

CAMPSITE IMPACTS ON SMALL MAMMALS OF THE COLORADO
RIVER, CANYONLANDS NATIONAL PARK, UTAH



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Steve W. Elmore

Steve W. Elmore

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ABSTRACT

Campsite Impacts on Small Mammals
of the Colorado River, Canyonlands
National Park, Utah

by

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Utah State University, 1978

Major Professor: Dr. Gar W. Workman
Department: Wildlife Science

Small mammal populations were live-trapped at two campsites and two control areas along the Colorado River in Canyonlands National Park, Utah, to determine the effects of camping impact on small mammal numbers. Data were collected from August 20 to September 10, 1976, and from April 11 to September 10, 1977. Captures of the canyon mouse (Peromyscus crinitis), least chipmunk (Eutamias minimus), antelope ground squirrel (Ammospermophilus leucurus), white-throated wood rat (Neotoma albigula) and rock squirrel (Spermophilus variegatus) populations were numerous enough to permit statistical comparison. At the Brown Betty campsite, small mammal populations, with the exception of rock squirrels, increased with campsite use. Campsites consistently supported greater numbers and more species of small mammals than the controls except for the rock squirrel. No significant difference was found between campsites and control areas for this rodent.

(113 pages)

INTRODUCTION

The popularity of whitewater float trips on rivers in National Parks in the Intermountain West has increased significantly in recent years. Various segments of the Colorado, Green and Yampa Rivers in Utah, Colorado and Arizona have become nationally recognized for their unique, high-quality whitewater environments. In Canyonlands National Park, visitor use of the Colorado and Green Rivers increased from 585 persons in 1969 to almost 5,000 persons in 1976. This rate of yearly increase in numbers of persons boating on these two rivers far exceeds the terrestrial use of the Park and has prompted the National Park Service to impose ceilings on river use.

The National Park Service is concerned that current or increased visitor use may have undesirable ecological impacts in reference to the basic management mandates stated in the "Organic Act of 1916." Park Service managers, commercial river operators and users in general are also concerned that high-density recreational use may destroy or severely reduce opportunities for solitude, enjoyment and understanding of the riparian communities adjacent to the river.

In most cases where human use is permitted, as in river campsites, management must establish acceptable levels of environmental change. Such restrictions, however, must be based on a knowledge of the resource and ability of the resource or the users to tolerate change. An important subset of this resource

is the impact of campsite use on small mammals along the Colorado River in Canyonlands National Park.

Small mammals in and around campsites frequently comprise a majority of the wildlife seen on the three-to-seven-day float trips through Canyonlands National Park. As a result, there has been an increased interest from river users and managers to more fully understand the impact of campsites on species diversity and abundance of small mammals there.

Previous studies on mammals of Canyonlands include those of Armstrong (1972, 1973), Durrant and Dean (1959), Sparks (1974), Woodbury et al. (1959), Wagner and Workman (1961). Most of our basic knowledge of the natural history of the area is based on the railroad surveys of the 1850's and the biological surveys of Glen Canyon in the early 1900's (Armstrong 1973).

Forty-one species of mammals are known to occur in Canyonlands National Park, and an additional 20 species are of suspected occurrence or are known to have occurred within historic time (Armstrong 1973). Of the total probable fauna of 61 species, 2 species are insectivores, 18 chiropterans, 2 lagomorphs, 24 rodents, 12 carnivores and 3 artiodactyls (Appendix A). In reference to speciation of mammals living along the Colorado River, Kelson (1951) states that nowhere throughout the Colorado's course in Utah are different genera limited to only one side of it; the river has been effective in restricting distribution only of species and subspecies.

The sampling of small mammals along the Colorado River within Canyonlands National Park, should provide significant results

in two respects: (1) The riparian habitat represents a major vegetation regime within the Park that has not received much attention concerning rodent populations; and (2) Changes in small mammal populations should be a sensitive indicator of significant human impact.

Only Clevenger (1976) has dealt with the relationships of campgrounds and their use on small mammal communities of an area. Given more definitive information on this small, yet significant topic, management decisions can be instated concerning allowable river usage, designation of campsite areas and the approximate level at which recreational influences on the ecosystem significantly alter its basic structure.

The need for this kind of information will become increasingly important in making decisions concerning resource preservation and visitor usage along wild and scenic waterways.

OBJECTIVES

1. To study the effects of campsites and their use on small mammal populations along the Colorado River in Canyonlands National Park.

2. To obtain information that will help park management modify or negate any undesirable effects that campsite use may have on the fauna of an area.

3. To obtain information on the occurrence of small mammal species along the Green and Colorado Rivers in Canyonlands National Park.

STUDY AREA

Field work was carried out in Canyonlands National Park, located in southeastern Utah (Figure 1). The Park covers approximately 845 km² (525 mi.²) and is located on the Colorado Plateau with a range in elevation from 1,250 m (4,100 ft.) along the Green and Colorado Rivers to 1,859 m (6,100 ft.) on the Island in the Sky Plateau (Lohman 1974). The Green and Colorado Rivers divide the Park into three disjunct land masses: the Needles, Maze and Island in the Sky districts.

Two campsites along the Colorado River, Lathrop and Brown Betty, were trapped during a three-week period from August 20 until September 10, 1976, and during a six-month period from April 1 until September 12, 1977 (Figure 1). Personal communications with Park Service personnel (May et al. 1976) and commercial outfitters (Williams and Sarton 1976) were the main criteria for choosing these campsites. An area similar in topography and vegetation was chosen near each of the two campsites to serve as a control for study. Appendix B summarizes the major features of each study site.

There are a number of factors river-runners consider when selecting good campsites. Included are: location in relation to travel time and location in relation to rapids, size of parties, water level, vegetation type, density along stream bank, height of stream banks, number of boat parties, shade, probability of flash floods, landslides, stream velocity, presence of debris in front

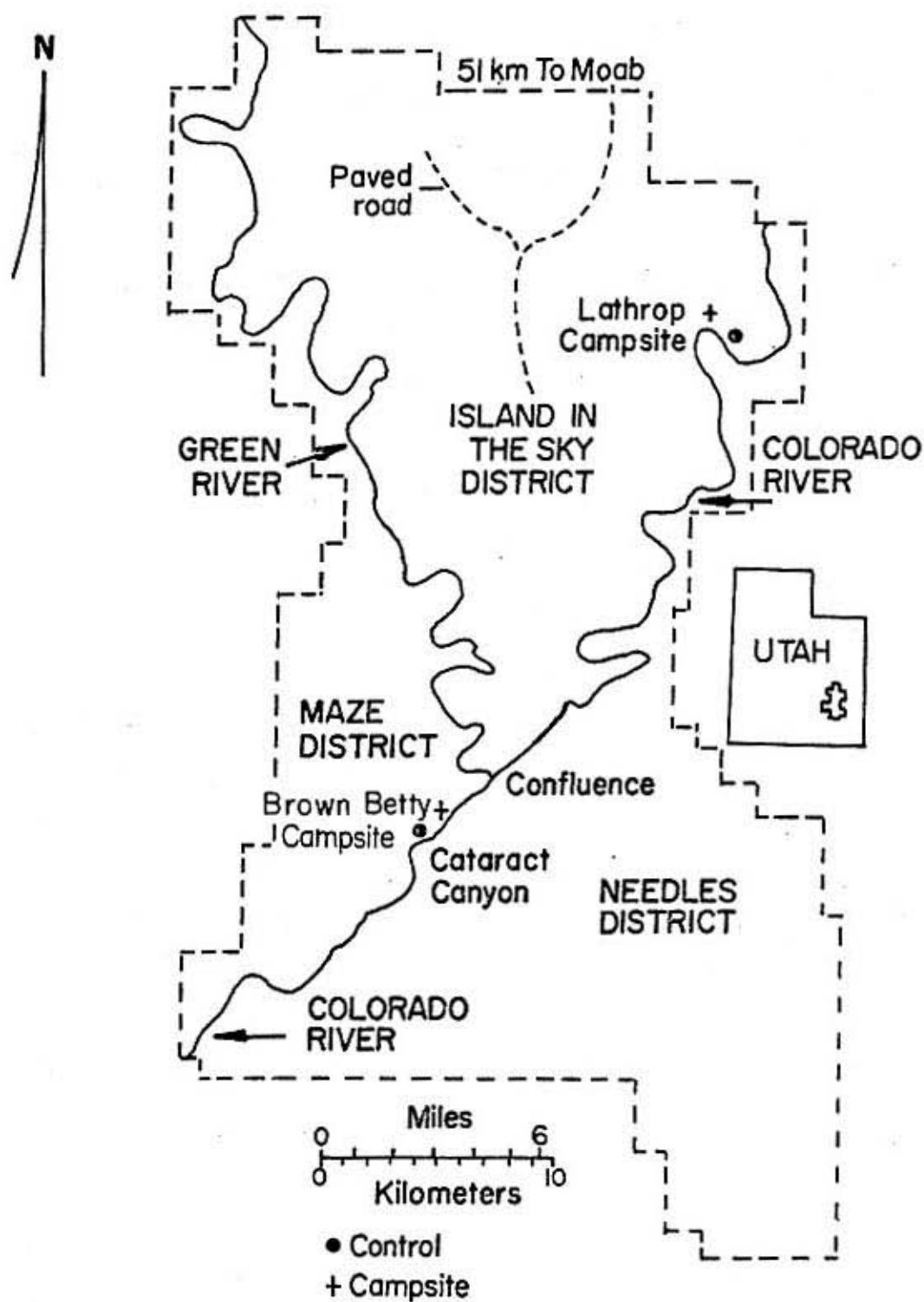


Figure 1. Canyonlands National Park, Utah, delineating campsite and control areas.

of boat landing site, suitability of site for sewage disposal, availability of firewood, slope, etc. (Hunt et al. 1974).

The first trap-site, designated the Lathrop Canyon site, was on a south facing slope 0.8 km ($\frac{1}{2}$ mi.) upriver from Lathrop Canyon. This area lies in a sector of Canyonlands known as the Island in the Sky District which encompasses all area between the Green and Colorado Rivers within the Park.

The underlying rock layer at the streamside portion of the campsite and control areas is in the Rico Formation with the terrace and hillside located in the Cedar Mesa Sandstone Member of the Cutler Formation, approximately 220 million years old (Lohman 1974). The distance from the river bank to the canyon wall at the experimental and control localities varies from 39 to 41 meters (128 to 135 ft.) with the canyon wall rising a vertical distance of 133 to 147 meters (436 to 482 ft.) from the terrace and 139 to 151 meters (455 to 495 ft.) above sea level. Elevations of the localities were interpolated from U.S.G.S. topographic maps, 15-minute series, or from the composite map, "Canyonlands National Park and Vicinity." Elevations are assumed to be correct only within the contour interval (24 m or 80 ft.). The substrate, where present, is thin, poorly developed and composed of sand and bare-rock on the streamside, sand and gravel on the terrace and gravel with boulders on the hillside. At the experimental trap-site, perennial herbs and grasses, shrubs, and trees cover 13 to 15 percent of the ground surface leaving the rest of the area bare or rock-strewn. On the other hand, at the control trap-site there is a 9 to 14 percent ground-vegetation coverage on the terrace and

hillside, and 2 percent coverage in the streamside zone.

The second trap-site was on an east-facing slope located 87 km (54 mi.) downriver from Potash, and 8 km (5 mi.) downriver from the confluence, between the first and second set of rapids in Cataract Canyon. The campsite area is better known as "Brown Betty" (Rigby et al. 1972).

The underlying rock structure at the streamside, terrace and hillside portion of Brown Betty campsite and control is interspersed with the Paradox Member and the unnamed upper member of the Hermosa Formation, approximately 50 million years older than the rock formations found at Lathrop Canyon (Lohman 1974; Baars and Molenaar 1971). The distance from the river bank to the canyon wall at the experimental and control trap-sites varies from 43 to 46 meters (142 to 152 ft.) with the canyon wall rising a vertical distance of 249 to 299 meters (818 to 980 ft.) from the terrace and 251 to 304 meters (825 to 997 ft.) from the river. The elevation of the river at Brown Betty campsite is approximately 1,189 m (3,900 ft.) above sea level with the river dropping an average of 2.1 meters (6.9 ft.) per mile down river from this point (Baars and Molenaar 1971). The substrate consists primarily of sand on the beach and terrace and gravel and boulders on the hillside. Vegetation coverage at the experimental and control trap-site varies from 15 to 22 percent on the terrace and hillside to approximately 3 percent on the streamside zone.

Climate

The climate of this desert riparian community is characterized by extreme heat and aridity in the summers and cold in the winters.

Annual precipitation in the Canyonlands area nowhere exceeds 25.0 cm (10 in.) except in the mountains (e.g. LaSal and Henry Mountains) or in the higher, distant plateaus. Temperature and precipitation data were obtained from the Island in the Sky and Needles district Ranger Stations, the recording station nearest to the Lathrop and Brown Betty campsites, respectively. Temperature data were adjusted using a lapse rate to account for differences in elevation between the trap-site locations and their nearest recording stations (Appendix C).

The adjusted mean maximum yearly temperature for 1976 and 1977 at Lathrop campsite averaged 0.7°C (1.3°F) and 1.0°C (1.8°F) above their respective annual averages. The mean minimum yearly temperatures in 1976 and 1977 averaged 0.4°C ($.7^{\circ}\text{F}$) and 1.2°C (2.1°F) below the respective annual averages (Appendix C).

At Brown Betty campsite the adjusted mean maximum yearly temperature for 1976 and 1977 averaged 2.5°C (4.5°F) and 2.2°C (4.0°F) above the respective annual averages. The mean minimum yearly temperatures in 1976 and 1977 averaged 0.4°C (0.8°F) below and 2.4°C (4.4°F) above the respective annual averages (Appendix C).

During 1976, the yearly precipitation at Lathrop and Brown Betty trap-sites averaged 36 percent and 30 percent below the respective annual averages for these areas. During 1977, the yearly precipitation for Lathrop and Brown Betty trap-sites averaged 65 percent and 64 percent below their respective averages.

Campsite Use

All commercial float trips using either the Green or the Colorado River in Canyonlands National Park float through Cataract

Canyon, resulting in a greater number of passenger days below the confluence than above (Appendix D).

Lathrop campsite is among the most popular campsite used for camping on the Colorado River above the confluence. Tamarisk and willow grow sparsely along the flat, sandy streamside. A conservative estimate would be that 90 percent of the potential camping space along the Colorado River would be on these sandy flats (Hunt et al. 1974).

As a result of unseasonably low water and channelization of the Colorado River on the opposite bank, visitor usage and impact at Lathrop campsite declined precipitously in late June, 1977. Flow rates of the Green River, however, were maintained by flood gates at Flaming Gorge Dam such that the Green River usage increased in proportion to the decreased use of the Colorado River above the confluence. The flow rates and departures from normal at Lathrop and Brown Betty campsites are presented in Appendix E.

Brown Betty is one of the most popular overnight campsites below the confluence. It is located in the back-eddy of the first rapid in Cataract Canyon. It serves as one of the most heavily used campsites on the river by the end of the second campday (Hunt et al. 1974).

The large, level, sandy beach area is free of ground cover, except for a few Russian thistle (Salsola kali) plants and a stand of salt cedar (Tamarix pentandra) established along the southern margin of the site. Unlike Lathrop campsite, Brown Betty was less affected by low water conditions and received fairly uniform use throughout the late spring and summer (See Appendix G for a

complete listing of common and scientific names of plants).

