community: Juniper/Grassland
Veg. Type: Grasses
Area Sampled: 13 plots each 1 square meter
Total Plants: 184
Total Cover: 3562 square centimeters
Percent Cover: 2.7

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Hilaria jamesii | 0.7 | 177 | 2447 | 69 | 96 | 69 | 1 |
| Bouteloua eriopoda | 0.08 | 2 | 869 | 8 | 1 | 24 | 2 |
| Oryzopsis hymenoides | 0.2 | 4 | 184 | 15 | 2 | 5 | 3 |
| Aristida fendleriana | 0.08 | 1 | 62 | 8 | 1 | 2 | 4 |

TABLE 9. Results of transect G-32/33.

Community: Juniper/Grassland
Veg. Type: Grasses
Area Sampled: 20 plots each 1 square meter
Total Plants: 294
Total Cover: 4725 square centimeters
Percent Cover: 2.4

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Hilaria jamesii | 0.7 | 274 | 4362 | 78 | 93 | 92 | 1 |
| Bouteloua eriopoda | 0.2 | 19 | 343 | 17 | 6 | 7 | 2 |
| Aristida fendleriana | 0.1 | 1 | 20 | 6 | 1 | 1 | 3 |

TABLE 10. Results of transect G-34.

Community: Juniper/Grassland
Veg. Type: Grasses
Area Sampled: 10 plots each 1 square meter
Total Plants: 195
Total Cover: 3662 square centimeters
Percent Cover: 3.7

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Hilaria jamesii | 0.7 | 144 | 2023 | 47 | 74 | 55 | 1 |
| Sporobolus flexuosus | 0.4 | 35 | 1374 | 26 | 18 | 38 | 2 |
| Bouteloua eriopoda | 0.3 | 15 | 227 | 20 | 7 | 6 | 3 |
| Muhlenbergia porteri | 0.1 | 1 | 37 | 7 | 1 | 1 | 4 |

TABLE 11. Results of transect G-31.

| | |
|---|---|
| Community: | Grassland |
| Veg. Type: | Shrubs |
| Area Sampled: | 5 plots each 20 square meters |
| Total Plants: | 28 |
| Total Cover: | 38996 square centimeters |
| Percent Cover: | 3.9 |

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Chrysothamnus nauseosus | 0.8 | 26 | 38402 | 80 | 93 | 98 | 1 |
| Opuntia macrorhiza | 0.2 | 2 | 594 | 20 | 7 | 2 | 2 |

TABLE 12. Results of transect G-50.

| | |
|---|---|
| Community: | Grassland |
| Veg. Type: | Shrubs |
| Area Sampled: | 10 plots each 20 square meters |
| Total Plants: | 39 |
| Total Cover: | 63611 square centimeters |
| Percent Sampled: | 3.2 |

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Chrysothamnus nauseosus | 0.6 | 39 | 63611 | 100 | 100 | 100 | 1 |

TABLE 13. Results of transect G-31.

Community: Grassland
Veg. Type: Herbs
Area Sampled: 5 plots each 10 square meters
Total Plants: 12
Total Cover: 2199 square centimeters
Percent Cover: 0.44

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Sphaeralcea subhastata | 0.4 | 5 | 1006 | 28.6 | 42 | 46 | 1 |
| Salsola kali | 0.4 | 3 | 842 | 28.6 | 25 | 38 | 2 |
| Aster arenosus | 0.2 | 2 | 55 | 14.3 | 17 | 3 | 3 |
| Stephanomeria pauciflora | 0.2 | 1 | 167 | 14.3 | 8 | 8 | 4 |
| Psilostrophe sparsiflora | 0.2 | 1 | 129 | 14.3 | 8 | 5 | 5 |

TABLE 14. Results of transect G-50

Community: Grassland
Veg. Type: Herbs
Area Sampled: 10 plots each 10 square meters
Total Plants: 178
Total Cover: 7192 square centimeters
Percent Cover: 0.72

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Salsola kali | 1.0 | 150 | 2137 | 40 | 84 | 30 | 1 |
| Sphaeralcea subhastata | 0.5 | 8 | 4077 | 20 | 5 | 57 | 2 |
| Euphorbia revoluta | 0.2 | 7 | 36 | 8 | 4 | 0.5 | 3 |
| Aster arenosus | 0.2 | 3 | 111 | 8 | 2 | 2 | 4 |
| Evolvulus pilosus | 0.1 | 2 | 297 | 4 | 1 | 4 | 5 |
| Gaillardia pinnatifida | 0.1 | 3 | 205 | 4 | 2 | 3 | 6 |
| Physalis fendleri | 0.1 | 2 | 109 | 4 | 1 | 2 | 7 |
| Stephanomeria pauciflora | 0.1 | 1 | 150 | 4 | 0.6 | 2 | 8 |
| Zinnia grandiflora | 0.1 | 1 | 40 | 4 | 0.4 | 0.5 | 9 |
| Cryptantha pterocarya | 0.1 | 1 | 30 | 4 | 0.4 | 0.4 | 10 |

TABLE 15. Results of transect G-31.

Community: Grassland
Veg. Type: Grasses
Area Sampled: 5 plots each 1 square meter
Total Plants: 86
Total Cover: 1728 square centimeters
Percent Cover: 3.5

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| *Hilaria jamesii* | 1.0 | 71 | 990 | 62.5 | 82 | 57 | 1 |
| *Stipa neomexicana* | 0.2 | 11 | 733 | 12.5 | 13 | 42 | 2 |
| *Oryzopsis hymenoides* | 0.4 | 4 | 5 | 25.0 | 5 | 1 | 3 |

TABLE 16. Results of transect G-50.

Community: Grassland
Veg. Type: Grasses
Area Sampled: 10 plots each 1 square meter
Total Plants: 432
Total Cover: 4463 square centimeters
Percent Cover 4.5

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| *Hilaria jamesii* | 1.0 | 339 | 3098 | 48 | 78 | 69 | 1 |
| *Stipa neomexicana* | 0.9 | 90 | 1285 | 43 | 21 | 29 | 2 |
| *Bouteloua eriopoda* | 0.2 | 3 | 80 | 9 | 1 | 2 | 3 |

TABLE 17. Results of transect G-70.

Community: Ponderosa Pine
Veg. Type: Shrubs
Area Sampled: 10 plots each 20 square meters
Total Plants: 140
Total Cover: 104677 square centimeters
Percent Cover: 5.2

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| *Fallugia paradoxa* | 0.8 | 140 | 104677 | 100 | 100 | 100 | 1 |

TABLE 18. Results of transect G-70.

Community: Ponderosa Pine
Veg. Type: Herbs
Area Sampled: 10 plots each 10 square meters
Total Plants: 13
Total Cover: 648 square centimeters
Percent Cover: 0.07

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| *Penstemon barbatus* | 2 | 2 | 371 | 22 | 15 | 57 | 1 |
| *Gilia aggregata* | 2 | 5 | 34 | 22 | 38 | 5 | 2 |
| *Euphorbia fendleri* | 1 | 2 | 142 | 11 | 15 | 22 | 3 |
| *Eriogonum racemosum* | 2 | 2 | 62 | 22 | 15 | 10 | 4 |
| *Euphorbia lurida* | 1 | 1 | 27 | 11 | 8 | 4 | 5 |
| *Eriogonum corymbosum* | 1 | 1 | 12 | 11 | 8 | 2 | 6 |

TABLE 19. Results of transect G-70.

| | |
|---|---|
| Community: | Ponderosa Pine |
| Veg. Type: | Grasses |
| Area Sampled: | 10 plots each 1 square meter |
| Total Plants: | 20 |
| Total Cover: | 2798 square centimeters |
| Percent Cover: | 2.8 |

| Species | Absolute Freq. | Absolute Den. | Absolute Cover | Relative Freq. | Relative Den. | Relative Cover | Rank of Imp. Value |
|---|---|---|---|---|---|---|---|
| Andropogon scoparius | 0.4 | 14 | 1795 | 57 | 70 | 64 | 1 |
| Andropogon hallii | 0.2 | 5 | 964 | 29 | 25 | 34 | 2 |
| Bouteloua gracilis | 0.1 | 1 | 39 | 14 | 5 | 2 | 3 |

TABLE 20. Summary for the point-centered quarter samples in the Juniper/Grassland to measure the tree composition. Density values are expressed in number of trees per hectare; mean distance and crown diameter in meters; and mean crown cover expressed in square meters.

| Transect Number | Dominant Species | # of Samples | Density | Mean Distance | Mean Crown Cover | Mean Crown Diameter |
|---|---|---|---|---|---|---|
| G-30 | Juniperus monosperma | 24 | 54.55 | 13.54 | 14.5 | 4.30 |
| G-32/33 | Juniperus monosperma | 40 | 90.00 | 10.54 | 17.9 | 4.77 |
| G-34 | Juniperus monosperma | 20 | 43.06 | 15.24 | 8.8 | 3.36 |

TABLE 21. Summary of the Ten Largest Families of Vascular Plants in Wuptaki and Sunset Crater Monuments

| Family | No. of Species | Percent of Flora |
|---|---|---|
| Compositae | 67 | 18.9 |
| Gramineae | 40 | 11.3 |
| Leguminosae | 27 | 7.6 |
| Chenopodiaceae | 13 | 3.6 |
| Cruciferae | 12 | 3.3 |
| Scrophulariaceae | 12 | 3.3 |
| Polygonaceae | 11 | 3.1 |
| Polemoniaceae | 11 | 3.1 |
| Boraginaceae | 10 | 2.8 |
| Solanaceae | 9 | 2.5 |

TABLE 22. Summary of the Five Largest Families of Vascular Plants in Wupatki National Monument

| Family | No. of Species | Percent of Flora |
|---|---|---|
| Compositae | 48 | 20 |
| Gramineae | 27 | 11 |
| Leguminosae | 17 | 7 |
| Chenopodiaceae | 11 | 5 |
| Polygonaceae | 10 | 4 |

TABLE 23. Endangered and Threatened Species of Plants of Wupatki and Sunset Crater National Monuments

| Species | Location | Status |
|---|---|---|
| *Amsonia palmeri* | W | T |
| *Amsonia peeblesii* | W | T |
| *Astragalus lancearius* | W | T |
| *Encelia frutescens resinosa* | W | T |
| *Penstemon clutei* | S | E |
| *Phacelia serrata* | S | T |
| *Phacelia welshii* | W | E |

TABLE 24. Grassland community. Flowering(F) and Seed Set(S)

| Shrubs Month: | A | M | J | J | A | S | O |
|---|---|---|---|---|---|---|---|
| Chrysothamnus nauseosus | | | | | F | F/S | S |
| Herbs | | | | | | | |
| Salsola kali | | | F/S | F/S | S | | |
| Sphaeralcea subhastata | F | F | F/S | F/S | S | | |
| Aster arenosus | | F | F | F/S | F/S | S | |
| Grasses | | | | | | | |
| Hilaria jamesii | | F | F | F/S | S | S | |
| Stipa neomexicana | | F | F/S | F/S | S | | |
| Bouteloua eriopoda | | | | | F | F/S | S |