Because Brown Betty campsite received approximately $3\frac{1}{2}$ hours less direct sunlight than Lathrop, boat parties were inclined to pitch camp earlier at Brown Betty, increasing the duration of camping impact. At Lathrop campsite, the longer period of direct sunlight resulted in a higher evaporative rate, and more pronounced xeric conditions, resulting in a different floral composition and density, and a possible effect on small mammal densities, particularly during the most adverse part of the summer.

Vegetation

The streamside or river-bank vegetation is the most dense and diverse in the Park. It frequently is inundated by water during spring runoff and periodic rainstorms (Clover and Jotter 1944, Irvine 1976).

Bare ground constitutes most of the streamside zone at Lathrop and Brown Betty trap-sites. The streamside width at Lathrop varies from approximately 2 to 8 meters (6.6 to 26.2 ft.) and from 6 to 18 meters (19.7 to 59.1 ft.) at Brown Betty. The width varies with rainfall and seasonal flow patterns. Lathrop streamside supports a much greater diversity and percent canopy coverage of plant species than Brown Betty (Appendix I). Salt cedar and sandbar willow (Salix exigua) are the dominant species found along the margin of moist sand near the river's edge. According to Lohman (1974) and Winbourn et al. (1977), fur trappers on the Colorado and Green Rivers in the 1930's and early 1940's, much of the streamside zone along the rivers was devoid of salt cedar and willow.

The terraces are old flood plains of the river which are now usually higher than the reach of flood waters. Communities of smaller shrubs and herbs occupy the main parts of the terraces, which are usually level or slightly rolling and, in the case of Lathrop campsite, traversed by small arroyos which drain into the river. Again, large percentages of sand and organic matter comprise most of the terrace substrate at both trap-sites. In addition to the two major streamside species, squawbush (Rhus trilobata), hackberry (Celtis douglasii) and single-leaf ash (Fraxinus anomala) are frequently an integral part of the terrace community. Herbs and grasses are more sporadic members of the community. Most frequent among the grasses are Indian ricegrass (Oryzopsis hymenoides), cheatgrass (Bromus tectorum), dropseed (Sporobolus airoides), saltgrass (Distichlis spicata) and scratchgrass (Muhlenbergia asperifolia), many of which form clumps or meadow-like stands in open places.

The terrace at Lathrop varies in width from 12 to 21 meters (39.4 to 68.9 ft.) and from 6 to 14 meters (19.7 to 45.9 ft.) at Brown Betty. Lathrop terrace supports a greater number of plant species yet a smaller percent total ground cover than Brown Betty terrace. This is due, in part, to the high percent ground coverage of snakeweed (Gutierrezia sarothrae) and Mormon tea (Ephedra torreyana) at Brown Betty.

The vegetation of the hillsides at both trap-sites is uniform, although there are variations depending upon the nature of the topography. At both sites the hillsides are strewn with large angular masses of sandstone, some in excess of 60 tons (Rigby et al.

1972). Sand, boulders and detritus constitute greater than eighty percent of ground coverage on the hillsides.

The soil is dry except at the bases of large boulders, where soil moisture may be amplified by drainage patterns. Here again, Lathrop hillside supports a greater species diversity and lower percent total ground coverage than Brown Betty hillside, due to the higher percentage of snakeweed and Mormon tea at Brown Betty.

METHODS

Vegetation Analysis

Vegetation along the Colorado River occurs in three general zones: hillside, terrace and streamside, the occurrence being determined largely by availability of water (Woodbury et al. 1959). Because percent of site covered by any one type varied, the frequency and percent coverage of each vegetation zone was sampled independently.

The Daubenmire canopy-coverage method and line intercept method were used for sampling species composition (Daubenmire 1968). The 66 meter (215 ft.) intersecting transect trap placement lines were also used as reference positions to sample the three vegetation zones. Three parallel lines crossed through the transect area, with the upper or hillside line connecting the top trap of the two transect lines, the middle or terrace line splitting the middle of the transect area and the bottom or streamside connecting the lower trap of each transect line (Figure 2). 25.4 x 50.8 cm (8 x 20 in.) quadrats were placed at 2.0 m (6.6 ft.) intervals alongside each transect line in a random manner. Composition and density of vegetation within the quadrat was estimated by visual observation. The line intercept method was only utilized in the streamside area where the distances intercepted by plant canopies on a tape measure were read. Since both methods yield the percentage of the ground covered by plant canopies, the results are comparable (Daubenmire 1968).

A coefficient of similarity (S) was calculated to compare the

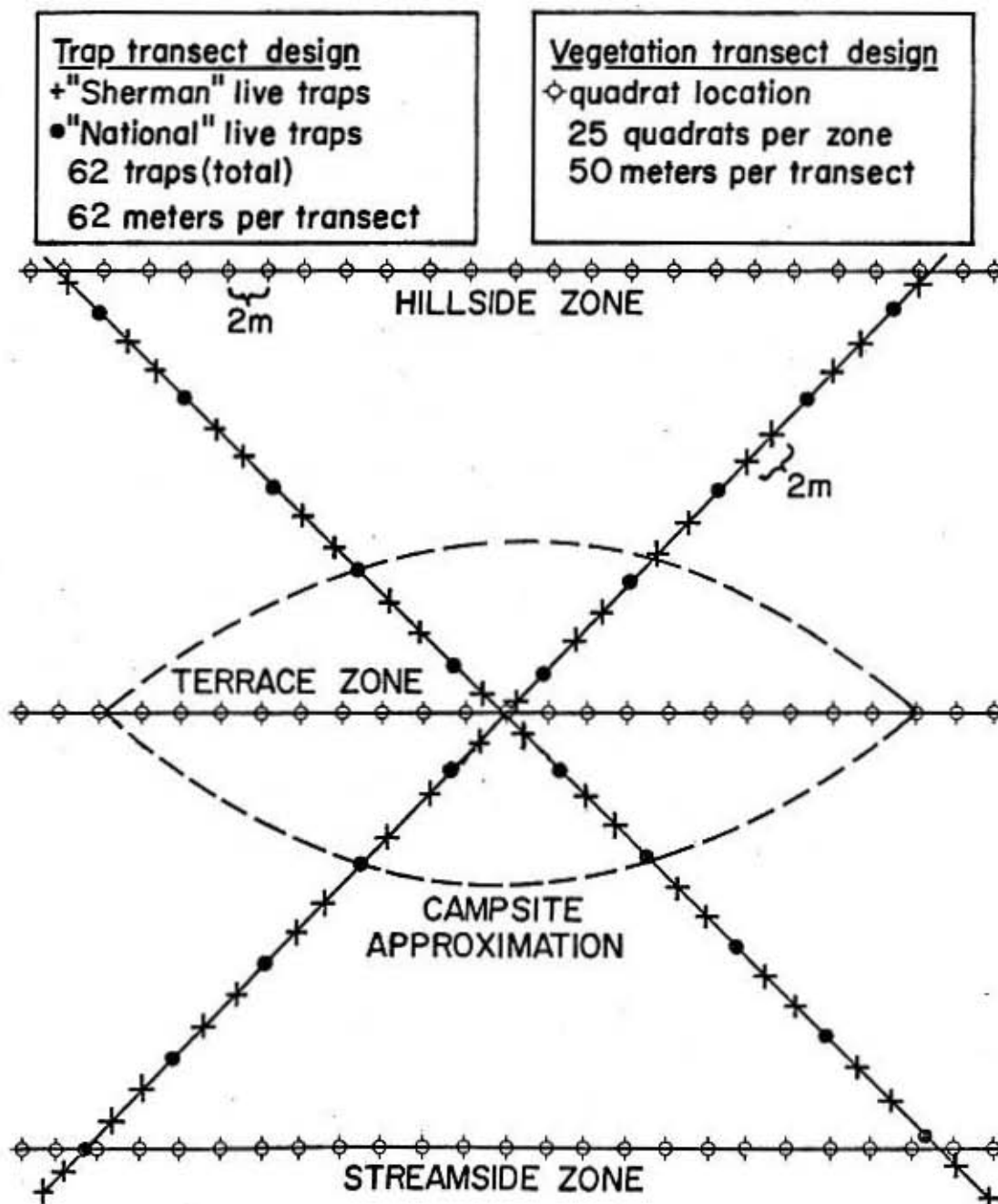


Figure 2. Diagrammatic representation of trap and vegetation transect designs for Lathrop and Brown Betty campsite and control areas, Canyonlands National Park, Utah.

streamside, terrace and hillside vegetation zones with respect to species present. The formula is:

$$S = 2w/(a + b)$$

where: w = the number of species common to both areas.

a = the number of species common to one area.

b = the number of species common to the other area.

Values of "S" will range from 0 to 1, with 1 indicating identical species composition (Cox 1972).

Voucher plant specimens of the dominant species at both sites were collected and pressed dry for later verification by Mr. Arthur H. Holmgren, Professor of Biology and Curator, Intermountain Herbarium, Utah State University; Mrs. Leila M. Shultz, Assistant Curator, Intermountain Herbarium; and Mrs. Joan Young, Professor of Biology, Mesa College, Grand Junction, Colorado.

Sampling Approach

The method of trap censusing employed was the mark-recapture technique. Two different sized traps were used: "Sherman" live-traps (8 x 8 x 23 cm) (3 x 3 x 9 in.), and "National" live-traps (18 x 18 x 48 cm) (7 x 7 x 19 in.). Some of the species of smaller animals are exposed to greater trapping pressure than species of larger ones because smaller mammals can be captured in the larger traps as well as those used specifically for them.

There are basically three approaches to measuring recreation-campsite-induced changes on small mammals. The most desirable is the before-after method; i.e., obtain trapping information prior to opening up an area and then inventory the area after some specified

period of use. Recreation areas may be surveyed without employing control trap-sites to obtain impact comparisons between types and intensities of use. A convenient and more reliable alternative to this method, and the one employed in this study, was to sample with transects in the campsite area and to locate a similar but undisturbed area nearby for a control trap-site (Settergren and Cole 1970).

Transect Design

Sixty-two traps were placed at two meter (6.6 ft.) intervals along two 62 meter (205 ft.) transects at each trap-site (Figure 2). Once the transect design was determined and the traps were positioned through the campsite, an area of similar vegetation and geographic characteristics was simultaneously trapped to provide a control area for the study. The traps were adjusted to close with the lightest possible pressure on the treadle. All "Sherman" brand live-traps were baited with peanut butter and rolled oats, since it appeared during a bait preference study that this type bait was most attractive to the animals in the area (Appendix F). Half of the "National" brand live-traps were baited with peanut butter and rolled oats and the remainder was baited with slices of fresh channel catfish (Ictalurus punctatus). Table 1 shows the relation between the number of trap-nights and trap-days spent at each site per month.

Data collected from each capture included: date of capture, trap location within the transect, trap-type, species sex, age (juvenile, subadult, or adult as judged by pelage color), reproductive

condition, individual field number (coded by toe-clipping), measurements and microhabitat variable (substrate, vegetation zone and the plant species nearest the trap). If no plants were within approximately one meter of the trap, a physical description of the trap location (such as slickrock, rock overhang, gravel slope) was recorded. After combining similar terms, 16 descriptors were employed, emphasizing the three major vegetation zones (streamside, terrace, hillside) and substrates without vegetation. Each capture was associated with one descriptor. The mammals were released at the place of capture. Trapping effort consisted of seven days per month at each trap-site. Traps were checked and baited twice every 24 hours: once at sunrise and once again prior to the sun's direct rays on the traps. The traps were checked, baited and closed during the heat of the day and reopened at sunset.

Statistical Analysis

Numbers of small mammals and species composition in campgrounds were compared with control areas to determine human impacts. For the purpose of this study it was not necessary to measure absolute densities of small mammals, only that the index obtained accurately reflect difference in populations for a given species among trapping sites and over time.

When a line-transect trap-line is used, it must be long enough to capture a sufficient number of small mammals to give a reliable sample of the population for statistical analysis. The length of the line transect is more important in getting an index of abundance of small mammals than the number of traps or number of days the traps

remain in operation (Hansson 1967, Dice 1941). Based on home range data for each species, the length of the line-transect for this study was sufficient to give such an index.

When using the capture-recapture method, four assumptions should be met. The assumptions include: (1) There must be a random distribution of marked animals, (2) Marked and unmarked animals have equal probability of capture, (3) Effects of marking (toe-clipping) must be minimal, (4) No influence by immigration or dilution, natality, or death during the sampling period. Few, if any, of these assumptions are ever met. However, methods have been proposed to adjust models to compensate for assumptions that are not met. Adjustments for these models include the effects of mortality (Jolly 1963, 1965, Darroch 1959), recruitment (Parker 1955), immigration and dilution (Ramsey and Briesse 1971), and differential trap response (Marten 1970, Hansson 1967).

After consultation with Dr. David L. Turner, associate professor in applied statistics-computer science at Utah State University, a statistical method was selected for comparing population numbers using the mark-recapture method. The chi-square formula is used to test the hypothesis that:

H₁: There is an equal number of captures between campsite and control trap-sites.

Chi-square is used to test two additional hypotheses concerning small mammal captures:

H₂: There is an equal number of captures per month over the seven-month trapping period.

H₃: The number of captures at trap-sites is independent of the month of capture.

Only canyon mice were captured in sufficient numbers to permit data analysis using H_2 (Sokal and Rohlf 1969). The Chi-square value is computed using the formula:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

where: O = observed proportion between captures of small mammals at the two areas.

E = expected proportion between the captures of small mammals at the two areas.

The percentage of each small mammal species associated with each microhabitat variable is used to estimate the niche breadth of each species and the niche overlap between the species. Niche breadth is computed using the formula:

$$B_i = -\sum P_{ij} \log_{10} P_{ij}$$

where: P_{ij} = the proportion of the species (i) associated with the microhabitat variable (j) (Shannon and Weaver 1949).

The resulting values of B_i are then compared to determine the degree of similarity of niche breadths between species. Niche overlap of two species is computed using the formula:

$$C_{ih} = 1 - \frac{1}{2} \sum P_{ij} - P_{hj}$$

where: P_{ij} = the same as above.

P_{hj} = the proportion of a second species associated with microhabitat variable (j) (Horn 1966).

Values of C_{ih} vary between 0 and 1, with 1 indicating complete overlap.

RESULTS

Vegetation Analysis

Appendix F summarizes the percent canopy coverage and frequency of plant species at the two trap-sites and respective controls. Figures 3 and 4 illustrate zones of floral differentiation. Other comparative vegetation analysis work along the Colorado River includes Holmgren and Schultz 1976; Woodbury et al. 1959; Loope 1977; Irvine 1976.

Appendix J presents the similarity indices for comparisons of the streamside, terrace and hillside vegetation zones at Lathrop and Brown Betty trap-sites. As shown by the high index of similarity (S), campsite and control trap-sites have similar species composition and overlap values.

Small Mammals

Mammal trapping

Field effort during 1976 and 1977 consisted of 12,152 trap-periods, apportioned evenly among the four localities along the Colorado River (Tables 1, 2, 3). Data were obtained on some 202 individual rodents representing 10 different species. The respective control sites had both fewer total numbers of species and fewer total animals captured.

At Lathrop trap-site, a total of 76 mammals were captured over a 6,076 trap-day period from August 19-26, 1976 and April 11 until September 16, 1977 (Table 2). The experimental or camping area

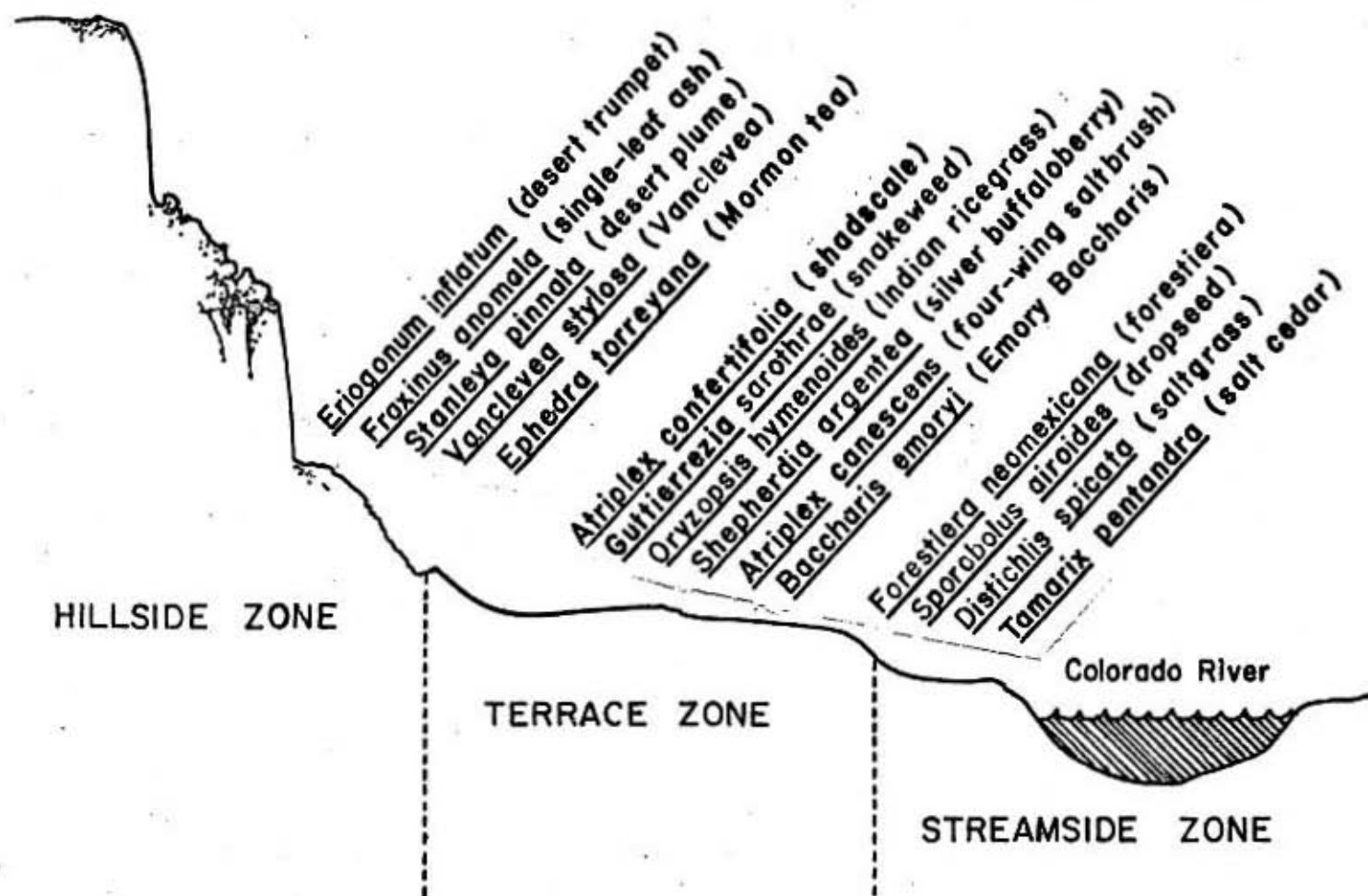


Figure 3. Zones of floral differentiation including major plant associations at Lathrop trap-site, Canyonlands National Park, Utah.

Table 1. Live-trapping effort for campsite and control areas for 12,152 trap-days and trap-nights in Canyonlands National Park, Utah (1977).

Trap-period Month	Lathrop Area		Brown Betty Area	
	Campsite	Control	Campsite	Control
April	434	434	434	434
May	434	434	434	434
June	434	434	434	434
July	434	434	434	434
August	868*	868*	434	434
September	434	434	868**	868**
TOTAL	3,038	3,038	3,038	3,038

*Data includes trapping effort for August 1976 and 1977.

**Data includes trapping effort for September 1976 and 1977.

Table 2. Total number of captures and recaptures of small mammals during a seven-month trapping period at Lathrop Canyon trap-site, Canyonlands National Park, Utah (1977).**

Species Campsite:	Month of Captures							Month of Captures						
	Apr	May	Jun	Jul	Aug	Sept	Total	Apr	May	June	July	Aug	Sept	Total
canyon mouse (n)	8	4	6	2	2	2 (8)*	33	16	25	25	16	8 (6)*	11	108
least chipmunk (d)	1	2	3	1	0	0 (4)	12	9	13	8	5	3 (5)	5	48
rock squirrel (d)	1	0	1	1	0	0 (2)	5	1	2	1	2	1 (0)	1	8
white-throated wood rat (n)	1	1	0	0	0	0 (1)	3	4	3	2	1	0 (1)	0	11
antelope ground squirrel (d)	1	1	0	2	0	0 (0)	4	1	2	3	1	0 (0)	1	8
ring-tailed cat (n)	1	0	0	1	0	0 (0)	2	0	0	0	0	0 (0)	0	0
Total	13	8	10	7	2	2 (15)*	59	31	45	40	25	12 (12)*	18	183
Species Control site:														
canyon mouse (n)	3	4	2	1	2	2 (2)*	15	6	5	6	4	3 (3)*	3	30
cactus mouse (n)	1	3	1	2	1	1 (0)	8	2	3	1	2	1 (0)	0	9
least chipmunk (d)	0	1	1	0	0	0 (0)	2	2	1	2	1	0 (0)	0	6
rock squirrel (d)	1	1	0	1	1	1 (0)	5	2	2	1	2	3 (0)	1	11
white-throated wood rat (n)	1	0	0	0	0	0 (0)	1	0	0	0	0	0 (0)	0	0
Ord kangaroo rat (n)	0	0	0	0	0	0 (1)	1	0	0	0	0	0 (0)	0	0
Total	6	9	4	4	4	4 (3)*	32	12	11	10	9	7 (3)*	4	56

*Results of one-week trapping effort in August 1976.

n = nocturnal, d = diurnal or crepuscular.

**See Appendix H for common and scientific names.

Table 3. Total number of captures and recaptures of mammals during a seven-month trapping period at Brown Betty trap-site, Canyonlands National Park, Utah (1977).*

Species Campsite:	Month of Captures							Total	Month of Captures							Total
	Apr	May	Jun	Jul	Aug	Sept	Apr		May	Jun	Jul	Aug	Sept			
canyon mouse (n)	14	8	5	5	4	2 (3)*	41	45	31	31	28	20	23 (1)	180		
least chipmunk (d)	1	2	1	2	1	1 (7)	15	3	5	7	4	1	3 (12)	35		
rock squirrel (d)	1	0	0	0	1	0 (1)	3	1	2	1	1	1	2 (1)	9		
white-throated wood rat (n)	1	1	1	0	1	0 (0)	4	2	2	1	1	0	0 (0)	6		
Northern grasshopper mouse (n)	0	2	1	2	2	1 (0)	8	0	3	3	5	2	3 (0)	16		
antelope ground squirrel (d)	1	1	2	0	1	1 (0)	6	4	3	4	2	1	2 (0)	16		
Total	18	14	10	9	10	5 (11)*	77	55	46	47	41	25	34 (14)*	262		

Species Control site:														
canyon mouse (n)	7	3	4	5	3	4 (4)	30	8	14	10	16	12	7 (1)	68
least chipmunk (d)	0	0	1	0	0	1 (8)	10	0	1	3	2	1	4 (4)	15
white-throated wood rat(n)	0	0	0	0	0	0 (1)	1	0	0	0	0	0	0 (0)	0
antelope ground squirrel (d)	1	0	0	1	0	1 (1)	4	1	0	0	0	0	0 (0)	6
rock squirrel (d)	1	1	1	0	0	0 (0)	3	2	1	2	1	0	2 (0)	8
gray fox (n)	0	0	0	0	0	0 (1)	1	0	0	0	0	0	0 (0)	0
Total	9	4	6	6	3	6 (15)*	49	11	16	16	20	14	15 (5)*	97

*Results of one-week trapping effort in September, 1976.

n = nocturnal, d = diurnal or crepuscular.

**See Appendix H for common and scientific names.

yielded 44 mammals with 183 recaptures, and the control area yielded 32 mammals with 56 recaptures. Five of the eight species were nocturnal, as noted in Table 21. Six different species were captured at both, experimental and control trap-sites.

At Brown Betty campsite, a total of 126 mammals were captured over a 6,076 trap-day period from September 3-10, 1976, and April 26 until September 6, 1977 (Table 3). The experimental area yielded 77 mammals with 262 recaptures, and the control area yielded 49 mammals, with 97 recaptures. The species captured included all those captured at Lathrop campsite, with the exception of the ring-tailed cat (Bassariscus astutus), kangaroo rat (Dipodomys ordii), and the cactus mouse (Peromyscus eremicus) plus two additional species: Northern grasshopper mouse (Onychomys leucogaster) and gray fox (Urocyon cinereoargenteus). Both of these additions are nocturnal.

Other mammals observed, though not captured, included the bobcat (Lynx rufus), mule deer (Odocoileus hemionus) and desert bighorn sheep (Ovis canadensis) at Brown Betty campsite and the badger (Taxidea taxus), beaver (Castor canadensis), porcupine (Erethizon dorsatum), striped skunk (Mephitis mephitis), bobcat, and mule deer at Lathrop campsite. A provisional checklist of mammals occurring in Canyonlands National Park compiled by Armstrong (1973) appears in Appendix A. An additional provisional checklist of terrestrial riparian mammals throughout the Park compiled in conjunction with this study, appears in Appendix H.

Statistical Analysis

With respect to χ^2 (H_1), a significantly higher number of captures was obtained over the seven-month trapping period in

the campsite than in the control areas for the canyon mouse, least chipmunk and white-throated wood rat at the .01 confidence level with one degree of freedom and for the antelope ground squirrel at the .05 confidence level (Table 4). No significant difference was found in the total number of captures between the campsite and control areas for the rock squirrel at the .05 confidence level.

Only canyon mice and least chipmunks were captured in sufficient numbers to permit data analysis using χ^2 (H_2) (Table 4). The results indicate that the campsite consistently supported a higher monthly capture rate for these two species at the .05 confidence level.

Only canyon mice were captured in sufficient numbers to permit data analysis using χ^2 (H_3) (Table 4). At Lathrop trap-site, the results indicate that the number of captures per month was dependent on the sight of capture at the .05 confidence level. Likewise, at Brown Betty trap-site, a significant relationship was found between month of capture and number of animals captured.

Table 5 presents the relative densities (captures per 100 trap-nights) of small mammals at the four trap-sites. The data shows that campsites consistently supported a higher relative density of small mammals than their respective controls, except for the rock squirrel (See Appendix A for scientific names of small mammals). The canyon mouse had the highest relative density, followed by the rock squirrel, least chipmunk, antelope ground squirrel and white-throated wood rat. Brown Betty campsite had the highest relative density of small mammals, followed by Lathrop campsite, Brown Betty control, and Lathrop control. All species analyzed showed

Table 4. Summary of small mammal captures at Lathrop and Brown Betty campsites and their respective controls, Canyonlands National Park, Utah (1977).^a

Species	Lathrop Campsite					Brown Betty Campsite				
	Campground captures	X ² value			Control captures	Campground captures	X ² value			Control captures
		H ₁	H ₂	H ₃			H ₁	H ₂	H ₃	
canyon mouse	141	24.77*	22.70*	.52	45	221	47.43*	52.41*	7.41	98
least chipmunk	60	39.76*	14.77*		8	50	8.33*	50.97*		25
antelope ground squirrel	12	12.00*			0	22	4.50**			10
white-throated wood rat	14	11.27*			1	10	7.37*			1
rock squirrel	13	.31			16	12	.043			11

*Significant at the .01 confidence level.

**Significant at the .05 confidence level.

^aBased on the formula: $\sum \frac{(O - E)^2}{E}$.

Table 5. Relative density of species captured at the four trap-sites expressed as a number of captures per 100 trap-nights, Canyonlands National Park, Utah (1977).

Species and Location	Number captured	Number of trap-nights	Relative density (captures/100 trap-nights)
<u>canyon mouse</u>			
Lathrop campsite	142	2,450	5.8
Lathrop control	45	"	1.8
Brown Betty campsite	221	"	9.0
Brown Betty control	98	"	4.0
<u>white-throated wood rat</u>			
Lathrop campsite	14	2,844	.49
Lathrop control	1	"	.04
Brown Betty campsite	10	"	.35
Brown Betty control	1	"	.04
<u>least chipmunk</u>			
Lathrop campsite	60	2,450	2.4
Lathrop control	8	"	0.33
Brown Betty campsite	50	"	2.0
Brown Betty control	25	"	1.0
<u>antelope ground squirrel</u>			
Lathrop campsite	12	2,844	.42
Lathrop control	0	"	---
Brown Betty campsite	24	"	.84
Brown Betty control	10	"	.35
<u>rock squirrel</u>			
Lathrop campsite	13	294	4.4
Lathrop control	16	"	5.4
Brown Betty campsite	12	"	4.1
Brown Betty control	11	"	3.7
<u>remaining species</u>			
Lathrop campsite	2	3,038	.07
Lathrop control	18	"	.59
Brown Betty campsite	24	"	.79
Brown Betty control	1	"	.03
<u>Total</u>			
Lathrop campsite	242	3,038	8.0
Lathrop control	88	"	2.9
Brown Betty campsite	339	"	11.1
Brown Betty control	146	"	4.8

a general similarity in monthly trapping success between campsite and control areas.

Microhabitat Variables

The percentage of each mammal species associated with each microhabitat variable at the four trap-sites was recorded and is presented in Appendix K. It should be recalled that all the variables occurred at all the trap-sites and that each capture was associated with only one set of variables. Microhabitat associations are summarized in the following paragraphs.

Canyon mouse

At Lathrop campsite, the canyon mouse was associated with 14 of the 16 possible variables. This decreased to 11 variables at Brown Betty campsite, 9 variables at Lathrop control, and 7 variables at Brown Betty control.

Over 70 percent of the captures of the canyon mouse were associated with boulders and slickrock. At Lathrop campsite and control trap-sites, the highest percentage of captures were recorded at boulder and slickrock on sand. At Brown Betty campsite, the highest percentage of captures were evenly distributed between sand substrate areas and boulder, slickrock areas on hillsides. At Brown Betty control, 48 percent of the captures were associated with grass, forb/boulder, slickrock areas on hillsides. A majority of captures were associated with bare areas except at Brown Betty control trap-site. Less than 17 percent of the captures were associated with gravel talus areas and less than 10 percent of the captures were recorded at streamside areas.

Least chipmunk

At Lathrop and Brown Betty trap-sites, over 70 percent of the captures were associated with boulder-slickrock areas. Also, a majority of the individuals were captured on grass, forb/hillside associations. Less than 13 percent of the captures were associated with gravel areas except at Brown Betty control (19 percent), and no captures were associated with streamside areas.

Rock squirrel

Over 60 percent of the captures at the four trap-sites were associated with bare areas, and approximately 23 percent on grass, forb areas. No captures were made in streamside areas.

White-throated wood rat

The association at boulder-slickrock areas varied from 91 percent at Lathrop control to 42 percent at Brown Betty campsite with an average of 69 percent for the four trap-sites. Over 52 percent of the captures were associated with bare areas on sand substrate. No captures were associated with hillside areas except at Lathrop campsite (20 percent). Less than 16 percent of the captures were associated with streamside areas at Brown Betty trap-sites, and no captures were associated with streamside areas at Lathrop trap-sites.