TABLE 25. Juniper-Grassland community. Flowering(F) and Seed Set(S)

| Shrubs / Month | A | M | J | J | A | S | O |
|---|---|---|---|---|---|---|---|
| Chrysothamnus nauseosus | | | | | F | F/S | S |
| Gutierrezia sarothrae | | | | | F | F/S | F/S |
| Atriplex canescens | | F | F | S | S | S | |
| Herbs | | | | | | | |
| Zinnia grandiflora | | | | F | F | F/S | S |
| Euphorbia spp. | | | F | F | F/S | F/S | |
| Aster arenosus | | F | F | F/S | F/S | S | |
| Sphaeralcea subhastata | F | F | F/S | F/S | S | | |
| Grasses | | | | | | | |
| Hilaria jamesii | | F | F | F/S | S | S | |
| Bouteloua eriopoda | | | | | F | F/S | S |
| Aristida fendleriana | | F | F | F/S | F/S | S | |
| Sporobolus flexuosus | | | F | F | F/S | F/S | S |

TABLE 26. Cold Desert Shrub community. Flowering(F) and Seed Set(S)

| Shrubs / Month | A | M | J | J | A | S | O |
|---|---|---|---|---|---|---|---|
| Atriplex canescens | | F | F | S | S | S | |
| Fallugia paradoxa | F | F | F/S | S | S | S | |
| Gutierrezia sarothrae | | | | | F | F/S | F/S |
| Chrysothamnus nauseosus | | | | | F | F/S | S |
| Atriplex confertifolia | | F | F | F/S | S | S | |
| Herbs | | | | | | | |
| Eriogonum cernuum | | | | F | F/S | S | |
| Euphorbia fendleri | F | F | F/S | S | S | | |
| Psilostrophe sparsiflora | | F | F | F/S | F/S | S | |
| Tetraclea coulteri | | | F | F | F/S | F/S | S |
| Stanleya pinnata | | F | F | F/S | F/S | S | S |
| Grasses | | | | | | | |
| Hilaria jamesii | | F | F | F/S | S | | |
| Muhlenbergia porteri | | | | | F | F/S | S |
| Sporobolus airoides | | F | F/S | F/S | S | S | |
| Stipa speciosa | | | F | F/S | F/S | S | |

III

# STUDIES OF AVIAN COMMUNITIES

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December, 1976

## INTRODUCTION

Sunset Crater and Wupatki National Monuments offer an opportunity to study birds in rather unique habitats. The monuments are characterized by their inconsistencies in vegetation type and geological formations, and the presence of cinders as ground-cover over most of the general area. The uniqueness of this area may also be increased by its proximity to the southern-most edge of the cold desert. Such environments may be found to contain unique avian communities when compared to similar vegetation types in other areas.

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

The present study was initiated in the spring of 1976. The results reported herein describe the avian communities in the monuments. Species composition, species diversity, and habitat utilization are discussed.

## METHODS AND MATERIALS

Three of the four study areas, the juniper-grassland, grassland, and cold desert shrub are the same as those described in section II. The fourth study area is in the ponderosa pine habitat at Sunset Crater National Monument.

The ponderosa pine community, at an elevation of 2300 m, is composed of four major vegetative strata: the tree, shrub, herb, and grass layers. The dominant species in each area are the ponderosa pine (Pinus ponderosa), apache plume (Fallugia paradoxa), beardtongue (Penstemon barbatus) and scarlet gilia (Gilia aggregata), and bluestem (Andropogon scoparius and A. hallii) and blue grama grass (Bouteloua gracilis), respectively.

In each of the four study areas, birds were censused by traversing a 1.61 km (1 mile) transect on consecutive days throughout the breeding season following Emlen's suggestions (1971). The transects were established in each habitat type by placing stakes at 31 m intervals. A distance of 125 m on either side of the transects yields a total area of 40 ha (100 acres) sampled in each of the study areas. Foliage position, distance from the transect, vocalizations, and, where detectable, sex of the birds, were recorded. The numbers of days censused for each community are: ponderosa pine, 13; juniper-grassland, 10; grassland, 10; and cold desert shrub, 9.

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

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

# RESULTS

A tentative bird species list was compiled in February 1976 from species lists compiled by park rangers at the monuments, and from study skins at the Museum of Northern Arizona. This list, containing 113 species in 34 families, plus an addendum with 11 species in 8 families appears at the end of this report.

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

The diversity index for this community is 3.0256 and the J' value is 0.844. Both values were determined from a population of 62.7 breeding pairs (Table 5). Each of the species was placed into appropriate feeding and nesting guilds (Table 1), and the relative proportions of species and pairs in each guild were calculated (Table 3). There was a relatively equal distribution of pairs represented in the four feeding guilds, while 53 per cent of the pairs were cavity and depression nesters.

Twelve breeding species and seven additional species were observed in the juniper-grassland community (Table 2). The Mourning Dove and Black-throated Sparrow contributed 16 breeding pairs per 40 ha or 40 per cent of all breeding pairs.

A diversity index of 3.2371 and a J' value of 0.903 were calculated from the 39.8 breeding pairs in the census area (Table 5). Numbers of species and numbers of pairs per 40 ha, and their respective proportions in each of the four feeding and four nesting guilds were calculated (Table 4). Sixty-three

per cent of the pairs were ground feeders, while 54 per cent of the pairs nested in foliage.

The Horned Lark was found to be the only species that bred along the grassland transect line (Table 6). Five additional species were observed in the area, but their numbers were not sufficient to be included in the "bred along transect" category.

The diversity index for the grassland community determined from 40 breeding pairs per 40 ha is 0.0144 (Table 5). A corresponding J' value could not be calculated with only one species representing the community. The grassland habitat is represented by only the ground feeder and ground nester guilds of the Horned Lark.

The cold desert shrub community had seven species breeding along the transect line (Table 7). The Black-throated Sparrow contributed 16 breeding pairs per 40 ha or 56 per cent of all breeding pairs in the community. Five additional species were seen in the area, but did not breed there.

From a total of 28.5 breeding pairs a diversity index of 2.09 and a J' value of 0.744 were calculated (Table 5). Two feeding and four nesting guilds were represented in this community, and their respective proportions were calculated (Table 8). Ninety-two per cent of the breeding pairs were ground feeders, and 64 per cent were ground nesters.

## DISCUSSION

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

Populations of breeding birds were greatest in the ponderosa pine community (62.7 pairs/40 ha), followed by the juniper-grasslands and grassland with

40 breeding pairs, and the cold desert shrub with 28.5 breeding pairs per 40 ha (Table 5). This may be a measure of the vegetative variety in each habitat whereby each habitat has a greater or lesser amount of total biomass (density and height of vegetation).

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

The juniper-grassland community might be thought of as intermediate between the pinon-juniper woodland and grassland community for the purpose of comparison. Although the juniper-grassland is not an ecotone of these two communities, it shares some of the major vegetative features of each. Laudenslayer and Balda (1976) found five species of breeding birds containing 46 breeding pairs per 40 ha. Although these data are from a pinon-juniper-ponderosa pine ecotone, these results were found to coincide with those of other pinyon-juniper areas studied. Grassland habitats have been found to be generally within the range of 3 to 5 species containing 40 to 95.6 breeding pairs per 40 ha (Wiens 1974). The juniper-grassland studied here consisted of 12 breeding species with 39.8 breeding pairs. The greater number of species may be due to the height diversity of the vegetation. The average number of pairs may be explained by the moderate amount of precipitation that the area receives which in turn may

influence primary productivity (Wiens 1974b), and thereby affect the densities of birds that can survive in the area.

As mentioned above, grassland communities of breeding birds can vary tremendously with from 3-5 species containing from 40-95.6 breeding pairs per 40 ha. The unique grassland community investigated here has only one breeding species containing 40 pairs/40 ha. This may be explained by unpredictable variations in climate, causing subsequent variations in productivity (Wiens 1974b).

The cold desert shrub community has a low number of breeding pairs when compared to other similar desert communities. Raitt and Maze (1968) summarized values recorded from several desert communities, and found that they ranged from 10-109 pairs per 40 ha. Raitt and Maze explain that the differences are explained by variation in rainfall, complexity of vegetation, and probably increasing productivity. Comparisons to other specifically cold desert shrub communities are not possible at this time.

The juniper-grassland has the greatest diversity of the four communities (Table 5). The number of species in each area has great importance to the diversity index. The grassland community readily exemplifies this point. It has an equal population of breeding pairs to the juniper-grassland, but in contrast has only one species representing the community. This drastically lowers the diversity to the point where calculations of diversity are meaningless. This is not to say, however, that the grassland habitat is not productive. Productivity is a relative measure, and it is difficult to compare it among different habitats.

Comparisons within habitat types show that in one ponderosa pine community, species diversity was 2.28 (Balda 1969), compared to 3.03 calculated for this community in this study. Szaro and Balda (1976) found diversities

ranging from 1.02 to 2.89 on several disturbed ponderosa pine forests in northern Arizona.

Diversities in comparable grassland habitats are decidedly higher than those found here (0.014). This is explained by only one breeding species being present on the study area. If, as Wiens (1974b) suggests, climatic irregularity imposes limits on the number of species that can inhabit a grassland community, then this grassland is probably severely limited by these irregularities.

Specific values for diversity comparisons in the juniper-grassland and cold desert shrub are not available. However, Raitt and Maze (1968) suggest that to increase densities in desert scrub avifaunas, addition of species is needed. This depends on densities and productivity of vegetation which in turn results from increased available moisture. The communities of Sunset Crater and Wupatki National Monuments appear to be limited by available moisture, and this limitation is heightened by the presence of cinders as ground-cover. A layer of cinders may reduce the available moisture by its inability to retain moisture, and thereby influence vegetative structure.

Subdividing species and pairs into proportions of feeding guilds offers another way to analyze communities. The ponderosa pine community has a relatively equitable distribution of pairs in feeding guilds, while the juniper-grassland, and cold desert shrub have a majority of pairs in the ground feeding guild. This is probably correlated with the vegetational diversity of the areas. Szaro and Balda (1976) found that certain guilds exhibit a positive correlation to increasing foliage volumes. The number of seeds dispersed in each area will vary with the type and amount of vegetation. Similarly, insect densities may play an important role in suggesting reasons for the diversity in feeding guilds among the areas.

Closely related to the feeding guilds, the nesting guilds also show a probable correlation with amount and type of vegetation. The ponderosa pine habitat is unique in having 50 per cent of both species and pairs nesting in cavities and depressions (Table 3). The juniper-grassland has 54 per cent of breeding pairs and 67 per cent of the species nesting in foliage (Table 4). Both the cold desert shrub with 64 per cent and the grassland have species that overwhelmingly nest on the ground (Tables 3, 8). As height of vegetation decreases the height of nests also decreases.

## CONCLUSION

The avian communities investigated in this report appear to be limited in varying degrees by the presence of cinders as ground-cover and by the presence of the southern-most edge of the cold desert. Available moisture may be the most severe limiting factor to the breeding birds. Diversities are quite high in all but the grassland community where climatic irregularities may restrict avian densities.