Antelope ground squirrel

The association at boulder, slickrock areas varied from 71 percent at Lathrop control to 93 percent at Brown Betty control with an average of 83 percent for the four trap-sites. Over 39 percent of the captures were associated with grass, forb areas.

Approximately 17 percent of the captures were associated with bare, sand substrate areas. Less than 5 percent of all captures were associated with streamside areas.

Cactus mouse

Fifty percent of captures were associated with boulder, slickrock areas; 37.5 percent with gravel talus areas; and 12.5 percent with streamside areas. All captures were associated with a bare sandy substrate.

Northern grasshopper mouse

Members of this species were captured only at Brown Betty campsite. 75 percent of the captures were associated with boulder, slickrock areas, and 25 percent with gravel, talus areas. All captures were associated with hillsides, 62.5 percent with shrubs, and the remainder with grass, forb areas.

Ring-tailed cat

Two individuals of this species were captured on the terrace and were associated with boulder, slickrock areas on a sand substrate.

Ord kangaroo rat

Only one capture was recorded on the streamside at a gravel talus area with a sand substrate.

Gray fox

Only one capture was recorded on a shrub, hillside area with a gravel talus substrate.

Niche Breadth and Overlap

Table 6 presents niche breadth measurements for the small mammals captured at the four study sites. Keep in mind, however, that these measurements are only approximations based on one or a few microhabitat variables. Sample size and home range of individual species were not considered when calculating niche breadth and niche overlap values. Canyon mice at Brown Betty campsite had the broadest niche of any of the species captured (.92), although in other areas this mouse had approximately the same niche breadth as other species. The species with the narrowest niche associations included: the canyon mouse (sandy substrate), Northern grasshopper mouse (hillsides) and white-throated wood rat (boulder, slickrock areas).

Tables 7, 8, 9 and 10 present indices of the amount of overlap in the microhabitat used by the small mammals at the four sites. At Brown Betty experimental trap-site, the antelope ground squirrel displayed significant overlap with the canyon mouse and with the rock squirrel. Low overlap values were displayed by white-throated wood rat and Northern grasshopper mouse. The average overlap among all the species captured more than once was 0.39.

The canyon mouse and the least chipmunk displayed the only significant overlap value at Brown Betty control trap-site. The rock squirrel and white-throated wood rat exhibited little overlap with each other and with the least chipmunk or canyon mouse. The average overlap among the species at the site was 0.38, the lowest average overlap for the four trap-sites.

At Lathrop experimental trap-site, the canyon mouse displayed significant overlap with the least chipmunk and the rock squirrel.

Table 6. Niche breadth for each small mammal species captured at the four trap-sites in Canyonlands National Park, Utah (1977).^a

Species	Capture Site			
	Lathrop campsite	Lathrop control	Brown Betty campsite	Brown Betty control
canyon mouse	.88	.84	.92	.62
cactus mouse	.42			
least chipmunk	.72	.86	.63	.56
white-throated wood rat	.47	.47	.76	.47
antelope ground squirrel	.82	.78	.75	.65
rock squirrel	.61	.65	.71	.73
Northern grasshopper mouse			.47	
Ord kangaroo rat		b		b
gray fox				
ring-tailed cat	b			

^aBased on the formula: $B_i = -\sum p_{ij} \log_{10} p_{ij}$ (Shannon and Weaver 1949).

^bInsufficient data for analysis.

Table 7. Niche overlap between small mammals at Brown Betty experimental trap-site in Canyonlands National Park, Utah (1977).^a

Species	least chipmunk	rock squirrel	white- throated wood rat	Northern grasshopper mouse	antelope ground squirrel
canyon mouse	.45	.50	.37	.26	.67*
least chipmunk		.39	.18	.50	.45
rock squirrel			.40	.20	.71*
white- throated wood rat				.00	.31
Northern grasshopper mouse					.26

^aBased on the formula: $C_{ih} = 1 - \frac{1}{2} \sum P_{ij} - P_{hj}$ (Horn 1966).

Values vary from 0 to 1, with 1 indicating complete overlap.

*Significant at the .05 confidence level.

Table 8. Niche overlap between small mammals at Brown Betty control trap-site in Canyonlands National Park, Utah (1977).^a

Species	least chipmunk	rock squirrel	white- throated wood rat	antelope ground squirrel	gray ^b fox
canyon mouse	.66*	.28	.18	.56	.00
least chipmunk		.39	.00	.58	.19
rock squirrel			.28	.50	.00
white- throated wood rat				.34	.00
antelope ground squirrel					.00

^aBased on the formula: $C_{ijh} = 1 - \frac{1}{2} \sum P_{ij} - P_{hj}$. Values vary from 0 to 1, with 1 indicating complete overlap. (Horn 1966).

*Significant at the .05 confidence level.

^bOne capture.

Table 9. Niche overlap between small mammals at Lathrop experimental trap-site in Canyonlands National Park, Utah (1977).^a

Species	least chipmunk	rock squirrel	white- throated wood rat	antelope ground squirrel	ring- tailed cat ^b
canyon mouse	.77*	.70*	.62	.56	.38
least chipmunk		.53	.65*	.49	.38
rock squirrel			.54	.60	.44
white- throated wood rat				.30	.60
antelope ground squirrel					.15

^aBased on the formula: $C_{ij} = 1 - \frac{1}{2} \sum P_{ij} - P_{hj}$. Values vary from 0 to 1, with 1 indicating complete overlap (Horn 1966).

*Significant at the .05 confidence level.

^bTwo captures.

Table 10. Niche overlap between small mammals at Lathrop control trap-site in Canyonlands National Park, Utah (1977).^a

Species	cactus mouse	least chipmunk	rock squirrel	white-throated wood rat	Ord kangaroo rat ^b
canyon mouse	.36*	.68*	.62	.54	.01
cactus mouse		.25	.29	.50	.19
least chipmunk			.76*	.59	.00
rock squirrel				.61	.03
white-throated wood rat					.00

^aBased on the formula: $C_{ijh} = 1 - \frac{1}{2} \sum P_{ij} - P_{hj}$. Values vary from 0 to 1, with 1 indicating complete overlap (Horn 1966).

*Significant at the .05 confidence level.

^bOne capture.

Overlap values were also significant between the least chipmunk and the white-throated wood rat. The low overlap of the ring-tailed cat reflects the dearth of ring-tailed cat captures. The average niche overlap among the species at the site was 0.57.

At Lathrop control trap-site, the least chipmunk displayed a significant degree of overlap with the canyon mouse and rock squirrel. The cactus mouse displayed a low degree of overlap with all species except the white-throated wood rat; the average overlap among the species at the site was 0.52.

Based on trapping data from three out of the four trap-sites on the Colorado River, there may be a similar habitat preference for the canyon mouse and least chipmunk. Consistent correlation in microhabitat associations for other small mammal species was not found. Keep in mind, however, that only three microhabitat variables were used for associating different small mammal species at the four trap-site areas. If more samples from other years were available (past or future), encompassing larger, more random trapping areas along the river, using a wider array of microhabitat variables, then a more complex and reliable method could be used to test small mammal associations which undoubtedly exist.

DISCUSSION

Results of this study indicate that campsites along the Colorado River have an influence on species diversity and density of small mammal populations inhabiting them. A significantly higher number of captures was obtained over the seven-month trapping period in the campsite than in the control areas for four of the five species analyzed at the .05 confidence level. Tables 2 and 3 also show that campsites supported more numbers of species (not including one-time captures) during 12 of the 14 trap periods.

Food Habits

One of the more obvious factors influencing small mammal populations inhabiting campgrounds is the increased food resource provided by campers (Clevenger 1976). The five species that were sampled have broad, opportunistic feeding habits.

Jameson (1952) and Williams (1959) stress availability as the overriding factor determining diet selection of mice. They state that seeds, fruits, and leaves constitute main items of diet in the summer and early fall with arthropods taken primarily in the spring. Balda et al. (1972) points out the importance of insects in the diet of desert-adapted mice. Whitaker (1963, 1966) and Landry (1970) state that mice are generally opportunistic omnivores with a jaw structure already well adapted for a combination herbivorous-carnivorous diet. Other carnivorous diet items include: Lepidopteran larvae and adults, earthworms, Chilopods, crickets, snails, ants, eggs, and crayfish (Telford 1943; Bailey 1931; Whitaker 1963 and

1966; Calhoun 1941; Cogshall 1928). MacMillen (1972) and Hanney (1975) state that many desert rodents can maintain themselves on a diet of dry seeds, grain, and/or arthropods, for not only does the seed contain about 10 percent of water by weight, but additional water can be produced by the breakdown and metabolism of carbohydrates in the body. The canyon mouse does not hibernate and no food is stored for the winter.

Chipmunks have been found to eat fruits, seeds, vegetation and flowers (Meserve 1974). MacMillen (1964) found that the chipmunk was also capable of utilizing and maintaining body weight on prickly pear cactus. Carnivorous food items include: frogs, crayfish, insects and lizards (Landry 1970).

According to Rice (1957), the least chipmunk prefers a diet of flowers and seed heads, which are rarely eaten by sciurids. Conversely, Johnson (1961) states that the least chipmunk relies heavily on arthropods for food. Sheppard (1965) states that soft foods, such as flowers, leaves, roots, fungi and insects are preferred diet items. He also states that seeds are eaten year round and are the only food stored for winter use. Olin (1975) states that the natural diet of chipmunks differs widely according to habitat. Desert-adapted species rely heavily on grass, seeds, berries, cactus fruits, fungi, small tubers and insects. Carnivorous diet items also include: meat, scorpions, beetles, ants, birds and pupae of moths (Aldous 1941; Schmidt 1931; Forbes 1966; Burt and Grossenheider 1964; Landry 1970).

Rock squirrel feed primarily on nuts and seeds, but often insects are eaten, and many individuals are not averse to eggs or

young birds (Sheppard 1965). Other items of diet include fruit, raw meat, grasshoppers, crickets and caterpillars (Howell 1938; Bailey 1931; Burt and Grossenheider 1964).

Brown (1973) and Brown and Lieberman (1973) found the antelope ground squirrel to be omnivorous, consuming green vegetation, arthropods, small vertebrates and carrion as well as seeds. Conversely, Chew and Butterworth (1964) state that the diet of the squirrel is confined to plants and seeds. Other recorded items of diet include: caterpillars, lizards, beetles, crickets and ants (Bailey 1931; Howell 1938; and Bradley 1968).

A review of food habits indicates the potential for each species to consume a wide variety of both plant and animal matter. Chipmunks and ground squirrels were often seen searching for food in the terrace-streamside vegetation zones of the campsite areas during the day. Less frequently, rock squirrels would be seen along the talus slopes of the campsite and control areas. None of the small mammals just mentioned were captured or directly observed feeding in the immediate area of the campsite "kitchen." Although probable, it is not known whether food scraps from campers were utilized.

Of the two remaining nocturnal species, only the canyon mouse was captured, as well as observed feeding, in the "kitchen" area of the campsite. The white-throated wood rat was never captured or directly observed in the "kitchen" area of the campsite, however, their tracks were noted in this area on occasion. In addition, human food scraps and assorted items were noted around their nest sites. The ability of these species to exploit the food resource provided by camping activity may be one of the reasons for higher populations

of certain species in the campsites.

There are a number of factors that could affect food habits and distribution of small mammals. Larger body size has been suggested as an important positive factor in aggressive, hence competitive encounters of one species with another (Sheppard 1965). King (1968) and Hanney (1975) state that canyon mice cannot compete very successfully with other mice and respond to aggressive encounters with other species by decreasing their population size and area of activity. Hall (1946) found that cactus mice, pinon mice and deer mice are able to invade and displace canyon mice. Where they do not have to compete with mice of other species, canyon mice expand their niche spatially. Sheppard (1965) also suggests that interspecific competition may result in differential use of space and/or food and thus serve to isolate populations of different species.

Home ranges vary greatly with canyon mice having the smallest, .2 to 1.2 hectares ($\frac{1}{2}$ to 3 acres) and antelope ground squirrels having the largest, .6 to 2.0 hectares (1.5 to 5 acres). The number of adult individuals per hectare also varies greatly with canyon mice and white-throated wood rats capable of reaching levels of 25 to 38 animals/hectare (10 to 15 animals/acre); least chipmunks and antelope ground squirrels, 5 to 13 animals/hectare (2 to 5 animals/acre); and rock squirrels, 8 animals/hectare (2-3 animals/acre). Rock squirrels tend to have more than two litters per year with canyon mice producing between three to five litters per year (Burt and Grossenheider 1964, Hall and Kelson 1959). The interaction of home range size, body size of the individual, territorial

nature, intraspecies aggressiveness and limited recruitment in the rock squirrel may partially explain the sparse capture results and possibly the similarity of trap success for campsite and control areas.

Arthropods, particularly Formicids and Dipterids are noticeably more numerous around campsites as opposed to their respective control areas. This is assumed to be related to impacts associated with camping, primarily increased food base and human waste. Commensurate with an increase in arthropods is an increase in the predator base, lizards, snakes, scorpions and insectivorous small mammal species. Analysis of stomach contents has shown the significance of arthropods in the diets of rodent species (Aldous 1941, Forbes 1966, Bradley 1968). In addition, Whitaker (1966), Hamilton (1941), Hisaw and Emery (1927), Jameson (1952) and Williams (1959) have also indicated the importance of arthropods in diets of small mammals, hence the food resource for rodents at campsites.

Dry firewood collected by boat parties along the river to be used at the campsites may also be another indirect source contributing to greater numbers of small mammals at campsites. Various assorted sizes of firewood (driftwood) are unloaded at the campsites for campfire and open-pit cooking in the evenings. Unused wood is left on the beach or stowed along the boulder-strewn terrace for future use. Residual firewood frequently serves as a source for insects, as well as nest-building material, cover and food for small rodents. Small mammal tracks were often found in association with residual firewood.

It has been shown (Royer et al. 1977; Hartman et al. 1977;

Ketchledge and Leonard 1970) that soil and plant disturbance by trampling and minor landscape alteration can disrupt insect activity (such as ant mounds) and dislodge seeds and/or insects from vegetation and soil. In addition, alteration of the landscape (rock, logs, branches) can potentially create new and unexposed microhabitat for small mammal species. Implications of human impacts on animal behavior, including land alteration and trampling, is discussed in a later section of this thesis.

Predation

Activity of predators in and around trap-sites was limited to ground predators. At the Lathrop trap-site, the only birds seen with any frequency were the common raven (Corvus corax). At Brown Betty trap-site, the common raven and the turkey vulture (Cathartes aura) were frequently observed soaring along the river in search of carrion. Both of these species are diurnal scavengers and were never observed capturing live animals.

Terrestrial predators at Lathrop trap-site included the ring-tailed cat, bobcat, striped skunk and the coyote (Canis latrans). At Brown Betty this list is similar with the deletion of the striped skunk and addition of the gray fox. Activity of predators at Brown Betty seemed to be transitory, with an occasional bobcat, ring-tailed cat, or coyote track, and a less frequent skunk or fox track. Trap disturbance by mammalian predators was infrequent. Conversely, at the Lathrop control and experimental trap-sites, ring-tailed cat and striped skunk signs were recorded on the average of three out of every four trap-days. Trap disturbance included an occasional trap being overturned, bait partially removed and/or

digging beneath or around the traps. To what extent activity of predators affected trapping results is not known. Frequency of occurrence of predators was similar at both experimental and control trap-sites and should not have biased comparative trapping results.