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Juniper-Grasslan

| Species | Br al tr |
|---|---|
| Sharp-skinned Hawk (*Accipiter striatus*) | |
| Mourning Dove (*Zenaida macroura*) | |

TABLE 3

Numbers and Per Cent of Breeding

Species and Breeding Pairs in the Ponderosa

Pine Community in each Guild

| Guilds* | Number of Species | Number of prs./40 ha | Per Cent of Species | Per Cent of prs./40 ha |
|---|---|---|---|---|
| Feeding | | | | |
| GF | 2 | 21.6 | 17 | 34 |
| HHA | 3 | 23.6 | 25 | 38 |
| PHT | 5 | 14.8 | 42 | 24 |
| PG | 2 | 2.7 | 17 | 4 |
| Nesting | | | | |
| FN | 5 | 21.2 | 42 | 34 |
| CD | 6 | 33.5 | 50 | 53 |
| GN | - | - | - | - |
| P | 1 | 8.0 | 8 | 13 |

*Guild abbreviations:

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

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

TABLE 4

Numbers and Per Cent of Breeding Species and Breeding Pairs in the Juniper-Grassland Community in each Guild

| Guilds | Number of Species | Number of prs./40 ha | Per Cent of Species | Per Cent of prs./40 ha |
|---|---|---|---|---|
| Feeding | | | | |
| GF | 6 | 25.0 | 50 | 63 |
| HHA | 4 | 11.6 | 33 | 29 |
| PHT | 1 | 1.2 | 8 | 3 |
| PG | 1 | 2.0 | 8 | 5 |
| Nesting | | | | |
| FN | 8 | 21.3 | 67 | 54 |
| CD | - | - | - | - |
| GN | 3 | 15.5 | 25 | 39 |
| P | 1 | 3.0 | 8 | 8 |

TABLE 5

Comparisons Between Communities

| Data | Ponderosa Pine | Juniper-Grassland | Grassland | Cold Desert Shrub |
|---|---|---|---|---|
| Total number of species | 16 | 19 | 5 | 12 |
| Total number of breeding species (N) | 12 | 12 | 1 | 7 |
| Number of days censused | 13 | 10 | 10 | 9 |
| Populations of breeding birds (prs./40 ha) | 62.7 | 39.8 | 40 | 28.5 |
| Diversity indices (H') | 3.0256 | 3.2371 | 0.0144 | 2.0900 |
| H' max values | 3.5849 | 3.5849 | 0.0000 | 2.8073 |
| J' values | 0.844 | 0.903 | - | 0.744 |

TABLE 8

Numbers and Per Cent of Breeding

Species and Breeding Pairs in the Cold Desert

Shrub Community in each Guild

| Guilds | Number of Species | Number of prs./40 ha | Per Cent of Species | Per Cent of prs./40 ha |
|---|---|---|---|---|
| Feeding | | | | |
| GF | 6 | 26.2 | 86 | 92 |
| HHA | 1 | 2.3 | 14 | 8 |
| PHT | - | - | - | - |
| PG | - | - | - | - |
| Nesting | | | | |
| FN | 3 | 5.7 | 43 | 20 |
| CD | 1 | 1.1 | 14 | 4 |
| GN | 2 | 18.3 | 29 | 64 |
| P | 1 | 3.4 | 14 | 12 |

IV

# STUDIES OF SELECTED MAMMALIAN POPULATIONS

Gary C. Bateman, Director

December, 1976

# INTRODUCTION

The mammalian communities of Sunset Crater and Wupatki National Monuments have not been the subject of any detailed studies. Early collecting done in this area by the Biological Survey and Museum of Vertebrate Zoology, University of California, Berkeley has resulted in the description of several unique subspecies of small rodents from the region (Cockrum 1960). It is not surprising that rather distinctive types would be found to occur on the volcanic soils characteristic of this area.

Lincoln (1962) compared mammalian skeletal remains excavated from Wupatki Ruin with the existing fauna of the area and concluded that ecological conditions indicated by the prehistoric remains were not significantly different than those of today.

During the 1960's several student projects were conducted on these monuments, including the following: 1) The study of a *Peromyscus* population in a volcanic region by R. P. Maynard Jr.; 2) The bats of Wupatki National Monument, Coconino Co., Arizona by T. A. Gustafson; and 3) The antelope of Wupatki National Monument by James A. Mack.

More recently faculty and graduate students at Northern Arizona University have become increasingly interested in mammals of this region and several studies were underway or already completed at the time the present project was begun. J. O. Wolff and G. C. Bateman studied torpor in the silky pocket mosue (*Perognathus flavus*) using specimens and field observations from Wupatki National Monument (1977) and B. H. Campbell and G. C. Bateman studied populations, diets, and habitats of this same species in Cedar Canyon and adjacent areas of Wupatki.

In many temperate and boreal localities small rodents are the most important components of the mammalian community in terms of energy conversions and transfers within the ecosystem. In order to appreciate and understand ecosystem functioning it is necessary to be aware of the kinds, abundances and distributions of such small mammals in the area of concern.

It is toward these ends that this study was directed. The objectives were to examine rodent communities existing in each of the three major plant communities at Wupatki National Monument with the goal of determining: 1) the species composition of the rodent community in each area; 2) the relative abundances of the species in each community; 3) the relative importance to ecosystem functioning of each component species of the community; and 4) seasonal changes in abundance and patterns of activity of the various species occurring in each major plant formation. (A final objective was to evaluate the probable ecological stability of each community with an eye toward management implications.)

## METHODS AND MATERIALS

### Live trapping grids

Three live-trapping quadrats were established at Wupatki National Monument to obtain data regarding the populations of important small mammals. Each quadrat, or trapping grid, was situated within a fairly homogeneous stand of vegetation representative of one of the three general plant communities (see section II). These communities were: 1) Grassland, 2) Juniper/Grassland and 3) Cold Desert Shrub.

The trapping grids were surveyed using an alidade and 50 meter (m) tapes. Horizontal distances were used in measuring as topographic complexity was essentially non-existant. Each grid consisted of 12 rows, each having 12 trap stations, spaced at 15 m intervals. Thus a quadrat was 165 m on a side

and included 2.723 hectares (ha) or 6.727 acres (ac). Each row of traps was assigned a letter and columns were numbered, hence any trapsite was designated by a combination of letter and number. Trapsites were marked by wooden stakes having this specific designation indicated on them. The locations of the mammal trapping grids are indicated on maps in Appendix 1.

As a convenient, although somewhat arbitrary, means of estimating the area sampled by each grid a boundary strip equal to one half the distance between traps was added to the perimeter of the grid. Hence the area sampled by a grid was roughly 3.240 ha (8.006 ac).

More sophisticated and accurate means of determining sampling area involve determining more about patterns of rodent movements than our trapping regime permitted. It is known that such patterns vary interspecifically and they have also been shown to vary intraspecifically on age, sex, and seasonal bases.

Trapping Program

Our plan was to trap each grid at two week intervals during the summer months and to reduce trapping effort during fall to approximately one sampling period per month or six weeks. Each sampling period involved two nights of trapping. We were sometimes able to operate two grids simultaneously, usually those in Grassland and Juniper/Grassland, but never attempted to run all three at the same time since sufficient manpower to set and run all traps was not available. If animals were allowed to remain in the traps for long after sunrise they could become hyperthermic and die. We used sheet metal, non-folding, live traps having dimensions of 7.6 x 7.6 x 25.4 centimeters (cm) and placed one at each trap site. Traps were set in late afternoon and baited with a small amount of rolled milo. A bit of milo was scattered just in front of the open trap door to entice animals to the area.

Traps were checked as early in the morning as it was possible to see. Unsprung traps were closed and left in place. Animals in traps were removed to a soft cloth bag for handing at the trap site. Each individual was examined to allow determination of species, sex and age (by pelage characteristics). Weights were taken on an Ohaus spring scale, while the animals were restrained in the bag; the weight of the empty bag was then subtracted from the initial reading. Each animal, if not previously marked, was given a distinctive toe clip, which allowed that individual's identity to be determined upon subsequent recapture. Additional observations regarding conspicuous wounds, reproductive features (e.g. lactation) and general behavior were made at this time. The animals were then released at the place of capture. All these data were recorded on a standard trapping form, punched onto computer cards as time became available and analyzed on a Xerox Sigma 6 Computer using programs written by Dr. W. S. Gaud.

Population Densities

Population densities were determined using two methods.

1) The computer printout simply listed the numbers of different individuals of each species trapped during a single sampling period. This gives a minimum estimate of densities. An individual caught during any single trapping period was considered a single sampling occurrence whether caught both nights or not.

2) The Lincoln Index was also used to estimate densities. The method is based upon marking a number of individuals and releasing them. Then after a time, one day in this case, the population is sampled again. An estimate of the total population is then computed from the ratio of marked to unmarked individuals by:

$$N = \frac{nT}{t} ,$$

where

T = number marked in the precensus period

t = number of marked animals trapped in the census period

n = total animals trapped in the census period

N = the population estimate

The standard error of the estimate is given by:

$$S.E. = \frac{T^2 n(n-t)}{t^3}$$

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

Rodent Activity

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

Rodent Diversity

Using data gathered following procedures above, the diversity of the community of nocturnal rodents in each of the major plant communities was determined. Additionally the diversity of rodents in each of the communities was determined on a seasonal basis considering the first three sampling periods to represent late spring and early summer, prior to normal summer monsoons, and the last four periods represented late summer and fall. The formula used to compute the diversity index is:

$$H' = -\sum pi \log_2 pi,$$

where

pi is the proportion of the total rodents in the community contributed by the ith species

# RESULTS

## Species Present and Population Densities

The rodent populations of each major plant community were sampled seven times (Table 1). As may be seen in Tables 2, 3 and 4 each major plant community has a distinctive assemblage of species of small rodents. For example, the grassland has the most depauperate fauna in terms both of numbers of species and numbers of individuals. It has no species which is exclusive to it and is dominated by the silky pocket mouse (*Perognathus flavus*). *Peromyscus maniculatus*, the deer mouse, was the only other species taken on the live trapping grid, although the diurnal spotted ground squirrel (*Spermophilus spilosoma*) has been trapped very rarely in this habitat (G. C. B., personal obs).

The Juniper/Grassland grid provided larger numbers of both species and individuals. As might be expected the silky pocket mouse was present, apparently in response to the limited grass cover extending into this zone. The pinyon mouse (*Peromyscus truei*) was consistently present during each trapping period and accounted for most of the captures in this zone. Again the deer mouse was present and its relative density and seasonal pattern of appearance in the traps were reminiscent of those at the Grassland grid. The last species occurring in this area was the Stephens woodrat (*Neotoma stephensi*) which accounted for only 4 sampling occurrences in 3 different periods (Table 3). This species is often found in areas of juniper woodland but Kuch (1969) reported the species to be absent from an area of juniper and dense grass where shrubs were totally absent. He further noted with regard to this area that "topography was flat with no rock outcrops or lava escarpments." Apparently,

then, the Juniper/Grassland mammal grid was situated in sub-optimal habitat for this species. Also, the animals were probably not very susceptible to capture in the small live traps that were used.

Numbers of species and individuals both increased at the Desert Shrub live-trapping grid. In fact, during the first sampling period a total of 9 species of small rodents was taken. This included those listed in Table 4 as well as an "accidental" capture of an early-rising white-tailed antelope ground squirrel (Ammospermophilus leucurus). Such captures of diurnal species, or of the juvenile desert cottontail (Sylvilagus audubonii) taken at this grid during the fifth sampling period are not considered in any of the following data treatments.

Several species not encountered on the other grids were present on the Cold Desert Shrub site. The most significant of these was the Arizona pocket mouse (Perognathus amplus) which comprised 61 per cent of the sampling occurrences at this site. It apparently replaced the more typically grassland species of small pocket mouse (P. flavus) in this shrubby community. Several other species occurring here were not taken on the other grids.

The western harvest mouse, Reithrodontomys megalotis, often associated with grassland, apparently does not require dense stands of grass and may occur in fairly open desert situations and weedy communities at low population densities. No more than 2 individuals were taken during any one sampling period and a total of only 5 sampling occurrences was recorded for this species.

The Ord kangaroo rat (Dipodomys ordii) occurred sparingly, but consistently on this study grid. This species is widespread throughout the Great Basin Desert (Hall and Kelson, 1959) and seems to prefer sandy soils. The species appears to be patchily distributed at Wupatki National Monument (GCB, pers. obs.), perhaps relating at least somewhat to favorability of edaphic factors.

I have not observed them in areas where cinders form a fairly continuous thick layer.

Onychomys leucogaster, the northern grasshopper mouse, is another widespread species in the Great Basin Desert area. It is unique among small rodents of this region in being primarily carnivorous/insectivorous. Apparently the plant items found in the digestive tracts of these mice, at least in summer, may represent only gut contents of prey of this species (Hansen 1975) but until this is conclusively shown to be the case on the study area the animal should be considered an omnivore, albeit one with a decided preference for animal flesh. Again this species was not abundant, accounting for only 7 of 304 (2.3 per cent) sampling occurrences, but it forms an interesting part of the fauna of small mammals. Studies of its social behavior and foraging ecology in the wild are apparently lacking, but the possibility that members of social groups might on occasion forage cooperatively is an intriguing concept.

The other species unique to this area, Perognathus intermedius (rock pocket mouse) was only encountered in the extreme southeast corner of the quadrat where a small side canyon of Antelope Wash penetrated the grid for a distance of roughly 35 m. With one exception all rock pocket mice (22 sampling occurrences) were within the canyon. The mice always sought shelter beneath the large slabs of sandstone that occurred here. Their propensity to inhabitat such rocky and rubble strewn terrain is indicated by the common name. The single individual occurring away from the canyon was a large, scrotal male which was taken in a trap about 25 m beyond the canyon rim. Perhaps this individual was captured while making a food hunting foray onto the rather flat terrain surrounding the canyon.

The three remaining species Peromyscus truei, P. maniculatus and Neotoma stephensi all occurred also on the Juniper/Grassland grid. Peromyscus truei was fairly important in the desert shrub where it accounted for 18.4 per cent of all sampling occurrences. The woodrat and deer mouse were much less abundant and together made up only 4.6 per cent of the sampling occurrences. It is perhaps significant that of seven individual deer mice on the grid all were males, of these five were taken only during a single period, one occurred during two consecutive periods (the first and second) and another was taken during three different periods. These suggest that these individuals were perhaps at a disadvantage at this site and were unable to establish a fairly stable population.

The Lincoln index estimates of population density parallel rather closely those based upon actual numbers of individuals captured during any single trapping period (Tables 5, 6 and 7). This suggests that most species were fairly susceptible to capture by the techniques used. The index does not give very reliable results for those extremely rare species, such as Reithrodontomys megalotis, since at least one individual had to be captured both nights during the sampling period to get any sort of an estimate. Where estimates are not given in Tables 5, 6 or 7, this indicates this criterion was not met. Since proportions change so quickly when small numbers are involved, such estimates have a high probability of considerable error.

For purposes of evaluating biomass and diversity (see below) the numbers of individuals known to be present, rather than Lincoln Index estimates of density, were used in computation.

## Rodent Activity

A rough index to rodent activity is the number of animals caught in a given amount of trapping effort. This assumes that all species are equally

trappable by the means employed and that methods of trapping are just as effective at one season as they are during another. I've already mentioned the possibility that the traps used were not as efficient in catching woodrats as they were in taking the smaller species; further it may be that the bait was not so attractive at some seasons (e.g. when "natural" food was abundant) as at others.

The per cent trapping success for each of the grids during each sampling period is expressed in Table 8. This index is based upon all captures during the two nights of trapping; hence, the total number of captures in a sampling period was divided by 288 to determine trapping success.

As would be presumed from total population densities expressed above and in Tables 2, 3 and 4, the three grids, in general, were aligned in the order Grassland, Juniper/Grassland and Cold Desert Shrub with regard to increasing overall trapping success. The Cold Desert Shrub, with a single exception, produced the greatest trapping success. The exception occurred during the fifth sampling period when heavy rain struck during the first night of trapping the Desert Shrub Grid, but the other grids, being trapped on different dates, did not receive rain. During the night of rain trapping success fell to 11.80 per cent, whereas on the second night when ground was still quite wet it was back up to a more typical level of 17.36, almost enough to again make it the highest "producer" during this period.

Trends in trapping success are not entirely consistent on each of the grids, but in general the index appeared to decline slightly through time on both the Juniper/Grassland and Cold Desert Shrub areas (Table 8). From late spring through late summer the trend on the Grassland grid was one of general increase with a slight tendency toward stabilization or, perhaps, decline during the early fall periods. At least part of the decline at both Grassland

and Juniper/Grassland is probably attributable to a decrease in activity of Perognathus flavus which may undergo short bouts of torpor during periods of cold weather (Wolff and Bateman, 1977). I have data from an earlier study done in Cedar Canyon indicating that silky pocket mice may disappear from trapping records in fall and winter only to have the same marked individuals reappear the following spring.

Such behavior may reduce trapping success to almost zero for some species even though few individuals have actually been removed from the rodent community extant at the time.

During the last sampling of the Grassland and Juniper/Grassland grids almost all of the silky pocket mice in the traps were torpid when the traps were run at dawn. For this reason it is difficult to successfully execute live trapping studies during winter in this area unless great precautions are made to provide abundant food and bedding materials for trapped individuals.

## Rodent Diversities

The simplest measure of rodent diversity is to count the number of species present in an area. Based upon this method the plant communities Grassland, Juniper/Grassland and Cold Desert Shrub have increasing diversity of rodents in the sequence of two species, four species and eight species.

Another measure of diversity in the Shannon index which takes into account the relative importance (as measured by numbers, biomass, energy transfer, etc) of the species. Using numbers of individuals as a measure of importance the sequence of diversity is in the same order as that given above: Grassland (H'=.7118), Juniper/Grassland (1.6286) and Cold Desert Shrub (1.8250).

When the rodent communities existing in each habitat were examined seasonally changes in diversity were apparent in each case (Table 9).

The decrease in the value of the index during late summer and early fall on the Grassland is attributable to the greatly decreased numbers of captures of Peromyscus maniculatus. Since the community has so few species, only two, a decrease in one causes a similar increase in the other, resulting in a marked drop in the diversity value.

The increase in diversity of the community inhabiting the Juniper/Grassland is due to the addition of Neotoma stephensi which appeared only during the last four sampling periods. Also, the tendency of the pocket mouse and the pinyon mouse to shift their relative importances to more similar levels during the later season was instrumental in causing the observed increase in diversity (Tables 3 and 9).

The rodent community of the Cold Desert Shrub habitat decreased in diversity through time (Table 9). Three species were largely responsible for this decrease in diversity through their decline in abundance during the last four sampling periods. These were the deer mouse, northern grasshopper mouse and Stephens' woodrat. These species comprised 11.2 per cent of the rodent community during late spring and early summer. During late summer and early fall they accounted for only 2.1 per cent of all sampling occurrences. All other species showed relative increases in occurrence during the second season. With decreased evenness in the proportions of individuals contributed by each species in the community a decline in diversity occurs.

Biomass

The number of individuals of each species occurring on the trapping grids per sampling period was determined. By dividing this number by the area sampled it was possible to determine the number of individuals/ha. Multiplying this by the mean body weights for each species and summing products allowed an estimate of biomass to be made.

Rodent biomass was lowest in the Grassland (83.71 gm/ha), intermediate in the Juniper/Grassland (183.68 gm/ha) and highest in the Cold Desert Shrub habitat (239.09 gm/ha). Biomass estimates do place high value on body size and diversity indices calculated using this parameter as a measure of importance would differ somewhat from those based on sheer numbers of individuals. The most striking example of this bias by weight involved the smallest and the largest of the species studied. In the Juniper/Grassland *Perognathus flavus* occurred with *Neotoma stephensi* in a ratio of 17.89 to 1. Owing to the large disparity in body size, however, *P. flavus* accounted for 15.6 per cent of the total body mass, while the much less abundant *N. stephensi* made up 13.78 per cent of the total biomass in this habitat.

The rodents were arbitrarily assigned to generalized feeding categories based upon information in the literature. Such assignment is not without risk in the absence of dietary studies in the area involved. For example, kangaroo rats are often considered as highly specialized granivores with a relatively narrow array of food items being included in the diet. It has recently been shown that some species (e.g. *Dipodomys microps*, Kenagy 1972; and *Dipodomys merriami*, Reichmann 1974) depend heavily upon foliage and, to a lesser extent, insects at certain times.

These difficulties notwithstanding, the heteromyids were all considered granivores; the cricetids, with the exceptions of the harvest mouse and woodrat, were considered omnivores and the two exceptions are here considered straight herbivores. The relative importance, in terms of biomass, of each feeding strategy is demonstrated in Table 11. The most pronounced shift in foraging strategies between habitats involves granivory. For example, in the Grassland 64 per cent of the biomass is supported strictly by granivory, whereas in the Juniper/Grassland only 16 per cent is so supported. This

apparently significant change in the importance of this feeding strategy is partly artifactual. Though strict granivores (i.e. heteromyids) are not very significant, in terms of biomass, in the Juniper/Grassland their dearth is compensated for by the high proportion of omnivorous cricetids, most of which rely heavily on seeds.

## DISCUSSION

Two families (one represented by two subfamilies) and 9 species of small nocturnal rodents are represented at the 3 trapping grids. There was considerable variation in complexity among the rodent communities present in each of the major plant communities.

The Grassland site had the fewest species (two); lowest densities (7.45 individuals/ha); lowest biomass (83.71 gm/ha) and least diversity as measured by Shannon Index, H' of .7118. The silky pocket mouse was the form most typical of this habitat. The only other species taken on this grid was the deer mouse (Peromyscus maniculatus) which was present during all sampling periods in low to moderate densities. Based on limited observations, I do know that deer mice were reproducing in this area as all three females taken during August were lactating. Pocket mice were known to be producing litters from at least May through August based upon the occurrence of lactating females. Also, one female was lactating when captured on 13 July and she was lactating when retaken on 28 Aug. She was not observed to be lactating during intervening trapping periods, thus she almost certainly produced at least two litters that summer. The low diversity in the Grassland is at least partly due to the simplicity of the vegetation in the area. Fewer resource types imply fewer potential niches. Although onsite weather stations were not maintained to monitor microclimatic conditions it is almost certain that small rodents which are active year around above ground in this habitat would encounter the most rigorous environment of

any of the three studied. It is known (GCB, unpublished data) that above ground activity of the silky pocket mouse is greatly curtailed during the colder months. Undoubtedly the uncensused pocket gopher (Thomomys bottae) and spotted ground squirrel (Spermophilus spilosoma) partially make up for the relative paucity of nocturnal primary consumers in this area. The former species is well-equipped to cope with extremes present here by its fossorial behavior and the latter by avoiding them since it hibernates during long cold periods.

Though biomass of small mammals in this area is apparently low (83.71 gm/ha) it falls well within the wide range for this measure given by French et al. (1976) who published extreme values of 3,075 gm/ha to 14 gm/ha for other grassland sites. It should be noted that these authors also included diurnal species in their computations.