Trapping Success

Factors determining trapping success can be placed into three categories: (a) Technical (trap construction and arrangement, etc.); (b) environmental (weather, food availability, etc.); and (c) species dependent (intra- and interspecific factors). Factors that are constant between the respective campsite and control areas include weather, trap type, and certain inherent mammalian behavioral and activity patterns. Those factors that are variable (and man-induced) include food availability and human activity patterns associated with campsite use.

All species for which trapping records were analyzed showed a general similarity in trapping success between the campsite and control areas. Significantly more captures of small mammals were recorded at campsites than at their respective control areas in eight out of ten instances.

General trends of trapping success show a period of population stabilization for the white-throated wood rat and antelope ground squirrel from April through July, followed by a period of decreasing success from August through September. The highest trapping success for the canyon mouse was recorded for April, followed by a lower, fairly stable period for the rest of the trapping season. The highest trapping success for the Northern grasshopper mouse was recorded in the months of June and July. No trend in trapping

was evident for the rock squirrel or least chipmunk. Data collected in this research indicates the occurrence of population recruitment for the canyon mouse and least chipmunk during the spring as was noted by the increased number of juvenile captures.

Camping Impact

In a previous study conducted in Canyonlands and Arches National Park, Utah, Clevenger (1976) found that campgrounds have an influence on small mammal populations inhabiting them. The populations of Ord kangaroo rat, antelope ground squirrel, deer mice, wood rats, Colorado chipmunks and desert cottontails inhabiting campgrounds were compared with populations in non-campground control areas. It was found that the chipmunks, wood rats and mice exhibited significantly different capture rates at the .05 confidence level. A significant difference in the number of captures was found between the campground and control area four out of five times, with the campgrounds exhibiting the higher capture rates. The results of the findings are believed to be, in part, a response to feeding habits and adaptability of the individual species to campground activity. The Clevenger (1976) study represents the only available, comprehensive study concerning the impact of campgrounds on the small mammal community of an area.

Mammalian Activity Patterns

O'Farrell (1974) and Kenagy (1974) point out that trapping results are affected by changing seasonal activity patterns of small mammals. As an adaptive mechanism to enable desert rodents to survive periods of environmental stress, some species exhibit a

spontaneous seasonal drop in body temperature, metabolic rate and cardiorespiratory functions, i.e. seasonal hibernation and aestivation (Howard 1951; Hanney 1975). Smith and Blessing (1969) contend that sex and reproductive condition, in addition to food availability, affect trapping success. Yousef and Dill (1971) indicated that many desert rodents undergo a type of hibernation called "obligate hibernation," which is triggered by inadequate food supply. It is believed the animal readjusts its body temperature and metabolic rate to new and lower levels in a pattern of daily cycles to compensate for reduced food supply.

Previous investigations (Bartholomew and Dawson 1968) indicate that body temperature fluctuations in desert rodents of a 4 to 5°C range were chiefly reflections of environmental changes. Kram (1972), however, demonstrated that even when environmental temperatures were constant, body temperatures oscillate over a range of 2 to 3°C daily. If the range is too great, with environmental temperatures reaching as low as 10 to 15°C, activity subsides and many desert rodents enter a state of torpor. French (1956) and Bing and Mendel (1931) found that small mammals responded to periods of restricted water supplies with a reduction in activity. Laboratory studies on desert rodents have reported foraging activity to be continuous throughout the night, rather than in bouts (French 1956; Kavanau 1962; Kavanau and Rischer 1968). In discussing home range sizes of small mammals, Dice (1941) and Stickel (1948) agree that the size of the home range often varies with the season, available food supply and population density. In addition, Burt (1943) indicates a possible influence of sex and age upon the cruising

ranges of rodents.

Weather

Weather affects trapping success as pointed out by Gentry and Odum (1957), Getz (1961) and Marten (1973), who found that warm, overcast nights resulted in greater activity for nocturnal species than on clear nights and a resulting higher capture rate. On the other hand, Blair (1943) and Jahoda (1973) found that clear, moonless nights resulted in the highest number of captures. Marten (1973) states that mouse activity is greatest at light intensities intermediate between bright moonlight and complete darkness. He also indicates that activity is greatest in open areas when there is no moon, yet under dense ground cover, it is greatest at half or full moon. When there is a forest canopy or an abundance of shadows, light intensity may have no effect at all. In addition, Marten (1970) found that relative humidity and barometric pressure have slight positive effects on mouse activity and that low temperatures have little effect at all. Marten found no correlation between activity and wind or cloud cover.

According to O'Farrell (1974), ambient temperature, wind, cloud cover, precipitation, and barometric pressure have little, if any, effect on small mammal activity. Conversely, Gentry et al. (1966), believed that rain does cause an increase in the number of mammals caught, but in general concludes that weather over a certain period of several days is a more important factor than day-to-day fluctuations. Jahoda (1973) found that during light rains the activity of grasshopper mice reached a level equal to or greater

than the peak activity at new moon.

Other studies by Beatley (1969), Van De Graff and Balda (1972) and Reynolds (1958, 1960) indicate the dependence of desert rodents on winter annuals and precipitation. When the rain critical to autumn germination came, winter annuals were present from autumn to spring, and there was spring reproduction in the rodents (as indicated by summer densities). When the critical rain failed to come, winter annual populations were negligible, and the rodents did not reproduce in the spring.

Food Availability

Fitch (1954), Smith and Blessing (1969) and Jameson (1952, 1955) believe that trapping success of small mammals declines in relation to an increase in the natural or man-induced food availability during the year. Conversely, Janion and Wierzbowska (1970) contend that trapability of rodents is dependent on reproductive rates and population densities. Other factors affecting trap response include type of trap (Smith and Blessing 1969, 1972; Cockrum 1947, Duran 1968) and age of animal (Gliwicz 1970).

In Canyonlands, increased seed production of grasses and shrubs was noted for hillside and terrace plants during July, August and September, hence, the food resource for small mammals. The streamside zone supported green, maturing and seed-producing forage throughout the spring and summer. Various seeds and nuts (primarily pinyon) constituted a large part of the shoreline debris along the river. In addition, small mammal tracks were identified along this shoreline debris area. Whether seeds or nuts were eaten or gathered is not known.

Camping Activity

As a direct result of the drought condition in the Intermountain West in 1977 and the resulting low-water conditions along the Colorado River above the confluence, camping activity at Lathrop campsite was curtailed during the spring and early summer and eventually terminated in July, 1977 (Appendix D).

At Brown Betty campsite, monthly river use impact in 1977 was low in April and September with 811 and 1612 user days, respectively, and high in June and July, with 2829 and 2643 user days, respectively.

The fluctuation in campsite use at Lathrop and Brown Betty through the spring and summer was closely associated with numbers of small mammals captured. Small mammal populations of the respective control area also underwent this seasonal fluctuation.

Because of higher small mammal capture rates at campsites for all but one species, it is believed that camping use does have a significant effect on some small mammals and that it is partially responsible for their increased numbers.

At Lathrop campsite, trapping effort for most species showed a steady, continual rise in numbers of small mammals captured from April to June, 1977. Visitor use during this period increased from 232 passenger days in April to 3208 passenger days in June. Along with the termination of campsite usage in July was associated a sharp decline in the number of small mammal captures. The population remained depressed throughout the rest of the trapping season (through September). At the control trap-site, which was not subjected to camping impact, small mammal populations tapered off

from July to September, 1977, as did those at the control trap-site at Brown Betty. The decline in camping activity and the associated decline in small mammal captures at the campsite with respect to the control suggests a correlation between campsite usage and small mammal numbers.

Behavior

Species-typical behavior in the form of exploration would proceed as a consequence of the formation of a camping area within the home range of the affected species (Barnett 1963). Once the area has been found and if the animal receives positive reinforcement, it will (particularly in mammals) respond in such a way as to maximize its gains by returning to the area to feed, gather nest material, etc.

Behavior of an animal is often directed towards the achievement of a consummatory state. Most of the obvious consummatory states are related to objects or conditions needed for survival, such as food or shelter. Assuming that exploration represents a type of reinforcement, then it is safe to say that variation of the stimuli acting on the animal may resemble a consummatory state. That is, small mammals are compelled to explore, in the same way as they are compelled to find and eat food (Manning 1972). It has been shown that once a novel area has become familiar, exploratory movements are repeated at intervals, but only when disturbance is at a minimum (Barnett 1963). A further consequence of exploration and one that may partially explain the rapid infiltration of small mammals into a novel area, is that odor trails (pheromones) are left on exploratory routes, and these are detected by other species

(Alcock 1975).

A certain degree of long-term habituation to human intervention and changes associated with camping areas would be exhibited by rodents as long as the stimuli remained neutral. Closely associated with habituation would be another type of learning, trial and error. Under this category, animals would have the capacity to form positive and negative responses to various stimuli (e.g. food types, nest materials, and the most advantageous times at night to feed). In addition, latent learning would also play a role in the ability of rodents to learn their home range, inclusive of the campsite (cooking area, sleeping area, recreation area). Latent learning would also affect selectivity of food scraps as in the case of delayed indigestion. There is the possibility that habitat imprinting of the young may occur at campsites in turn creating a partially reliant situation, whereby rodents become dependent upon campers for essential habitat requirements. Rigidity in this type of situation is likely to have drastic effects upon reliant animal populations if sudden environmental changes occur.

Perceptual systems of rodents (mice, rats, squirrels) include olfaction, hearing and vision in order of acuity (King 1971). Novel olfactory cues are more than likely the overriding stimuli that rodents are responding to at campsites. On the other hand, a combination of sensory inputs may constitute a type of heterogeneous summation affecting the intensity to the response (Manning 1972). Barnett (1963) has shown that in wild rats an increase in external stimulation (noise, smell, vision) results in an increase in

exploratory activity. In addition, he has shown that activity in rats, measured in a wheel, in a maze or in a more open space is increased by three kinds of stimulation. First, changing environmental stimulation, such as odor, or noise, acting on the exteroceptors, increase activity. Some kinds of constant environmental stimulation, such as bright light, do the same, since bright light is avoided. In addition, deprivation (for example of food) lowers the threshold of response to external changes and may itself increase activity in a constant environment. This leads to the question of what releasers from camping areas are eliciting what responses by small mammals?

In summary, when small mammals are given access to an unfamiliar area, they explore it. The resulting experience is of value in determining information about the resource (food, shelter, danger, etc.). Subsequently, each species is thought to possess a delicately balanced and highly efficient combination of movements of approach and avoidance, which enables them safely to make the most of what the environment has to offer.

SUMMARY

Data were gathered at two campsites and two control areas along the Colorado River in Canyonlands National Park to determine whether campsites had any effect on small mammals inhabiting them. The results are summarized as follows:

- 1) Campsite use does have a significant effect on small mammals inhabiting the sites.
- 2) More small mammal species were recaptured in campsites than in their respective controls.
- 3) Any one or a combination of the following factors may, in part, explain the higher population of small mammals at campsites as opposed to their respective controls:
 - a) The effect of increased food resource provided by camping use.
 - b) The effect of habitat disturbance entailing the rearrangement of the landscape (sand, rocks, brush, logs) and trampling.
 - c) The effect of importing campfire wood and starter branches.
 - d) The pyramidal effect of camping areas on other biotic components. For example, an increase in the insect population, the resulting increase in lizards, snakes, and scorpions, and the effect this would have on the small mammal population and composition.

- e) The behavioral effects of exploration of and habituation to campsite areas.
- 4) Other unrecognized factors may also be responsible for a higher population of small mammals in campsites than in non-campsite areas.
- 5) Camping activity may increase populations of most riparian small mammal species.

MANAGEMENT IMPLICATIONS

In 1971, it became apparent to the National Park Service that use of the Colorado River was growing at a tremendous rate (60 percent annually), and that the riparian ecosystems were being placed in stress due to this increase (Hunt et al. 1974). As a result, steps were taken to stabilize use and limit commercial outfitter operations until answers could be obtained for the following:

- A) What is the carrying capacity for the Colorado River in Canyonlands National Park?
- B) What is the assessment of impact on vegetation and wildlife?
- C) What impact is acceptable?

(Hartman et al. 1977, p. 106)

These steps were designed to protect the interest of the Park and its environment until results of scientific study now underway could be completed and incorporated into further management decisions.

The three major limiting factors that have been used as a basis for determining carrying capacity in river running are:

- 1) Physical capacity - actual numbers of people that can be physically accommodated at launch sites, campsites, etc.;
- 2) Sociological capacity - the number of people that can be on a river at any one time without interacting to the point of degrading each other's experience; and
- 3) Ecological capacity - the number of people that a river

system can accommodate without impairment to components of the various indigenous ecosystems (Hartman et al. 1977).

This study accomplishes only a small part of the last factor, that dealing with human impacts on riparian small mammals. It was found that human impact at two heavily-used campsites along the Colorado River altered faunal populations and composition.

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APPENDICES

Appendix A:
A Provisional Checklist of Mammals
Canyonlands National Park, Utah
(Armstrong 1973)

Table 11. Provisional checklist of mammals, Canyonlands National Park, Utah (Armstrong 1973).**

TAXON	DISTRIBUTION BY DISTRICT		
	Island in the sky	Needles	Maze
ORDER INSECTIVORA--Insectivores			
Family SORICIDAE--Shrews	*?	*	*?
<u>Sorex merriami</u> --Merriam's shrew	*?	*	*?
<u>Notiosorex crawfordi</u> --Desert shrew			
ORDER CHIROPTERA--Bats			
Family VESPERTILIONIDAE--Vespertilionid bats			
<u>Myotis lucifugus</u> --Little brown bat	*	*	*
<u>Myotis yumanensis</u> --Yuma myotis	*	D	*
<u>Myotis evotis</u> --Long-eared myotis	*?	D	*?
<u>Myotis thysanodes</u> --Fringed myotis	*?	D	*?
<u>Myotis volans</u> --Hairy-winged myotis	*	*	D
<u>Myotis californicus</u> --California myotis	*	*	*
<u>Myotis leibii</u> --Small-footed myotis	D	D	D
<u>Lasionycteris noctivagans</u> -- Silver-haired bat	*	*	*
<u>Pipistrellus hesperus</u> -- Western pipistrelle	0	D	D
<u>Eptesicus fuscus</u> --Big brown bat	*	D	D
<u>Lasiurus borealis</u> --Red bat	*?	*?	*?
<u>Lasiurus cinereus</u> --Hoary bat	*	*	*
<u>Plecotus townsendii</u> --Townsend's big- eared bat	*	D	*
<u>Plecotus phyllotis</u> --Allen's big-eared bat	*?	D	*?
<u>Euderma maculatum</u> --Spotted bat	*	*	*
<u>Antrozous pallidus</u> --Pallid bat	D	D	D

Table 11. Continued.

TAXON	DISTRIBUTION BY DISTRICT		
	Island in the Sky	Needles	Maze
Family GEOMYIDAE--Pocket gophers			
<u>Thomomys bottae</u> --Valley pocket gopher	*?	*?	*?
Family HETEROMYIDAE--Pocket mice and allies			
<u>Perognathus apache</u> --Apache pocket mouse	D	D	D
<u>Perognathus parvus</u> --Great Basin pocket mouse	--	--	D
<u>Dipodomys ordii</u> --Ord's kangaroo rat	D	D	D
Family CASTORIDAE--Beaver			
<u>Castor canadensis</u> --Beaver	*	*	*
Family CRICETIDAE--Native rats and mice			
<u>Reithrodontomys megalotis</u> --Western harvest mouse	*	D	*
<u>Peromyscus crinitis</u> --Canyon mouse	D	D	D
<u>Peromyscus maniculatus</u> --Deer mouse	D	D	D
<u>Peromyscus boylii</u> --Brush mouse	D	D	*
<u>Peromyscus truei</u> --Pinon mouse	D	D	D
<u>Onchomys leucogaster</u> --Northern grasshopper mouse	*	D	*
<u>Neotoma lepida</u> --Desert woodrat	*	--	D
<u>Neotoma mexicana</u> --Mexican woodrat	--	D	--
<u>Neotoma albigula</u> --White-throated wood rat	D	D	--
<u>Neotoma cinerea</u> --Bushy-tailed wood rat	D	D	*
Family ERETHIZONTIDAE--New World porcupines			
<u>Erethizon dorsatum</u> --Porcupine	D	D	D

Table 11. Continued.