The Juniper/Grassland site had both species which occurred at the Grassland as well as two additional species, Peromyscus truei and Neotoma stephensi. These latter forms are typically associated with shrubs and/or trees and it is not surprising that they did not occur in the Grassland area proper. Not only was the absolute number of species higher here than in the Grassland but density and biomass were also higher. The fact that density increased just slightly from 7.45 individuals/ha in Grassland to 9.00/ha in the Juniper/Grassland while comparable biomass figures are 83.71 gm/ha and 183.68 gm/ha indicated that the "average" small mammal in Juniper/Grassland is roughly twice as large as its counterpart in Grassland. The pinyon mouse, P. truei was the most abundant (3.84/ha) small mammal taken in this habitat. Its density and relatively large size ($\bar{x}$ body weight=24.2 gm) explain how it accounted for just over 50 per cent of the small mammal biomass in this area. This species is largely responsible for the apparent shift from granivory as the important dietary strategy in the

Grassland to omnivory as the important feeding tactic in the Juniper/Grassland. The diversity index increased greatly here (H'=1.6286) as compared to the Grassland site (.7118) and showed a seasonal tendency to increase (Table 9). This increase was related to the decrease in the proportion of the community comprised of P. truei and the relative increase in abundance of the silky pocket mouse. It was also related to the appearance on the grid of woodrats during late summer and fall. The woodrat may be a more significant component of the Juniper/Grassland community than was indicated by these results. Different traps might have enhanced opportunities of capture and the absence of shrubs from the area studied would likely have significantly lowered Neotoma densities (see Kuch, 1969).

The richest and most diverse community was the Cold Desert Shrub. This finding was expected, but would likely be a surprise to the average Monument visitor, most of whom would probably "bet on" the Juniper/Grassland, since it is a forest of sorts.

The Cold Desert Shrub exceeded the other study sites in all respects. It had eight species of rodents, whereas the others had only one half as many. Density (13.41/ha) and biomass (239.09 gm/ha) both increased as well in this area. A species not encountered on the other plots, Perognathus amplus, was numerically superior here (8.20/ha) and contributed 86.1 gm/ha to the total biomass (239.09 gm/ha) in this area. Thus, this single species provided more biomass at this site than did all species (only two present) at the Grassland grid.

The complexity in the rodent community in the Cold Desert Shrub parallels and is related to, the vegetational complexity of the area. Variations in soil type and topographic features probably underlie these increases in diversity. As examples of the effect of local conditions upon diversity

within this community type are the presence of the rock pocket mouse (Perognathus intermedius) and Stephens' woodrat (Neotoma stephensi on the trapping grid. The former species almost certainly and the latter species probably would not have occurred in the sampled rodent community if not for the presence of the small side arroyo of Antelope Wash at the extreme corner of the grid. These species were definitely and distinctly associated with the clumps of sandstone blocks which had broken from the outcrops as well as the crevices within the formation itself. Though it might be argued, therefore, that their presence in this community is "artifactual" and they should not be included as present on the grid, the point is better taken that the Cold Desert Shrub plant community is rich in such localized microhabitats. The very restricted nature of such sites makes them difficult to study on a large scale. They operate, in a sense, as small islands within a relatively vast sea of fairly homogeneous, yet distinctively different terrain. It would be most instructive to study populations inhabiting such sites with regard to their structure, aspects of social behavior, gene flow and modes of dispersal through "foreign" terrain. Almost certainly much new biological information could be accrued.

A diversity index computed using proportions of biomass supported by various feeding strategies does, as expected, support the view that the cold desert shrub is more complex in this regard (H'=1.3633) than are either of the other communities (Grassland=.9444; Juniper/Grassland=1.1670). Since the best measure of stability is often a measure of complexity, it is expected that the most stable community would be the Cold Desert Shrub. Care must be taken, of course, in applying these conclusions rigorously owing to the rough categorization of food habits and a number of other assumptions made in coming to this conclusion, but the conclusion does seem a reasonable

one. Certainly the plant and small mammal communities considered in this report are fragile and great care must be taken in their administration.

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TABLE 1. Dates of live-trapping during 1976 on each small mammal grid. Sampling periods are given the date of the first morning on which animals were examined.

| Sampling Period | Grassland | Juniper/Grassland | Cold Desert Shrub |
|---|---|---|---|
| 1 | 31 May | 31 May | 25 May |
| 2 | 19 June | 19 June | 14 June |
| 3 | 30 June | 30 June | 28 June |
| 4 | 13 July | 13 July | 11 July |
| 5 | 28 July | 28 July | 18 July |
| 6 | 28 Aug | 28 Aug | 21 Aug |
| 7 | 10 Oct | 10 Oct | 18 Sept |

TABLE 2. Total numbers of individuals present on the Grassland grid during each of the sampling periods

| Sampling Period | *Perognathus flavus* | | *Peromyscus maniculatus* | | Totals |
|---|---|---|---|---|---|
| | ♂/♀ | both | ♂/♀ | both | |
| 1 | 7/2 | 9 | 7/2 | 9 | 18 |
| 2 | 13/5 | 18 | 4/2 | 6 | 24 |
| 3 | 10/10 | 20 | 2/4 | 6 | 26 |
| 4 | 12/9 | 21 | 2/0 | 2 | 23 |
| 5 | 18/8 | 26 | 2/2 | 4 | 30 |
| 6 | 11/9 | 20 | 2/3 | 5 | 25 |
| 7 | 15/7 | 22 | 1/0 | 1 | 23 |
| Totals | | 136 | | 33 | 169 |

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

| Sampling Period | *Perognathus flavus* | | *Peromyscus maniculatus* | | *Peromyscus truei* | | *Neotoma stephensi* | | Totals |
|---|---|---|---|---|---|---|---|---|---|
| | ♂/♀ | both | ♂/♀ | both | ♂/♀ | both | ♂/♀ | both | |
| 1 | 5/1 | 6 | 6/4 | 10 | 9/9 | 18 | | - | 34 |
| 2 | 7/2 | 9 | 3/4 | 7 | 8/9 | 17 | | - | 33 |
| 3 | 8/3 | 11 | 3/5 | 8 | 11/8 | 19 | | - | 38 |
| 4 | 10/2 | 12 | 2/4 | 6 | 6/3 | 9 | 0/1 | 1 | 28 |
| 5 | 10/9 | 19 | 1/2 | 3 | 4/6 | 10 | 1/1 | 2 | 34 |
| 6 | 6/5 | 11 | 2/2 | 4 | 5/4 | 9 | | - | 24 |
| 7 | 3/2 | 5 | 1/1 | 2 | 2/3 | 5 | 0/1 | 1 | 13 |
| Totals | | 73 | | 40 | | 87 | | 4 | 204 |

| Sampling Period |
| --- |
| 1 |

TABLE 5. Lincoln Index population estimates for species of small mammals occurring on the Grassland trapping grid

| Sampling Period | *Perognathus flavus* | *Peromyscus maniculatus* |
|---|---|---|
| 1 | 21.0 ± 17.1 | 8.8 ± 2.0 |
| 2 | 21.0 ± 4.9 | 8.0 ± 4.0 |
| 3 | 29.8 ± 9.7 | 6.7 ± 2.4 |
| 4 | 30.6 ± 9.1 | 2.0 ± 0 |
| 5 | 32.0 ± 7.2 | 4.0 ± 2.0 |
| 6 | 31.2 ± 10.7 | 9.0 ± 7.3 |
| 7 | 18.3 ± 1.7 | 1.0 ± 0 |

TABLE 6. Lincoln Index population estimates for species of small mammals occurring on the Juniper/Grassland trapping grid. An asterisk indicates the species present on the grid during this period but no Lincoln Index estimate is available.

| Sampling Period | *Perognathus flavus* | *Peromyscus maniculatus* | *Peromyscus truei* | *Neotoma stephensi* |
|---|---|---|---|---|
| 1 | 8.0 ± 5.7 | 12.0 ± 4.2 | 19.1 ± 2.7 | |
| 2 | 12.0 ± 4.9 | 6.7 ± 2.4 | 19.5 ± 4.3 | |
| 3 | 16.0 ± 6.5 | 8.4 ± 2.0 | 22.8 ± 5.3 | |
| 4 | 13.3 ± 2.7 | * | 10.5 ± 3.0 | * |
| 5 | 22.5 ± 5.4 | 3.0 ± 0 | 14.0 ± 5.7 | * |
| 6 | 11.0 ± 2.0 | 4.0 ± 0 | 10.5 ± 3.0 | |
| 7 | 5.0 ± 1.1 | * | 6.0 ± 2.4 | * |

TABLE 7. Lincoln Index population

on the Cold Desert Shrub trapping grid.

this period but no Li

| Sampling Period | *Dipodomys ordii* | *Perognathus amplus* | *Perognathus intermedius* | *Pe ma* |
|---|---|---|---|---|
| 1 | 2.0 ± 0 | 29.1 ± 2.8 | 3.0 ± 2.4 | |

TABLE 8. 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 | 7.64 | 17.36 | 28.47 | 17.82 |
| 2 | 11.80 | 16.32 | 28.47 | 18.86 |
| 3 | 10.41 | 18.75 | 27.43 | 18.86 |
| 4 | 10.76 | 13.19 | 18.75 | 14.23 |
| 5 | 14.58 | 17.70 | 14.24 | 15.51 |
| 6 | 11.46 | 13.54 | 25.35 | 16.78 |
| 7 | 13.19 | 6.60 | 21.52 | 13.77 |
| Mean per cent trap success | 11.41 | 14.78 | 23.46 | |

TABLE 9. Shannon Diversity Indices for communities of nocturnal rodents existing in each of the three major plant communities

| | Grassland | Juniper/Grassland | Cold Desert Shrub |
|---|---|---|---|
| Spring and Early Summer | .8920 | 1.4858 | 1.9149 |
| Late Summer and Early Fall | .5264 | 1.6373 | 1.6684 |
| Overall Value of H' | .7118 | 1.6286 | 1.8250 |

Dipodomya

Perognath

TABLE 11. The percent of the biomass in each habitat type that is supported by the three general feeding strategies: herbivory, granivory and omnivory

| | Habitats | | |
|---|---|---|---|
| Feeding Strategy | Grassland | Juniper/Grassland | Cold Desert Shrub |
| herbivory | 0 | 13.8 | 11.6 |
| granivory | 63.8 | 15.6 | 55.0 |
| omnivory | 36.2 | 70.6 | 33.4 |

# APPENDIX A

# A CHECKLIST OF THE VASCULAR PLANTS OF SUNSET CRATER AND WUPATKI NATIONAL MONUMENTS

James M. Rominger, Botanist

December 1, 1976

POLYPODIACEAE - Fern Family

| | |
|---|---|
| Asplenium septentrionale | S |
| Cheilanthes feei | S,W |
| Dryopteris filix-mas | S |
| Pellaea atropurpurea | S |
| Woodsia mexicana | S |

PINACEAE - Pine Family

| | |
|---|---|
| Pinus edulis | S,W |
| Pinus flexilis | S |
| Pinus monophylla | S |
| Pinus ponderosa | S |
| Pseudotsuga menziesii | S |

CUPRESSACEAE - Cypress Family

| | |
|---|---|
| Juniperus deppeana | S |
| Juniperus monosperma | W |
| Juniperus osteosperma | S |

EPHEDRACEAE - Jointfir Family

| | |
|---|---|
| Ephedra torreyana | W |
| Ephedra viridis | W |
| Ephedra viridis var. viscida (E. cutleri) | W |