TAXON	DISTRIBUTION BY DISTRICT		
	Island in the Sky	Needles	Maze
ORDER CARNIVORA--Carnivores			
Family CANIDAE--Dogs and allies			
<u>Canis latrans</u> --Coyote	0	0	0
<u>Canis lupus</u> --Wolf	E*	E*	E*
<u>Vulpes vulpes</u> --Red fox	*	*	*
<u>Urocyon cinereoargenteus</u> --Gray fox	0	*	*
Family URSIDAE--Bears			
<u>Ursus arctos</u> --Grizzly bear	E*?	E*?	--
Family PROCYONIDAE--Raccoons and allies			
<u>Bassariscus astutus</u> --Ringtail	0	0	0
Family MUSTELIDAE--Weasels and allies			
<u>Mustela frenata</u> --Long-tailed weasel	*	*	*
<u>Taxidea taxus</u> --Badger	0	0	0
<u>Mephitis mephitis</u> --Striped skunk	*	*	*
<u>Spilogale putorius</u> --Spotted skunk	*	*	*
Family FELIDAE--Cats			
<u>Felis concolor</u> --Puma	*	*	*
<u>Lynx rufus</u> --Bobcat	0	0	*
ORDER ARTIODACTYLA--Even-toed hoofed mammals			
Family CERVIDAE--Deer and allies			
<u>Odocoileus hemionus</u> --Mule deer	0	0	0
Family ANTILOCAPTIDAE--Pronghorn			
<u>Antilocapra americana</u> --Pronghorn	--	--	E*
Family BOVIDAE--Cattle and allies			
<u>Ovis canadensis</u> --Bighorn sheep	0	*	*

Table 11. Continued.

**"Species listed as documented (D) are represented by museum specimens. Observations (O) indicate sight records of mammals or of their certain sign. An asterisk denotes a species of probable occurrence, or of certain occurrence but not observed or collected to date by the survey. An asterisk and a question mark suggest a species of possible occurrence, based on ecological and geographic considerations. Species designated by extirpated (E) may once have ranged in the area of the Park, but have been removed by human intervention since the advent of European civilization" Armstrong (1973).

Appendix B:

Geologic and Topographic Features of Lathrop
and Brown Betty Experimental and Control
Trap-sites, Canyonlands National
Park, Utah (1977)

Table 12. Geologic and topographic features of Lathrop experimental and control trap-sites, Canyonlands National Park, Utah (1977).

Feature	Location	
	Lathrop experimental	Lathrop Control
Location on U.S.G.S. Upheaval Dome quadrangle (15-min. series)	SW $\frac{1}{4}$ NW $\frac{1}{4}$ Sec. 18 R20E T28S	Approx. 380 meters upriver from exp.
Elevation above sea level	1188 m	1188 m
Distance from river to canyon wall	38-40 m	39-41 m
Height of cliffs above river	138-150 m	138-150 m
Rock formations present	Cutler-Cedar Mesa Sandstone Member (streamside and terrace) Rico (hillside)	same
Major vegetation zones (Figure 3)	$\frac{1}{4}$ streamside $\frac{1}{2}$ terrace $\frac{1}{4}$ hillside	same
Percent of bare soil	52.81% - streamside 65.34% - terrace 4.71% - hillside	41.22% - streamside 75.76% - terrace 2.03% - hillside
Percent of talus	0.00% - streamside 16.43% - terrace 48.30% - hillside	0.00% - streamside 8.73% - terrace 48.40% - hillside
Percent boulders and/or slick rock	33.84% - streamside 4.71% - terrace 38.61% - hillside	56.46% - streamside 2.00% - terrace 83.62% - hillside
Soil type (where present)	aridisol (sand and/or gravel)	same
Average depth of soil (where present)	10 cm	same
Means of access to site	boat, foot trail	same

Table 13. Geologic and topographic features of Brown Betty Experimental and control trap-sites, Canyonlands National Park, Utah (1977).

Feature	Location	
	Brown Betty Exper.	Brown Betty Cont.
Location on U.S.G.S. Needles, quadrangle (15 min. series)	NW $\frac{1}{4}$ NE $\frac{1}{4}$ Sec. 27 R18E T30 $\frac{1}{2}$ S	Approx. 850 meters downriver from exp.
Elevation above sea level	1182 m	1182 m
Distance from river to canyon wall	43-46 m	43-46 m
Height of cliffs above river	250-302 m	250-302 m
Rock formations present	Hermosa-Unnamed Upper Member (hillside) Paradox Member (streamside and terrace)	same
Major vegetation zone (Figure 4)	1/2 - streamside 1/4 - terrace 1/4 - hillside	1/3 - streamside 1/3 - terrace 1/3 - hillside
Percent of bare soil	96.63% - streamside 2.50% - terrace 1.50% - hillside	91.43% - streamside 1.57% - terrace 0.52% - hillside
Percent of talus	0.00% - streamside 40.31% - terrace 33.52% - hillside	2.33% - streamside 48.23% - terrace 35.53% - hillside
Percent of boulders and/or slickrock	0.00% - streamside 34.30% - terrace 47.35% - hillside	3.80% - streamside 29.00% - terrace 47.52% - hillside
Soil type (where present)	aridisol (sand and/or gravel)	same
Average depth of soil (where present)	10 cm	same
Means of access to site	boat, foot trail	same

Appendix C:

Climate Data for Lathrop and Brown

Betty Trap-sites, Canyonlands

National Park, Utah (1977)

Table 14. Adjusted monthly maximum and minimum mean temperatures for Lathrop trap-site, Canyonlands National Park, Utah (1977). (National Park Service data).*

Month	Mean Maximum Temperatures (°C)			Mean Minimum Temperatures (°C)		
	Average**	1976	1977	Average	1976	1977
January	10.3 (50.6)***	10.2 (50.3)	10.2 (50.3)	1.1 (33.9)	-.39 (31.3)	5.4 (41.8)
February	18.4 (65.2)	16.9 (62.4)	16.8 (62.2)	4.6 (40.2)	6.4 (43.5)	5.3 (41.5)
March	19.7 (67.5)	17.8 (64.1)	19.6 (67.2)	7.9 (46.3)	4.7 (40.4)	5.7 (42.3)
April	23.8 (74.9)	26.3 (79.3)	28.5 (83.3)	10.8 (51.4)	11.2 (52.1)	13.4 (56.1)
May	31.9 (100.0)	32.2 (89.9)	30.6 (87.1)	18.3 (64.9)	16.9 (62.5)	15.9 (60.6)
June	37.8 (104.9)	37.7 (99.9)	40.4 (104.7)	22.7 (72.8)	21.4 (70.5)	32.6 (90.6)
July	39.9 (103.9)	41.7 (107.0)	39.1 (102.4)	27.0 (80.6)	26.2 (79.2)	21.0 (69.8)
August	39.0 (102.2)	38.8 (101.8)	38.7 (101.6)	25.1 (77.1)	23.4 (74.1)	20.9 (69.7)
September	33.1 (92.5)	34.1 (93.3)	34.3 (93.8)	19.9 (67.9)	20.2 (68.3)	17.2 (62.9)
October	24.4 (76.9)	26.0 (78.8)	27.5 (81.5)	13.6 (56.5)	13.1 (55.6)	7.3 (45.1)
November	16.4 (62.5)	19.2 (66.6)	17.6 (63.6)	7.1 (44.8)	8.7 (47.7)	1.0 (33.8)
December	10.3 (50.6)	12.2 (54.3)	14.1 (57.4)	1.7 (35.1)	2.8 (37.0)	-0.4 (31.3)
Yearly Avg.	25.4 (77.7)	26.1 (79.0)	26.4 (79.5)	13.3 (55.9)	12.9 (55.2)	12.1 (53.8)

*Temperatures were adjusted using a lapse rate of 6.5°C/1 km.

**1968-1974.

***Values in parenthesis expressed in degree Fahrenheit.

Table 15. Adjusted monthly maximum and minimum mean temperatures for Brown Betty trap-site, Canyonlands National Park, Utah (1977). (National Park Service data).*

Month	Mean Maximum Temperatures (°C)			Mean Minimum Temperatures (°C)		
	Average**	1976	1977	Average	1976	1977
January	6.3 (43.4)***	6.9 (44.5)	7.7 (45.8)	-5.4 (22.3)	-9.3 (15.3)	2.3 (32.7)
February	13.5 (56.3)	15.0 (59.0)	14.9 (58.8)	-2.3 (27.9)	2.1 (32.3)	-3.5 (25.7)
March	15.8 (65.8)	15.8 (60.4)	15.6 (60.1)	1.9 (35.5)	5.4 (41.8)	-.50 (31.1)
April	22.6 (72.6)	22.9 (73.3)	25.3 (77.5)	4.9 (40.8)	6.5 (43.7)	6.7 (44.1)
May	30.7 (87.2)	28.9 (84.1)	28.5 (83.3)	11.3 (52.4)	11.7 (53.0)	11.7 (53.1)
June	35.2 (95.4)	34.9 (94.8)	38.7 (101.6)	20.8 (69.4)	15.2 (59.3)	18.6 (65.4)
July	38.8 (101.9)	39.6 (103.3)	36.8 (98.3)	20.4 (68.8)	21.2 (70.2)	20.9 (69.6)
August	35.8 (96.4)	36.6 (97.8)	36.0 (96.8)	19.3 (66.8)	18.9 (66.0)	20.2 (68.3)
September	31.7 (89.0)	31.4 (88.6)	31.7 (89.0)	13.2 (55.8)	14.7 (58.4)	16.9 (62.5)
October	23.5 (74.3)	23.3 (74.0)	24.7 (76.4)	7.3 (45.2)	4.5 (40.1)	11.8 (53.2)
November	15.2 (59.3)	17.7 (63.8)	15.7 (60.3)	1.2 (34.2)	-1.2 (29.8)	3.2 (37.7)
December	7.4 (45.3)	10.2 (50.4)	11.5 (52.7)	-6.1 (21.1)	-8.6 (16.5)	1.6 (34.8)
Yearly Avg.	21.7 (71.0)	23.6 (74.5)	23.9 (75.0)	7.2 (45.0)	6.8 (44.2)	9.2 (48.6)

*Temperatures were adjusted using a lapse rate of 6.5°C/1 km.

**1968-1974.

***Values in parenthesis expressed in degree Fahrenheit.

Table 16. Monthly precipitation and percent of average for Needles (Lathrop), and Island in the Sky (Brown Betty) Districts, Canyonlands National Park, Utah (1977). (National Park Service data).

Month	Needles		Precipitation		Island in the Sky	
	Average *	1976	1977	Average	1976	1977
January	1.06**	.89 (84)***	.94 (87)	1.13	.13 (11)	.66 (58)
February	.74	2.31 (312)	1.35 (182)	.67	1.09 (162)	.46 (69)
March	1.40	1.22 (87)	.81 (58)	1.27	2.59 (204)	.13 (10)
April	1.86	.48 (26)	.23 (12)	1.83	.61 (33)	1.75 (96)
May	1.65	2.95 (179)	.03 (2)	1.31	1.96 (150)	.81 (62)
June	1.80	.36 (20)	.00 (0)	1.47	.84 (57)	.30 (20)
July	2.85	1.60 (56)	1.93 (67)	2.10	2.64 (126)	.50 (24)
August	2.24	2.01 (90)	1.43 (64)	2.79	1.14 (41)	.46 (27)
September	1.51	1.83 (121)	.05 (3)	1.72	3.53 (205)	1.00 (58)
October	3.60	.74 (21)	.59 (16)	3.33	.46 (14)	.58 (17)
November	1.84	.05 (3)	.00 (0)	1.92	.10 (5)	.68 (35)
December	1.98	.00 (0)	.44 (22)	1.95	.00 (0)	.45 (23)
Yearly Total	22.53	14.43 (64)	7.80 (35)	21.49	15.09 (70)	7.78 (36)

*1965-1975.

**Data expressed in centimeters.

***Percent of average expressed in parenthesis.

Appendix D:
Colorado River Travel Summary,
Canyonlands National Park, Utah
(1977)

Table 17. Colorado River travel summary, Canyonlands National Park, Utah (1977). (National Park Service data).

Month:	Lathrop Campsite						Brown Betty Campsite					
	1976			1977			1976			1977		
	T	P	D	T	P	D	T	P	D	T	P	D
March	2	25	196	-	-	-	2	25	196	1	20	100
April	8	136	598	3	65	232	8	136	598	8	212	811
May	33	559	1960	23	400	1072	38	631	2323	32	503	1680
June	62	1441	6123	46	1052	3208	67	1513	6381	50	794	2829
July	58	1033	4155	20	350	967	67	1158	4691	50	744	2643
August	52	894	3855	20	341	986	61	1016	4545	50	744	2643
September	27	337	2097	8	154	596	30	358	2175	21	247	1612
October	7	32	165	2	18	54	7	32	165	4	26	98
TOTAL	249	4432	18,788	122	2380	7115	280	4869	21,075	220	3378	13,146

T = Trips

P = Passengers

D = Passenger days in Canyonlands National Park: Any calendar day, or portion thereof, that any individual is accompanied or serviced by an operator or permittee on the public land.

Appendix E:
Monthly Cubic Feet Per Second Flow Rates
on the Colorado River for Lathrop
and Brown Betty Trap-sites,
Canyonlands National Park,
Utah (1977)

Table 18. Monthly cubic feet per second flow rates and percent of average on the Colorado River for Lathrop and Brown Betty trap-sites, Canyonlands National Park, Utah (1977).*

Month:	Cubic feet per second									
	Lathrop						Brown Betty			
	Avg.**	1976	(% of Avg.)	1977	(% of Avg.)		Avg.	1976	(% of Avg.)	1977 (% of Avg.)
January	2,814	2,849	(101)	3,359	(119)		4,990	5,495	(110)	7,209 (144)
February	2,963	3,269	(110)	2,631	(89)		5,707	7,177	(126)	6,223 (109)
March	3,270	3,169	(97)	2,009	(61)		7,370	8,302	(113)	6,674 (91)
April	8,056	4,751	(59)	1,644	(20)		15,466	10,362	(67)	6,118 (40)
May	18,507	13,624	(74)	2,322	(13)		32,877	27,692	(84)	7,972 (24)
June	21,032	11,410	(54)	2,820	(13)		38,582	24,515	(64)	7,230 (19)
July	8,104	3,732	(46)	1,913	(24)		15,109	8,186	(54)	4,891 (32)
August	3,856	2,270	(59)	1,559	(40)		7,295	5,155	(71)	4,289 (59)
September	3,081	2,455	(80)	2,075	(67)		5,412	5,939	(110)	4,433 (82)
October	3,595	3,559	(104)	2,221	(62)		6,207	7,044	(113)	4,166 (67)
November	3,541	3,691	(104)	2,153	(61)		6,136	7,375	(120)	4,167 (68)
December	3,055	3,567	(117)	2,270	(74)		5,306	7,238	(136)	4,023 (76)

*Data taken from Green River at Green River, Utah and Colorado River near Cisco, Utah (U.S. Geological Survey).