GRAMINEAE - Grass Family

| | |
|---|---|
| Angropyron smithii | S |
| Andropogon barbinodis | W |
| Andropogon hallii | S,W |
| Andropogon scoparius | S |
| Aristida barbata | W |
| Aristida divaricata | S |
| Aristida fendleriana | W |
| Aristida longiseta | W |
| Aristida purpurea | W |
| Blepharoneuron tricholepis | S |
| Bouteloua barbata | W |
| Bouteloua curtipendula | W |
| Bouteloua eriopoda | W |
| Bouteloua gracilis | S,W |
| Bromus porteri (B. anomalus) | S |
| Bromus tectorum | S |
| Distichlis stricta | W |
| Enneapogon desvauxii | W |
| Eragrostis diffusa | S |
| Festuca arizonica | S |
| Hilaria jamesii | S,W |

| | |
|---|---|
| *Hordeum jubatum* | S |
| *Muhlenbergia minutissima* | S |
| *Muhlenbergia montana* | S |
| *Muhlenbergia porteri* | W |
| *Muhlenbergia rigens* | S |
| *Oryzopsis hymenoides* | S,W |
| *Phragmites communis* | W |
| *Poa fendleriana* | S |
| *Scleropogon brevifolius* | W |
| *Setaria leucopila* | W |
| *Sitanion longifolium* (*S. hystrix*) | S,W |
| *Sporobolus airoides* | W |
| *Sporobolus flexuosus* | S,W |
| *Sporobolus giganteus* | W |
| *Stipa arida* | W |
| *Stipa comata* | S,W |
| *Stipa neomexicana* | W |
| *Stipa speciosa* | W |
| *Tridens pulchellus* | W |
| CYPERACEAE - Sedge Family | |
| *Carex occidentalis* | S |
| *Cyperus fendleriana* | S |
| COMMELINACEAE - Spiderwort Family | |
| *Commelina dianthifolia* | S |
| LILIACEAE - Lily Family | |
| *Androstephium breviflorum* | S |
| *Yucca angustissima* (*Y. navahoa*) | S,W |
| SALICACEAE - Willow Family | |
| *Populus fremontii* | W |
| *Populus tremuloides* | S |
| *Salix laevigata* | S |
| *Salix scouleriana* | W |
| LORANTHACEAE - Mistletoe Family | |
| *Phoradendron juniperinum* | W |

POLYGONACEAE - Buckwheat Family

| | |
|---|---|
| Eriogonum aureum | S,W |
| Eriogonum corymbosum | W |
| Eriogonum corymbosum var. glutinosum | S,W |
| Eriogonum deflexum | W |
| Eriogonum divaricatum | W |
| Eriogonum hookeri | W |
| Eriogonum inflatum | W |
| Eriogonum jonesii | W |
| Eriogonum leptocladon | W |
| Eriogonum racemosum | S |
| Eriogonum wetherillii | W |

CHENOPODIACEAE - Goosefoot Family

| | |
|---|---|
| Allenrolfea occidentalis | W |
| Atriplex canescens | W |
| Atriplex confertifolia | W |
| Atriplex obovata (A. jonesii) | W |
| Chenopodium album | S |
| Chenopodium fremontii | W |
| Chenopodium graveolens (C. incisum) | S |
| Chenopodium hians | W |
| Chenopodium leptophyllum | W |
| Eurotia lanata | W |
| Salsola kali | S,W |
| Sarcobatus vermiculatus | W |
| Suaeda torreyana | W |

AMARANTHACEAE - Pigweed Family

| | |
|---|---|
| Amaranthus albus | W |
| Amaranthus graecizans | W |
| Amaranthus retroflexus (A. powellii) | S |

NYCTAGINACEAE - Four-o'clock Family

| | |
|---|---|
| Abronia elliptica | W |
| Allionia incarnata | W |
| Boerhaavia coulteri | W |
| Boerhaavia torreyana | W |
| Boerhaavia wrightii | W |
| Mirabilis multiflora | W |
| Oxybaphus linearis | S |
| Tripterocalyx micranthus | W |

PORTULACACEAE - Purslane Family

| | |
|---|---|
| Portulaca mundula | W |
| Portulaca retusa | W |

CARYOPHYLLACEAE - Pink Family

| | |
|---|---|
| *Arenaria eastwoodiae* | W |
| *Drymaria tenella* | S |

BERBERIDACEAE - Barberry Family

| | |
|---|---|
| *Berberis fremontii* | S |
| *Berberis repens* | S |

RANUNCULACEAE - Buttercup Family

| | |
|---|---|
| *Delphinium scaposum* | S |
| *Thalictrum fendleri* | S |

PAPAVERACEAE - Poppy Family

| | |
|---|---|
| *Corydalis aurea* | S |

CRUCIFERAE - Mustard Family

| | |
|---|---|
| *Arabis fendleri* | S |
| *Descurainia obtusa* | S |
| *Descurainia pinnata* | W |
| *Dithyrea wislizeni* | W |
| *Erysimum capitatum* | S |
| *Lesquerella arizonicum* | W |
| *Lesquerella intermedia* | S,W |
| *Physaria newberryi* | S |
| *Sisymbrium altissimum* | S,W |
| *Sisymbrium linearifolium* | S |
| *Stanleya pinnata* | W |
| *Streptanthella longirostris* | W |

CAPPARIDACEAE - Capter Family

| | |
|---|---|
| *Cleome serrulata* | S,W |
| *Polanisia trachysperma* | W |
| *Wislizenia refracta* | W |

SAXIFRAGACEAE - Saxifrage Family

| | |
|---|---|
| *Heuchera parvifolia* | S |
| *Lithophragma tenella* | S |
| *Ribes cereum* | S,W |
| *Ribes pinetorum* | S |
| *Ribes viscosissimum* | S |

ROSACEAE - Rose Family

| | |
|---|---|
| *Amelanchier utahensis* | S |
| *Cowania mexicana* | W |
| *Fallugia paradoxa* | S,W |
| *Holodiscus dumosus* | S |
| *Petrophytum caespitosum* | W |
| *Rosa arizonica* | S |

LEGUMINOSAE - Pea Family

| | |
|---|---|
| *Alhagi camelorum* | W |
| *Astragalus amphioxus* | W |
| *Astragalus episcopus* | W |
| *Astragalus humistratus* | S |
| *Astragalus lancearius* | W |
| *Astragalus lentiginosus* | W |
| *Astragalus praelongus* | W |
| *Astragalus recurvus* | S |
| *Astragalus tephrodes* | S,W |
| *Astragalus wootoni* | W |
| *Calliandra humilis* | S |
| *Cassia bauhinioides* | W |
| *Dalea filiformis* | W |
| *Dalea terminalis* | W |
| *Dalea whitingii* | W |
| *Hoffsmaneggia drepanocarpa* | W |
| *Hoffmanseggia jamesii* | W |
| *Lathyrus leucanthus* | S |
| *Lotus wrightii* | W |
| *Lupinus kingii* | S |
| *Lupinus palmeri* | S |
| *Melilotus alba* | S |
| *Oxytropis lambertii* | S |
| *Parryella filifolia* | W |
| *Phaseolus angustissimus* | S,W |
| *Psoralea lanceolata* | S |
| *Thermopsis pinetorum* | S |

GERANIACEAE - Geranium Family

| | |
|---|---|
| *Erodium cicutarium* | S |
| *Geranium caespitosum* | S |

LINACEAE - Flax Family

| | |
|---|---|
| *Linum aristatum* | S |
| *Linum lewisii* | S |

ZYGOPHYLLACEAE - Caltrop Family

| | |
|---|---|
| Kallstroemia californica | W |
| Kallstroemia parviflora | W |
| Tribulus terrestris | W |

EUPHORBIACEAE - Sponge Family

| | |
|---|---|
| Croton texensis | W |
| Euphorbia albomarginata | W |
| Euphorbia fendleri | S,W |
| Euphorbia lurida | S |
| Euphorbia micromera | W |
| Euphorbia parryi | W |
| Euphorbia revoluta | W |
| Euphorbia serpyllifolia | W |
| Tragia stylaris (T. nepetaefolia) | S,W |

ANACARDIACEAE - Sumac Family

| | |
|---|---|
| Rhus trilobata | S,W |

MALVACEAE - Mallow Family

| | |
|---|---|
| Abutilon parvulum | W |
| Sphaeralcea fendleri | S |
| Sphaeralcea grossulariaefolia | W |
| Sphaeralcea leptophylla | W |
| Sphaeralcea parvifolia | W |
| Sphaeralcea subhastata | W |

TAMARICACEAE - Tamarix Family

| | |
|---|---|
| Tamarix pentandra | W |

LOASACEAE - Stickleaf Family

| | |
|---|---|
| Mentzelia albicaulis | W |
| Mentzelia pumila | S,W |

CACTACEAE - Cactus Family

| | |
|---|---|
| Coryphantha vivipara | W |
| Echinocereus fendleri | W |
| Opuntia macrorhiza (O. compressa) | S,W |
| Opuntia whipplei | W |
| Pediocactus simpsonii | W |

ONAGRACEAE - Evening-primrose Family

| | |
|---|---|
| Gaura coccinea | S,W |
| Gaura gracilis | S |
| Oenothera boothii | W |
| Oenothera caespitosa | S |
| Oenothera lavandulaefolia | W |
| Oenothera pallida | W |
| Oenothera runcinata | W |
| Oenothera walkeri | W |

UMBELLIFERAE - Carrot Family

| | |
|---|---|
| Cymopterus bulbosus | W |
| Cymopterus multinervatus | W |
| Cymopterus purpurascens | W |
| Lomatium macdougalii | S |

PRIMULACEAE - Primrose Family

| | |
|---|---|
| Androsace septentrionalis | S |

OLEACEAE - Olive Family

| | |
|---|---|
| Forestiera neomexicana | S,W |
| Menodora scabra | S |

APOCYNACEAE - Dogbane Family

| | |
|---|---|
| Amsonia eastwoodiana | W |
| Amsonia jonesii | W |
| Amsonia palmeri | W |
| Amsonia peeblesii | W |

ASCLEPIADACEAE - Milkweed Family

| | |
|---|---|
| Asclepias engelmanniana | S |
| Asclepias involucrata | W |
| Asclepias latifolia | S,W |
| Asclepias subverticillata | S,W |

CONVOLVULACEAE - Morning Glory Family

| | |
|---|---|
| Evolvulus pilosus | W |
| Ipomoea plumerae | S |

POLEMONIACEAE - Phlox Family

| | |
|---|---|
| Gilia aggregata | S |
| Gilia gunnisoni | W |
| Gilia hutchinsifolia | W |
| Gilia leptomeria | W |

| | |
|---|---|
| Gilia longiflora | S,W |
| Gilia multiflora | W |
| Gilia opthalmoides (G. tenuiflora) | W |
| Gilia polycladon | W |
| Gilia sinuata | W |
| Microsteris gracilis | S |
| Phlox woodhousei | S |

HYDROPHYLLACEAE - Waterleaf Family

| | |
|---|---|
| Nama dichotomum | W |
| Nama hispida | W |
| Phacelia crenulata | W |
| Phacelia integrifolia | S,W |
| Phacelia magellanica | S |
| Phacelia serrata | S |
| Phacelia welshii | W |

BORAGINACEAE - Borage Family

| | |
|---|---|
| Coldenia hispidissima | W |
| Coldenia nuttallii | W |
| Cryptantha crassisepala | W |
| Cryptantha fendleri | S |
| Cryptantha jamesii | S,W |
| Cryptantha pterocarya | W |
| Heliotropium curassavicum | W |
| Lappula redowskii | W |
| Lithospermum incisum | S,W |
| Lithospermum multiflorum | S |

VERBENACEAE - Vervain Family

| | |
|---|---|
| Aloysia wrightii | W |
| Tetraclea coulteri | W |
| Verbena bracteata | S |
| Verbena gooddingii | W |
| Verbena macdougalii | S |
| Verbena wrightii | W |

LABIATAE - Mint Family

| | |
|---|---|
| Hedeoma drummondii | W |
| Hedeoma nanum | W |
| Marrubium vulgare | S,W |
| Monarda pectinata | S |
| Monardella odoratissima | S |
| Poliomintha incana | W |

SOLANACEAE - Nightshade Family

| | |
|---|---|
| *Chamaesaracha coronopus* | W |
| *Datura meteloides* | W |
| *Lycium andersoni* | W |
| *Lycium pallidum* | W |
| *Nicotiana attenuata* | W |
| *Nicotiana trigonophylla* | W |
| *Physalis fendleri* | S,W |
| *Physalis hederaefolia* | W |
| *Solanum elaeagnifolium* | W |

SCROPHULARIACAE - Figwort Family

| | |
|---|---|
| *Castilleja chromosa* | W |
| *Castilleja integra* | S,W |
| *Castilleja linariaefolia* | W |
| *Mimulus guttatus* | W |
| *Mimulus rubellus* | W |
| *Penstemon ambiguus* | W |
| *Penstemon barbatus* | S |
| *Penstemon clutei* | S |
| *Penstemon jamesii* | S |
| *Penstemon linarioides* | S |
| *Penstemon virgatus* | S |
| *Verbascum thapsus* | S,W |

OROBANCHACEAE - Broomrape Family

| | |
|---|---|
| *Orobanche fasciculata* | S |

RUBIACEAE - Madder Family

| | |
|---|---|
| *Galim wrightii* (*G. rothrockii*) | S |

CAPRIFOLIACEAE - Honeysuckle Family

| | |
|---|---|
| *Symphoricarpos oreophilus* | W |

CUCURBITACEAE - Gourd Family

| | |
|---|---|
| *Cucurbita foetidissima* | W |

COMPOSITAE - Composite Family

| | |
|---|---|
| *Ambrosia artemisiifolia* | W |
| *Artemisia bigelovii* | W |
| *Artemisia caruthii* | S |
| *Artemisia dracunculoides* | S |
| *Artemisia filifolia* | W |
| *Artemisia frigida* | W |
| *Artemisia ludoviciana* | W |
| *Artemisia pacifica* | S |

| | |
|---|---|
| Aster arenosus | S,W |
| Aster canescens | S,W |
| Aster spinosus | W |
| Aster tephrodes | W |
| Baccharis pteronioides | W |
| Baccharis wrightii | W |
| Bahia dissecta | S |
| Brickellia californica | S,W |
| Brickellia grandiflora | S |
| Brickellia oblongifolia | W |
| Brickellia scabra | W |
| Chaenactis macrantha | W |
| Chaenactis stevioides | W |
| Chrysopsis foliosa | S |
| Chrysothamnus nauseosus | S,W |
| Chrysothamnus viscidiflorus | W |
| Cirsium arizonicum | W |
| Cirsium pulchellum | S,W |
| Conyza schiedeana (Erigeron schiedeana) | S |
| Dicoria canescens | W |
| Dyssodia pentachaeta | W |
| Encelia frutescens var. resinosa | W |
| Erigeron concinnus | S,W |
| Erigeron divergens | S,W |
| Franseria acanthicarpa | W |
| Gaillardia pinnatifida | S,W |
| Gutierrezia microcephala (G. lucida) | W |
| Gutierrezia sarothrae | S,W |
| Haplopappus heterophyllus | W |
| Helianthus petiolaris | S,W |
| Hymenopappus lugens | S |
| Hymenoxys acaulis | S |
| Hymenoxys bigelovii | S |
| Hymenoxys richardsoni | S |
| Iva axillaris | W |
| Kuhnia rosmarinifolia | S |
| Lactuca seriola | S |
| Lygodesmia spinosa | S,W |
| Malacothrix sonchoides | W |
| Malacothrix torreyi | W |
| Pericome caudata | W |
| Psilostrophe sparsiflora | S,W |
| Sanvitalia aberti | W |
| Senecio longilobus | S,W |
| Senecio multicapitatus | S,W |
| Senecio multilobatus (S. uintahensis) | S,W |
| Senecio spartioides | S,W |
| Solidago sparsiflora | S |
| Stephanomeria pauciflora | W |
| Stephanomeria tenuifolia | W |
| Stephanomeria thurberi | S |
| Taraxacum officinale | S |
| Tetradymia canescens | W |
| Townsendia incana | S,W |
| Tragopogon dubius | S,W |
| Verbesina encelioides | S |
| Viguiera multiflora | S |

| | |
|---|---|
| *Xanthium strumarium* (*X. saccharatum*) | W |
| *Zinnia grandiflora* | W |

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APPENDIX B

# A CHECKLIST OF AMPHIBIANS AND REPTILES OF SUNSET CRATER AND WUPATKI NATIONAL MONUMENTS

February 1976

Compiled by:
Gary C. Bateman

# INTRODUCTION

This checklist of the amphibians and reptiles of Sunset Crater and Wupatki National Monuments was compiled through use of collections at the Museum of Northern Arizona and the Northern Arizona University Museum of Vertebrates. This list includes five species of Amphibia representing three families and 27 species of Reptilia representing five families. It is expected that further collecting will reveal the presence of several additional forms.

| | | REMARKS |
|---|---|---|
| URODELA | | |
| AMBYSTOMIDAE | | |
| *Ambystoma tigrinum* | Tiger Salamander | E |
| ANURA | | |
| PELOBATIDAE | | |
| *Scaphiopus hammondi* | Western Spadefoot | |
| BUFONIDAE | | |
| *Bufo woodhousei* | Woodhouse's Toad | E |
| *Bufo cognatus* | Great Plains Toad | |
| *Bufo punctatus* | Red-Spotted Toad | |
| SQUAMATA | | |
| IGUANIDAE | | |
| *Holbrookia maculata* | Lesser Earless Lizard | |
| *Crotaphytus wislizeni* | Leopard Lizard | |
| *Crotaphytus collaris* | Collared Lizard | |
| *Sceloporus magister* | Desert Spiny Lizard | |
| *Sceloporus undulatus* | Eastern Fence Lizard | |
| *Uta stansburiana* | Side-Blotched Lizard | |
| *Urosaurus ornatus* | Tree Lizard | E |
| *Phrynosoma douglassi* | Short-Horned Lizard | |
| SCINCIDAE | | |
| *Eumeces obsoletus* | Great Plains Skink | E |
| *Eumeces multivirgatus* | Many-Lined Skink | E |

| | | |
|---|---|---|
| TEIIDAE | | |
| *Cnemidophorus tigris* | Western Whiptail | E |
| *Cnemidophorus velox* | Plateau Whiptail | |
| *Cnemidophorus inornatus* | Little Striped Whiptail | |
| COLUBRIDAE | | |
| *Masticophis taeniatus* | Striped Whipsnake | |
| *Salvadora hexalepsis* | Western Patch-Nosed Snake | |
| *Pituophis melanoleucus* | Gopher Snake | |
| *Arizona elegans* | Glossy Snake | |
| *Lampropeltis triangulum* | Milk Snake | |
| *Lampropeltis getulus* | Common Kingsnake | E |
| *Thamnophis cyrtopsis* | Black-Necked Garter Snake | |
| *Thamnophis elegans* | Western Terrestrial Garter Snake | |
| *Hypsiglena torquata* | Night Snake | |
| CROTALIDAE | | |
| *Crotalus molossus* | Black-Tailed Rattlesnake | E |
| *Crotalus viridis* | Western Rattlesnake | |

Note: E indicates species which have not actually been collected from either of the Monuments, but which have been taken very nearby from habitats which are similar to those within the study areas.

APPENDIX C

# A CHECKLIST OF BIRDS OF SUNSET CRATER AND WUPATKI NATIONAL MONUMENTS

Russell P. Balda, Director

Lynn Beatty, Research Assistant

February 18th, 1976

# INTRODUCTION

This checklist of the birds of Sunset Crater and Wupatki National Monuments was compiled from a survey of birds at the Museum of Northern Arizona, and from the available literature. There are 113 species known to inhabit this area encompassing 34 families and 12 orders.

| | |
|---|---|
| ANSERIFORMES | |
| ANATIDAE - Ducks | |
| Mallard | *Anas platyrhynchos* |
| FALCONIFORMES | |
| ACCIPITRIDAE - Hawks & Eagles | |
| Goshawk | *Accipiter gentilis* |
| Sharp-shinned Hawk | *Accipiter striatus* |
| Cooper's Hawk | *Accipiter cooperii* |
| Red-tailed Hawk | *Buteo jamaicensis* |
| Rough-legged Hawk | *Buteo lagopus* |
| Golden Eagle | *Aquila chrysaetos* |
| Marsh Hawk | *Circus cyaneus* |
| FALCONIDAE - Falcons | |
| Prairie Falcon | *Falco mexicanus* |
| Sparrow Hawk | *Falco sparverius* |
| GALLIFORMES | |
| MELEAGRIDIDAE - Turkeys | |
| Turkey | *Meleagris gallopavo* |
| GRUIFORMES | |
| RALLIDAE - Rails & Coots | |
| American Coot | *Fulica americana* |
| CHARADRIIFORMES | |
| SCOLOPACIDAE - Sandpipers | |
| Spotted Sandpiper | *Actitis macularia* |
| Lesser Yellowlegs | *Tringa flavipes* |
| LARIDAE - Gulls | |
| Sabine's Gull | *Xema sabini* |

PICIFORMES - Woodpeckers

PICIDAE

| | |
|---|---|
| Common Flicker | Colaptes auratus |
| Lewis's Woodpecker | Melanerpes lewis |
| Yellow-bellied Sapsucker | Sphyrapicus varius |
| Williamson's Sapsucker | Sphyrapicus thyroideus |
| Hairy Woodpecker | Picoides villosus |

PASSERIFORMES

TYRANNIDAE - Tyrant Flycatchers

| | |
|---|---|
| Western Kingbird | Tyrannus verticalis |
| Cassin's Kingbird | Tyrannus vociferans |
| Ash-throated Flycatcher | Myiarchus cinerascens |
| Black Phoebe | Sayornis nigricans |
| Say's Phoebe | Sayornis saya |
| Gray Flycatcher | Empidonax wrightii |
| Western Wood Pewee | Contopus sordidulus |