**Data accumulated from 1941-1970.

Appendix F:

Bait Selectivity Study Along the Colorado and

Green Rivers in Canyonlands

National Park, Utah (1976)

Bait selectivity studies were carried out along the Colorado and Green Rivers at six different locations in Canyonlands National Park in order to determine bait preference by small mammals.

Eighty "Sherman" live-traps (8 x 8 x 23 cm) (3 x 3 x 9 in.) and 20 "National" live-traps (18 x 18 x 48 cm) (7 x 7 x 19 in.) were scrubbed and cleaned with a commercial cleanser. In the Sherman live-traps five different baits were used and 16 traps were employed using each type of bait.

- 1) Chewed oats (Rolled oats were chewed by trappers until a paste-like consistency developed).
- 2) Peanut butter
- 3) Peanut butter and rolled oats
- 4) Quaker national cereal and raisins
- 5) Birdseed

In the National live-traps five different baits were used and 4 traps were employed using each type of bait.

- 1) Apples
- 2) Carrots
- 3) Peanut butter and rolled oats
- 4) Chewed oats
- 5) Fresh catfish

One hundred trap-days were recorded on the Green River in Canyonlands National Park at Potato Bottom, 6.1 km (38 mi.) upriver from the confluence of the Green and Colorado Rivers and at Anderson Bottom, 49.9 km (31 mi.) upriver from the confluence. One hundred trap-days were recorded on the Colorado River at Lathrop jeep campsite and at Lathrop experimental campsite, 37.8 km (23.5 mi.) and 39.4 km

(24.5 mi.) upriver from the confluence, respectively. In addition, one hundred trap-days were recorded at Spanish Bottom and at Brown Betty experimental campsite 6.4 km (4 mi.) and 8 km (5 mi.) downriver from the confluence.

The work resulted in a trapping effort of 600 trap-nights and has yielded 65 animals, consisting of seven different species (Table 19). Fifty-two small mammals (four species) were captured in the Sherman live-traps, and thirteen mammals (six species) were captured in the National live-traps.

Conclusion

No significant difference was found between the number of small mammal captures in the Sherman live-traps for peanut butter and oats, chewed oats, and peanut butter at the .05 confidence level. Number of captures were too low to permit data analysis for those traps baited with birdseed and Quaker natural cereal with raisins. For the National live-traps, no significant difference was noted, between traps baited with peanut butter and oats, chewed oats, and fresh catfish at the .05 confidence level. Number of captures were too low to permit data analysis for those traps baited with carrots or apple slices.

Based on percentage of small mammals associated with bait types, the results indicate a preference for peanut butter and rolled oats in both the Sherman and National live-traps for the smaller herbivores and omnivores. The carnivores preferred fresh catfish.

As a result of the study, peanut butter and rolled oats were used exclusively in the Sherman live-traps. In the National live-traps,

half of the traps were baited with peanut butter and oats and half were baited with catfish. It became policy to wire the catfish pieces into the National brand traps posterior to the treadle to prevent theft of bait.

Table 19. Bait preference of small mammals along the Green and Colorado Rivers in Canyonlands National Park, Utah (1976).

Bait	Species captured	Number captured	Percent captured	Total percent captured
<u>Sherman live-traps</u>				
Peanut butter and oats	canyon mouse	12	23.1	
	least chipmunk	4	7.7	
	antelope ground squirrel	1	1.9	
	Northern grasshopper mouse	1	1.9	34.6
Chewed oats	canyon mouse	8	15.4	
	least chipmunk	2	3.8	
	antelope ground squirrel	1	1.9	
	Northern grasshopper mouse	2	3.8	24.9
Peanut butter	canyon mouse	10	19.2	
	least chipmunk	2	3.8	
	antelope ground squirrel	1	1.9	24.9
Birdseed	canyon mouse	4	7.7	
	least chipmunk	1	1.9	
	antelope ground squirrel	1	1.9	11.5
Quaker natural cereal and raisins	canyon mouse	2	3.9	3.9
TOTAL		52		99.8

Table 19. Continued.

Bait	Species captured	Number captured	Percent captured	Total percent captured
<u>National live-traps</u>				
Peanut butter and oats	rock squirrel	3	23.1	46.2
	antelope ground squirrel	1	7.7	
	white-throated wood rat	2	15.4	
Chewed oats	rock squirrel	3	23.1	30.8
	white-throated wood rat	1	7.7	
Fresh catfish	ring-tailed cat	1	7.7	15.4
	spotted skunk	1	7.7	
Carrots	Audubon cottontail	1	7.7	7.7
Apple slices	None	--	----	
TOTAL		13		100.1

Appendix G:
A List of Common Plants Located
at Lathrop and Brown Betty
Trap-sites, Canyonlands
National Park, Utah
(1977)

Table 20. A list of plants with common and scientific names from Holmgren and Reveal (1966).

Common Name	Scientific Name
<u>Trees</u>	
coyote willow	<u>Salix exigua</u> Nutt.
tamarisk	<u>Tamarix pentandra</u> Pall.
netleaf hackberry	<u>Celtis reticulata</u> Torr.
buckthorn	<u>Rhamnus betulaeifolia</u> Green var.
New Mexican foresteria	<u>Forestiera neomexicana</u> A. Gray
skunkbush sumac	<u>Rhus trilobata</u> Nutt.
singleleaf ash	<u>Fraxinus anomala</u> Torr.
<u>Shrubs</u>	
Torrey ephedra	<u>Ephedra torreyana</u> Wats.
green ephedra	<u>Ephedra viridis</u> Cov.
prickly-pear cactus	<u>Opuntia phaeacantha</u> Engelm.
echinocereus	<u>Echinocereus triglochidiatus</u> Engelm.
rubber rabbitbrush	<u>Chrysothamnus nauseosus</u> Pall.
vanclevea	<u>Vanclevea stylosa</u> Greene
broom snakeweed	<u>Gutierrezia sarothrae</u> Pursh
Amsonia	<u>Amsonia jonesii</u> Woodson
Russian centaurea	<u>Centaurea repens</u> Pall.
cliff rose	<u>Cowania mexicana</u> D. Don
longleaf brickellia	<u>Brickellia longifolia</u> S. Wats.
silver buffaloberry	<u>Shepherdia argentea</u> Pursh
echinocactus	<u>Echinocactus whipplei</u> Engelm.
shadscale	<u>Atriplex confertifolia</u> Torr.
longspine horsebrush	<u>Tetradymia axillaris</u> A. Nels.
fourwing saltbush	<u>Atriplex canescens</u> Pursh
fineleaf yucca	<u>Yucca angustissima</u> Engelm.
Emory baccharis	<u>Baccharis emoryi</u> A. Gray
Anderson wolfberry	<u>Lycium andersonii</u> A. Gray
<u>Herbs</u>	
desert princesplume	<u>Stanleya pinnata</u> Pursh
aster	<u>Aster spp.</u>
desert trumpet	<u>Eriogonum inflatum</u> Torr.
Russian thistle	<u>Salsola kali</u> A. Nelson
wirelettuce	<u>Stephanomeria exigua</u> Nutt.
coldenia	<u>Coldenia hispidissima</u> Torr.
yellow beeplant	<u>Cleome lutea</u> Hook.
showy milkweed	<u>Asclepias subverticillata</u> A. Gray
locoweed	<u>Astragalus spp.</u>
pepperweed	<u>Lepidium montanum</u> Nutt.
globemallow	<u>Sphaeralcea munroana</u> Dougl.
dogbane	<u>Apocynum cannabinum</u> Woodson
white sweet clover	<u>Melilotus alba</u> Desr.
ragweed	<u>Ambrosia spp.</u>
fendler spurge	<u>Euphorbia fendleri</u> Torr.
blazing star	<u>Mentzelia albicaulis</u> Dougl.

Table 20. Continued.

Common Name	Scientific Name
<u>Herbs cont'd</u>	
curlycup gumweed	<u>Grindelia squarrosa</u> Pursh.
milkweed	<u>Asclepias speciosa</u> Torr.
phacelia	<u>Phacelia crenulata</u> Torr.
jimson weed	<u>Datura meteloides</u> Torr.
cocklebur	<u>Xanthium strumarium</u> Torr.
<u>Grasses</u>	
cheatgrass	<u>Bromus tectorum</u> Spenner
Indian ricegrass	<u>Oryzopsis hymenoides</u> Roem.
desert saltgrass	<u>Distichlis spicata</u> Green
alkali sacaton	<u>Sporobolus airoides</u> Torr.
scratchgrass	<u>Muhlenbergia asperfolia</u> Nees.
fluffgrass	<u>Tridens pulchellus</u> A.S. Hitchc.
galleta	<u>Hilaria jamesii</u> Torr.
little bluestem	<u>Andropogon scoparius</u> Michx.
purple three-awn	<u>Aristida purpurea</u> Nutt.

Appendix H:
A Provisional Checklist and Status of
Terrestrial Mammals Along the
Colorado and Green Rivers
in Canyonlands National
Park, Utah (1977)

The purpose of this section has two major aims: (1) mammal inventory (exclusive of chiropterans); and (2) comparison with small mammals captured at the two Colorado River campsites. The purpose of the inventory was to determine the kinds of small mammals present in the riparian areas of the Colorado and Green Rivers in the Park and to gain at least a crude impression of their status (Table 22). This information will be used to supplement a checklist of the mammalian fauna of the Park (exclusive of riparian areas) organized by Armstrong (1973) (Appendix A). Lathrop trap-sites in the Island in the Sky District, and Brown Betty trap-sites in the Maze District, have been included in the checklist for long-run comparative purposes.

Table 21. Provisional checklist of terrestrial mammals along the Colorado and Green Rivers, including totals for trap-nights, animal captures and species observed and/or captured, in Canyonlands National Park, Utah (1977).

Species	Common Name	District									
		Island in the Sky				Needles		Maze			
		LC*	LCC	LBC	MB	LRL	RC	VB	SB	BB	BBC
ORDER RODENTIA											
Family Cricetidae											
** (s) <u>Peromyscus crinitis</u>	canyon mouse	141	45	13	11	5	6	8	6	221	98
(s) <u>Peromyscus eremicus</u>	cactus mouse	0	17	1	2						
(n,s) <u>Neotoma albigula</u>	white-throated wood rat	14	1	1						10	1
(s) <u>Onychomys leucogaster</u>	Northern grasshopper mouse	0	0	1		1			3	24	0
<u>Ondatra zibethica</u>	muskrat	*** +	+			+		+			
Family Sciuridae											
(s) <u>Eutamias minimus</u>	least chipmunk	60	8	4		2	1			50	25
(s) <u>Eutamias quadrivittatus</u>	Colorado chipmunk					1					
(n,s) <u>Ammospermophilus leucurus</u>	antelope ground squirrel	12	0	1	1		2			22	10
(n) <u>Spermophilus variegatus</u>	rock squirrel	13	16		1			1		12	11
Family Heteromyidae											
(s) <u>Dipodomys ordii</u>	Ord kangaroo rat	0	1				1				
Family Castoridae											
<u>Castor canadensis</u>	beaver	+	+	+	+	+		+		+	+

Table 21. Continued.

Species	Common Name	District									
		Island in the Sky				Needles		Maze			
		LC	LCC	LBC	MR	LRL	RC	VB	SB	BB	BBC
Family Erithizontidae											
<u>Erethizon dorsatum</u>	porcupine	+	+			+					
ORDER LAGOMORPHA											
Family Leporidae											
(n) <u>Sylvilagus audubonii</u>	desert cottontail						+	1	1		
<u>Lepus californicus</u>	black-tailed jackrabbit			+				+			
ORDER CARNIVORA											
Family Canidae											
(n) <u>Urocyon cinereoargenteus</u>	gray fox					+				0	1
<u>Canis latrans</u>	coyote	+	+							+	+
Family Felidae											
<u>Lynx rufus</u>	bobcat	+	+		+					+	+
Family Bassariscidae											
(n) <u>Bassariscus astutus</u>	ring-tailed cat	2	+	+			+				
Family Mustelidae											
<u>Taxidea taxus</u>	badger	+	+	+				+			
(n) <u>Mephitis mephitis</u>	striped skunk				1						
ORDER ARTIODACTYLA											
Family Cervidae											
<u>Odocoileus hemionus</u>	mule deer	+	+	+	+			+	+	+	+

Table 21. Continued.

Species	Common Name	District									
		Island in the Sky				Needles		Maze			
		LC	LCC	LBC	MB	LRL	RC	VB	SB	BB	BBC
Family Bovidae <u>Ovis canadensis</u>	bighorn sheep					+			+		
Total Trap-Nights		6125	6125	200	200	100	100	200	200	6125	6125
Total animals captured		242	88	21	16	9	10	10	10	339	146
Total number of species observed and/or captured		13	14	11	8	8	7	8	4	11	10

*Trap-site code: LBC - Little Bridge Canyon, MB - Monument Basin, LRL - Lower Red Lake Canyon, RC - Rustler Canyon, VB - Valentine Bottom, SB - Spanish Bottom, LC - Lathrop Canyon, LCC - Lathrop Canyon Control, BB - Brown Betty, BBC - Brown Betty Control (taken from Rigby et al. 1972).

**(s) = capture with Sherman live-trap.

(n) = capture with National live-trap.

*** + = species observed yet not captured.

Table 22. Captures per 100 trap-nights at 10 sites along the Green and Colorado Rivers in Canyonlands National Park, Utah (July 1976 - September 1977).

Site*	Species Captured												
	Pc**	Pe	Na	Ol	Em	Eq	Al	Sv	Do	Sa	Uc	Ba	Mm
LC	2.30	--	.23	--	.98	--	.20	.21	--	--	--	.03	--
LCC	.73	.28	.02	--	.13	--	--	.26	.02	--	--	--	--
LBC	6.50	.50	.50	.50	2.00	--	.50	--	--	--	--	--	--
MB	5.50	1.00	.50	.50	--	--	--	--	--	--	--	--	.50
LRL	5.00	--	--	--	2.00	1.00	--	--	--	--	--	--	--
RC	6.00	--	--	--	1.00	--	--	--	1.00	--	--	--	--
VB	4.00	--	--	--	--	--	1.00	--	--	.50	--	--	--
SB	3.00	--	--	1.50	--	--	--	.50	--	.50	--	--	--
BB	3.61	--	.16	.39	.82	--	.36	.20	--	--	--	--	--
BBC	1.60	--	.02	--	.41	--	.16	.18	--	--	.02	--	--
MEANS	3.82	.18	.12	.29	.73	.10	.22	.14	.10	.10	.002	.003	.05

*Trap-site code: LBC - Little Bridge Canyon, MB - Monument Basin, LRL - Lower Red Lake Canyon, RC - Rustler Canyon, VB - Valentine Bottom, SB - Spanish Bottom, LC - Lathrop Canyon, LCC - Lathrop Canyon Control, BB - Brown Betty, BBC - Brown Betty Control (taken from Rigby *et al.* 1972).

**Species code: Pc - canyon mouse, Pe - cactus mouse, Na - white-throated wood rat, Ol - Northern grasshopper mouse, Em - least chipmunk, Eq - Colorado chipmunk, Al - antelope ground squirrel, Sv - rock squirrel, Do - Ord kangaroo rat, Sa - desert cottontail, Uc - gray fox, Ba - ring-tailed cat, Mm - striped skunk.

Appendix I:
Plant Species Composition for Lathrop
and Brown Betty Campsite and
Control Trap-sites,
Canyonlands National
Park, Utah (1977)

Table 23. Plant species composition for campsite and control areas, Lathrop trap-site, Canyonlands National Park, Utah (1977). (See Appendix G for common and scientific names).