ALAUDIDAE - Larks

| | |
|---|---|
| Horned Lark | Eremophila alpestris |

HIRUNDINIDAE - Swallows

| | |
|---|---|
| Violet-green Swallow | Tachycineta thalassina |

CORVIDAE - Jays, Magpies, Crows

| | |
|---|---|
| Steller's Jay | Cyanocitta stelleri |
| Scrub Jay | Aphelocoma coerulescens |
| Common Raven | Corvus corax |
| Common Crow | Corvus brachyrhynchos |
| Piñon Jay | Gymnorhinus cyanocephalus |
| Clark's Nutcracker | Nucifraga columbiana |

| | |
|---|---|
| PARIDAE | |
| Mountain Chickadee | Parus gambeli |
| Plain Titmouse | Parus inornatus |
| Common Bushtit | Pasltriparus minimus |
| SITTIDAE - Nuthatches | |
| White-breasted Nuthatch | Sitta carolinensis |
| Red-breasted Nuthatch | Sitta canadensis |
| Pygmy Nuthatch | Sitta pygmaea |
| CERTHIIDAE - Creepers | |
| Brown Creeper | Certhia familiaris |
| TROGLODYTIDAE - Wrens | |
| House Wren | Troglodytes aedon |
| Canon Wren | Catherpes mexicanus |
| Rock Wren | Salpinctes obsoletus |
| MIMIDAE - Mockingbirds, Thrashers | |
| Mockingbird | Mimus polyglottos |
| Crissal Thrasher | Toxostoma dorsale |
| Sage Thrasher | Oreoscoptes montanus |
| TURDIDAE - Thrushes | |
| Robin | Turdus migratorius |
| Western Bluebird | Sialia mexicana |
| Mountain Bluebird | Sialia currucoides |
| Townsend's Solitaire | Myadestes townsendi |
| SYLVIIDAE - Kinglets | |
| Blue-gray Gnatcatcher | Polioptila caerulea |
| Ruby-crowned Kinglet | Regulus calendula |

| | |
|---|---|
| COLUMBIFORMES | |
| COLUMBIDAE - Pigeons & Doves | |
| Band-tailed Pigeon | *Columba fasciata* |
| Mourning Dove | *Zenaida macroura* |
| STRIGIFORMES - Owls | |
| STRIGIDAE | |
| Screech Owl | *Otus asio* |
| Great Horned Owl | *Bubo virginianus* |
| Pygmy Owl | *Glaucidium gnoma* |
| Long-eared Owl | *Asio otus* |
| Saw-whet Owl | *Aegolius acadicus* |
| CAPRIMULGIFORMES - Goatsuckers | |
| CAPRIMULGIDAE | |
| Poor-will | *Phalaenoptilus nuttallii* |
| Common Nighthawk | *Chordeiles minor* |
| APODIFORMES | |
| APODIDAE - Swifts | |
| White-throated Swift | *Aeronautes saxatalis* |
| TROCHILIDAE - Hummingbirds | |
| Black-chinned Hummingbird | *Archilochus alexandri* |
| Broad-tailed Hummingbird | *Selasphorus platycercus* |
| Rufous Hummingbird | *Selasphorus rufus* |
| Calliope Hummingbird | *Stellula calliope* |
| CORACIIFORMES - Kingfishers | |
| ALCEDINIDAE | |
| Belted Kingfisher | *Megaceryle alcyon* |

| | |
|---|---|
| BOMBYCILLIDAE - Waxwings | |
| Bohemian Waxwing | Bombycilla garrulus |
| Cedar Waxwing | Bombycilla cedrorum |
| PTILOGONATIDAE - Silky Flycatchers | |
| Phainopepla | Phainopepla nitens |
| LANIIDAE - Shrikes | |
| Loggerhead Shrike | Lanius ludovicianus |
| STURNIDAE - Starlings | |
| Starling | Sturnus vulgaris |
| VIREONIDAE - Vireos | |
| Gray Vireo | Vireo vicinior |
| Solitary Vireo | Vireo solitarius |
| PARULIDAE - Wood Warblers | |
| Orange-crowned Warbler | Vermivora celata |
| Yellow Warbler | Dendroica petechia |
| Yellow-rumped Warbler | Dendroica coronata |
| Townsend's Warbler | Dendroica townsendi |
| Black-throated Gray Warbler | Dendroica nigrescens |
| Grace's Warbler | Dendroica graciae |
| MacGillivray's Warbler | Oporornis tolmiei |
| ICTERIDAE - Black Birds, Orioles | |
| Eastern Meadowlark | Sturnella magna |
| Western Meadowlark | Sturnella neglecta |
| Red-winged Blackbird | Agelaius phoeniceus |
| Scott's Oriole | Icterus parisorum |
| Brewer's Blackbird | Euphagus cyanocephalus |
| Brown-headed Cowbird | Molothrus ater |

THRAUPIDAE - Tanagers

| | |
|---|---|
| Western Tanager | Piranga ludoviciana |
| Hepatic Tanager | Piranga flava |

FRINGILLIDAE - Grosbeaks, Finches, Sparrows, Buntings

| | |
|---|---|
| Black-headed Grosbeak | Pheucticus melanocephalus |
| Evening Grosbeak | Hesperiphona vespertina |
| Cassin's Finch | Carpodacus cassinii |
| Gray-crowned Rosy Finch | Leucosticte tephrocotis |
| Black Rosy Finch | Leucosticte atrata |
| Pine Siskin | Carduelis pinus |
| Lesser Goldfinch | Carduelis psaltria |
| Red Crossbill | Loxia curvirostra |
| Green-tailed Towhee | Pipilo chlorura |
| Rufous-sided Towhee | Pipilo erythrophthalmus |
| Vesper Sparrow | Pooecetes gramineus |
| Lark Sparrow | Chondestes grammacus |
| Black-throated Sparrow | Amphispiza bilineata |
| Sage Sparrow | Amphispiza belli |
| Dark-eyed Junco | Junco hyemalis |
| Gray-headed Junco | Junco caniceps |
| Chipping Sparrow | Spizella passerina |
| Brewer's Sparrow | Spizella breweri |
| White-crowned Sparrow | Zonotrichia leucophrys |
| Song Sparrow | Melospiza melodia |
| Lapland Longspur | Calcarius lapponicus |
| Chestnut-collared Longspur | Calcarius ornatus |

ADDENDUM - (Dec. 1976)

CICONIIFORMES

ARDEIDAE - Herons and Bitterns

| | |
|---|---|
| Snowy Egret | *Egretta thula* |

FALCONIFORMES

ACCIPITRIDAE - Hawks, Eagles

| | |
|---|---|
| Ferruginous Hawk | *Buteo regalis* |

CHARADRIIFORMES

SCOLOPACIDAE - Sandpipers

| | |
|---|---|
| Common Snipe | *Capella gallinago* |
| Least Sandpiper | *Calidris minutilla* |

PASSERIFORMES

HIRUNDINIDAE - Swallows

| | |
|---|---|
| Rough-winged Swallow | *Stelgidopteryx ruficollis* |
| Cliff Swallow | *Petrochelidon pyrrhonota* |

MIMIDAE - Mockingbirds, Thrashers

| | |
|---|---|
| Bendire's Thrasher | *Toxostoma bendirei* |

PARULIDAE - Wood Warblers

| | |
|---|---|
| Virginia's Warbler | *Vermivora virginiae* |
| Wilson's Warbler | *Wilsonia pusilla* |

ICTERIDAE - Blackbirds, Orioles

| | |
|---|---|
| Yellow-headed Blackbird | *Xanthocephalus xanthocephalus* |

FRINGILLIDAE - Grosbeaks, Finches, Sparrows, Buntings

| | |
|---|---|
| House Finch | *Carpodacus mexicanus* |

APPENDIX D

# A CHECKLIST OF MAMMALS OF SUNSET CRATER AND WUPATKI NATIONAL MONUMENTS

Terry A. Vaughan

March 1976

# INTRODUCTION

This checklist is based entirely on distributional records given by Hall and Kelson (1959) and by Cockrum (1960), and on records of specimens taken during preliminary field work in the summer of 1975. Included in this checklist are 42 species of 14 families. Future field work will probably reveal the presence of several species of bats and rodents not listed here.

INSECTIVORA

Soricidae

| | |
|---|---|
| *Notiosorex crawfordi* | Desert Shrew |

CHIROPTERA

Vespertilionidae

| | |
|---|---|
| *Myotis leibii* | Small-footed Myotis |
| *Myotis lucifugus* | Little Brown Bat |
| *Lasionycteris noctivagans* | Silver-Haired Bat |
| *Pipistrellus hesperus* | Western Pipistrelle |
| *Lasiurus cinereus* | Hoary Bat |
| *Plecotus townsendii* | Townsend's Big-eared Bat |
| *Antrozous pallidus* | Pallid Bat |

LAGOMORPHA

Leporidae

| | |
|---|---|
| *Sylvilagus auduboni* | Desert Cottontail |
| *Lepus californicus* | Black-tailed Jackrabbit |

RODENTIA

Sciuridae

| | |
|---|---|
| *Eutamias dorsalis* | Cliff Chipmunk |
| *Ammospermophilus leucurus* | White-tailed Angelope Squirrel |
| *Spermophilus spilosoma* | Spotted Ground Squirrel |
| *Spermophilus variegatus* | Rock Squirrel |
| *Sciurus aberti* | Abert's Squirrel |

| | |
|---|---|
| Geomyidae | |
| *Thomomys bottae* | Botta's Pocket Gopher |
| Heteromyidae | |
| *Perognathus flavus* | Silky Pocket Mouse |
| *Perognathus apache* | Apache Pocket Mouse |
| *Perognathus amplus* | Arizona Pocket Mouse |
| *Perognathus intermedius* | Rock Pocket Mouse |
| *Dipodomys ordii* | Ord's Kangaroo Rat |
| Cricetidae | |
| *Reithrodontomys megalotis* | Western Harvest Mouse |
| *Peromyscus maniculatus* | Deer Mouse |
| *Peromyscus crinitus* | Canyon Mouse |
| *Peromyscus boylii* | Brush Mouse |
| *Peromyscus truei* | Pinyon Mouse |
| *Onychomys leucogaster* | Northern Grasshopper Mouse |
| *Neotoma albigula* | White-throated Woodrat |
| *Neotoma stephensi* | Stephen's Woodrat |
| *Neotoma mexicana* | Mexican Woodrat |
| Erethizontidae | |
| *Erethizon dorsatum* | Porcupine |
| CARNIVORA | |
| Canidae | |
| *Canis latrans* | Coyote |
| *Urocyon cinereoargenteus* | Gray Fox |
| Procyonidae | |
| *Procyon lotor* | Raccoon |

| | |
|---|---|
| Mustelidae | |
| *Taxidea taxus* | Badger |
| *Spilogale gracilis* | Western Spotted Skunk |
| *Mephitis mephitis* | Striped Skunk |
| Felidae | |
| *Felis concolor* | Mountain Lion |
| *Lynx rufus* | Bobcat |
| ARTIODACTYLA | |
| Cervidae | |
| *Cervus elaphus* | Elk |
| *Odocoileus hemionus* | Mule Deer |
| Bovidae | |
| *Antilocapra americana* | Pronghorn |

## LITERATURE CITED

Cockrum, E. L. 1960. The Recent mammals of Arizona. Univ. Ariz. Press, 276 pp.

Hall, E. R., and K. R. Kelson. 1959. The mammals of North America. The Ronald Press Co., New York. 2 vols.

ADDENDUM TO: A checklist of Mammals of Sunset Crater and Wupatki National Monuments, compiled by Terry A. Vaughan. March, 1976

CHIROPTERA

Vespertilionidae

| | |
|---|---|
| *Myotis yumanensis* | Yuma Myotis |
| *Myotis evotis** | Long-eared Myotis |
| *Myotis thysanodes* | Fringed Myotis |
| *Myotis californicus* | California Myotis |
| *Eptesicus fuscus* | Big Brown Bat |

* The capture of this bat at Wupatki National Monument appears to represent an accidental occurrence, since it is generally a more montane species.

This addendum is based upon: The Bats of Wupatki National Monument, Coconino County, Arizona by Terry A. Gustafson.

Prepared By: Gary C. Bateman. December, 1976.