Species	Percent Coverage						Percent Frequency					
	Campsite			Control			Campsite			Control		
	S**	T	H	S	T	H	S	T	H	S	T	H
Trees												
coyote willow *		*		*	*		5.81	5.88		7.53	4.65	
tamarisk 4.20				1.20			28.63			26.55		
New Mexican foresteria *		*		.81	*		10.28	3.61		12.42	15.54	
netleaf hackberry *		*		.31	*		12.66	1.51		8.25	3.61	
skunkbush sumac			*			*			15.54			9.16
singleleaf ash			1.21			*			22.68			13.21
Shrubs												
silver buffalo-berry		1.50	.51		.53			23.51	14.63		38.63	
Torrey ephedra		*	2.62		1.71			20.23	35.51		33.22	
prickly-pear cactus		*			5.10	1.30		5.63			70.38	30.11
echinocactus		*			*			13.57			18.56	
echinocereus		*			*			14.51			12.77	
rubber rabbit-brush		*			*			35.61			30.10	61.32
vanclevea		1.05	1.82		*	2.63		14.80	26.33	14.31	36.88	41.29
broom snakeweed		*	*	*	1.62	.86		30.61	15.11		50.38	33.60
shadscale		1.85	1.36		3.35	2.27		8.22	25.34			
longspine horsebrush		*			*						6.31	

Table 23. Continued.

Species	Percent Coverage						Percent Frequency					
	Campsite			Control			Campsite			Control		
	S	T	H	S	T	H	S	T	H	S	T	H
<u>Shrubs cont'd</u>												
fourwing saltbush		3.10	.55		*			68.94	11.68		28.24	
fineleaf yucca		*	*		*	*		12.33	23.45		9.81	18.60
Emory baccharis	3.85	5.60					71.64	41.23				
Anderson wolfberry		*	*			*		12.55			18.63	
longleaf brickellia		*	*			*		16.11	6.51		5.41	
<u>Herbs</u>												
blazing star		*	*		*	*		12.24	24.61		10.61	8.00
desert princes- plume			.31			.60		8.85	22.61			13.40
desert trumpet			*		*	1.85		10.31			16.55	24.80
Russian thistle	*	*			*		7.64	14.25			18.32	
wirelettuce		*			*	*		14.20			17.66	19.80
coldenia		*	*		*	*		18.32	20.61		16.80	22.35
curlycup gumweed		*	*		*	*		8.85	11.64		18.43	16.68
showy milkweed	*			*			21.34			8.61		
phacelia		*		*	*			17.73		16.34	14.80	
jimson weed		*	*					5.42	11.63			
locoweed	*	*		*	*			28.21	19.68		25.41	18.30
cocklebur	*						6.62					
globemallow		*		*				8.63			14.48	
Russian centaurea		*			*			13.61			15.55	
fendler spurge		*	*		*	*		11.50	9.22		10.51	17.51

Table 23. Continued.

Species	Percent Coverage								Percent Frequency							
	Campsite				Control				Campsite				Control			
	S	T	H	S	T	H	S	T	S	T	H	S	T	H	S	T
Grasses																
cheatgrass	*	*	*	*	*	*	*	*	26.32	11.35	14.62	21.30	16.30	14.81		
fluffgrass	.20	*	*	*	*	*	*	*	21.21	11.26	18.31	12.90	16.54	9.81		
Indian ricegrass	*	1.12	*	*	1.20	*	*	*	19.65	31.25	4.65	14.63	26.35	5.10		
galleta	*	*	*	*	*	*	*	*	36.52	11.61	13.61	16.52	12.60	12.86		
little bluestem		*	*	*	*	*	*	*	18.23	16.53	21.65	11.20	16.52	15.62		
purple three-awn		*	*	*	*	*	*	*	41.22	18.23	14.45	18.62	5.13	9.10		
alkali sacaton	2.1	*	*	*	*	*	*	*	28.36	16.31	24.68	4.22	13.63			
desert salt-grass	3.2	*	*	*	*	*	*	*								
scratchgrass	*	*	*	*	*	*	*	*								
Total species present:		38	26	13	35	24										
Total percent canopy coverage:		14.22	8.38	2.32	13.51	9.51										

* = species known to be present but not sampled.

** S = Streamside

T = Terrace

H = Hillside

Table 24. Plant species composition for campsite and control areas, Brown Betty trap-site, Canyonlands National Park, Utah (1977). (See Appendix G for common and scientific names).

Species	Percent Coverage						Percent Frequency					
	Campsite			Control			Campsite			Control		
	S**	T	H	S	T	H	S	T	H	S	T	H
<u>Trees</u>												
coyote willow	1.21			1.61			25.11			21.22		
tamarisk	.53						28.70					
netleaf hackberry		.80			2.80			38.60			35.15	
buckthorn					*						2.32	
skunkbush sumac		*			*			11.40			16.51	
<u>Shrubs</u>												
Torrey ephedra		4.40	3.30		2.64	3.00		41.60	38.21		18.50	56.50
green ephedra						*			22.62			13.51
prickly-pear												
cactus		.24	*		.20	.15		34.01	23.29		31.63	25.80
echinocereus		.15	*		*	.42		20.52	18.36		19.62	31.80
rubber rabbitbrush		.41			.63	*		18.73			17.58	22.31
vanclevea		1.40	*		.80	.83		25.82	21.32		28.67	21.65
broom snakeweed		5.30	4.61		4.72	3.20		37.11	39.54		26.60	33.04
Amsonia	*	.81	*	.22	2.70	*	18.60	28.40	11.35	16.52	20.11	
Russian centaurea	.30	.61					22.10	18.70			16.20	
cliffrose						*						7.80
longleaf brickellia		.38	.21		.42	.15		16.81	11.50		21.66	12.79
<u>Herbs</u>												
desert princesplume		.41	.20		*			31.51	18.73		28.65	

Table 24. Continued.

Species	Percent Coverage						Percent Frequency					
	Campsite			Control			Campsite			Control		
	S	T	H	S	T	H	S	T	H	S	T	H
<u>Herbs cont'd</u>												
aster	*	.25		*	*		16.52	13.60		25.24	15.30	
desert trumpet			.40			*			20.33			
Russian thistle	.40			*			13.60		7.50			
wirelettuce	.81			.10	1.12		17.51		8.62		16.35	
coldenia		*	.18		*			16.41	22.81		17.50	
yellow beeplant			*		*	*			21.22		12.30	16.99
showy milkweed				*						16.20		
milkweed	*	*		*			18.83	26.50		14.83		
locoweed	*	.21		*			16.54	28.22			17.85	
pepperweed		*	*		*	*		12.67	21.59		18.33	23.20
globemallow		.30	.11		*			23.68	18.28		26.54	
dogbane		*						15.21				
white sweet												
clover	*	*		*	*		15.20	17.67		24.98	14.22	
ragweed	.22			*	*		25.30			17.73		
fendler spurge	*	*	*		*	*		6.81	9.65		12.55	14.21
<u>Grasses</u>												
cheatgrass	*	2.80	2.51	*	.81	2.10	25.80	38.71	43.54	21.62	30.20	38.61
Indian ricegrass	.20	3.20	3.82	.51	3.10	3.53	33.36	66.81	71.54	14.20	29.66	68.51
desert saltgrass	*			*			22.11			25.40		
alkali sacaton	*	*		*	*		28.72	16.88		31.42	14.25	
scratchgrass	*	*		*	*		16.75	18.22		17.51	23.66	
Total species												
present: 17		26	18	16	27	17						
Total % can. cover: 3.37		20.67	15.34	2.44	19.94	13.38						

Appendix J:
Similarity Index of Vegetation Zones
at Lathrop and Brown Betty
Trap-sites, Canyonlands
National Park, Utah
(1977)

Table 25. Similarity index of the streamside, terrace and hillside vegetation zones at Lathrop and Brown Betty trap-sites.*

	Campsite vs. Control		
	Streamside	Terrace	Hillside
Lathrop trap-site	.81	.93	.88
Brown Betty trap-site	.85	.91	.80

*Based on the formula: $S = 2w/(a + b)$ (Cox 1972).

Appendix K:
Association of Small Mammal Species
With Microhabitat Variables,
Canyonlands National Park,
Utah (1977)

Table 26. Percentage of small mammal species associated with microhabitat variables, Canyonlands National Park, Utah (1977).

Microhabitat Variable/substrate	Species: Site:	Percent of individuals caught											
		canyon mouse				least chipmunk				rock squirrel			
		L*	LC	BB	BBC	L	LC	BB	BBC	L	LC	BB	BBC
1. Streamside (beach)		2.3		7.4	3.8					6.2			
2. Gravel talus**/sand		1.2	3.0	15.8				3.2				6.7	21.4
3. Boulders, slickrock/sand		38.4	33.0	13.7	3.8	38.5	25.0			43.8	31.6	33.3	21.4
4. Grass, forbs/hillside/gravel, talus		2.3		1.1	1.3			3.2					
5. Grass, forbs/hillside/boulder, slickrock		17.4	12.1	15.8	48.7	25.0	20.8	58.1	43.8	25.0	31.6	20.0	14.3
6. Grass, forbs/terrace/gravel talus		1.2						6.5					
7. Grass, forbs/terrace/boulder, slickrock		8.1	9.1	9.5	9.0	3.8	12.5	6.5		12.5	21.0		
8. Grass, forbs/streamside/sand, pebbles***													
9. Shrubs/hillside/gravel talus		4.7	3.0			11.5	4.2						
10. Shrubs/hillside/boulders, slickrock		4.7	15.2	9.5	21.8		4.2	12.9	12.5				
11. Shrubs/terrace/gravel talus		3.5		1.1			8.3		18.7			13.3	
12. Shrubs/terrace/boulders, slickrock		9.3	6.1	5.3	9.0	7.7	16.7	6.5	25.0		15.8	20.0	28.6
13. Shrubs/streamside/sand, pebbles													
14. Trees/streamside/sand		2.3				3.8							
15. Trees/terrace/gravel talus		1.2	12.1	1.1			4.2						7.1
16. Trees/terrace/boulders, slickrock		3.5	6.1	17.9		11.5	4.2	3.2		12.5	5.3	6.7	7.1
Number of variables		14	9	11	7	7	9	8	4	5	5	6	6

*L = Lathrop exp.; LC = Lathrop control; BB = Brown Betty exp.; BBC = Brown Betty control.

**Gravel talus $\leq \frac{1}{2}$ meter in diameter.

***Pebbles ≤ 10 cm in diameter.

Table 26. Continued.

Microhabitat Variable/substrate	Species: Site:	Percent of individuals caught											
		white-throated wood rat				antelope ground squirrel				cactus mouse			
		L*	LC	BB	BBC	L	LC	BB	BBC	L	LC	BB	BBC
1. Streamside (beach)				5.3	14.3	5.0					12.5		
2. Gravel talus**/sand				10.5	7.1			8.7			37.5		
3. Boulders, slickrock/sand	60.0	54.5	36.8	50.0	15.0	21.4	17.4	13.3			50.0		
4. Grass, forbs/hillside/gravel talus			5.3		5.0	14.3							
5. Grass, forbs/hillside/boulders, slickrock	10.0				15.0	28.6	26.1	33.3					
6. Grass, forbs/terrace/gravel talus			15.8	14.3				6.7					
7. Grass, forbs/terrace/boulders, slickrock		18.2	5.3	14.3	30.0	14.3	13.0	20.0					
8. Grass, forbs/streamside/sand, pebbles***			5.3										
9. Shrubs/hillside/gravel talus	10.0				5.0								
10. Shrubs/hillside/boulders, slickrock					10.0	7.1							
11. Shrubs/terrace/gravel talus		9.1				7.1							
12. Shrubs/terrace/boulders, slickrock	20.0	9.1					21.7	26.7					
13. Shrubs/streamside/sand, pebbles			10.5										
14. Trees/streamside/sand			5.3										
15. Trees/terrace/gravel talus													
16. Trees/terrace/boulders, slickrock		9.1			15.0	7.1	13.0						
Number of variables	4	5	9	5	8	7	6	5		3			

*L = Lathrop exp.; LC = Lathrop control; BB = Brown Betty exp.; BBC = Brown Betty control.

**Gravel talus $\leq \frac{1}{2}$ meter in diameter.

***Pebbles ≤ 10 cm in diameter.

Table 26. Continued.

Microhabitat Variable/substrate	Species:	Percent of individuals caught							
		Northern grasshopper				ring-tailed			
		mouse				cat			
Site:		L*	LC	BB	BBC	L	LC	BB	BBC
1. Sand (beach)									
2. Gravel talus**/sand									
3. Boulders, slickrock/sand						100.0			
4. Grass, forbs/hillside/gravel, talus									
5. Grass, forbs/hillside/boulders, slickrock				37.5					
6. Grass, forbs/terrace/gravel talus									
7. Grass, forbs/terrace/boulders, slickrock									
8. Grass, forbs/streamside/sand, pebbles***									
9. Shrubs/hillside/gravel talus				25.0					
10. Shrubs/hillside/boulders, slickrock				37.5					
11. Shrubs/terrace/gravel, talus									
12. Shrubs/terrace/boulders, slickrock									
13. Shrubs/streamside/sand, pebbles									
14. Trees/streamside/sand									
15. Trees/terrace/gravel talus									
16. Trees/terrace/boulders, slickrock									
Number of variables				3		1			

*L = Lathrop exp.; LC = Lathrop control; BB = Brown Betty exp.; BBC = Brown Betty control.

**Gravel talus $\leq \frac{1}{2}$ meter in diameter.

***Pebbles ≤ 10 cm in diameter.

VITA

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Major Field: Wildlife Science

Objective: To work in the field of wildlife or range biology, conservation, zoology, or agriculture, which would entail, in part, inter-personal communication and consultation.

Education: Master of Science in Wildlife Science, 1978 - Utah State University, Logan, Utah

Bachelor of Science in Zoology and Wildlife Science, 1976 - Utah State University, Logan, Utah

Botany and Zoology course-work, 1972-1974 - Eastern Illinois University, Charleston, Illinois

Academic Fields:

Wildlife Science	38 qtr. hrs.
General Science and Biology	34 qtr. hrs.
Zoology	30 qtr. hrs.
Chemistry and Physics	25 qtr. hrs.
Botany	21 qtr. hrs.
Math and Statistics	20 qtr. hrs.
Range Science	20 qtr. hrs.
English and Speech	18 qtr. hrs.

Experience: Canyonlands National Park, Graduate Research, small mammals - April 1977 - September 1977; June 1976 - September 1975.

Bryce Canyon National Park, Undergraduate Research Biologist, Utah prairie dog - June 1975 - September 1975.

Bruning-Addressograph Corporation, Machine Shop - July 1974 - September 1974.

Moore's farm buildings, construction and painting - June 1973 - August 1973.

Eastern Illinois University greenhouse, groundsman and maintenance - October 1972 - January 1973.

Honors, Publications:

Honors graduate at Utah State University

Member, National Wildlife Society

Undergraduate research assistant, Utah State University
(1975)

Graduate research assistant, Utah State Cooperative
Wildlife Research Unit (1976)

Elmore, S. W., and G. W. Workman. 1976. A baseline study of the past and present status of the Utah prairie dog (Cynomys parvidens) in Bryce Canyon National Park. Dept. of Wildlife Science, Utah State Univ., Logan, Utah. 44 pp.

Elmore, S. W., and G. W. Workman. 1977. Status of the Utah prairie dog in Bryce Canyon National Park, Utah. Utah Academy of Science, Arts, and Letters. 54 (1): 3 pp.

Elmore, S. W., and G. W. Workman. 1977. Repopulating Bryce Canyon. Utah Science. 38 (3): 79-81.

Elmore, S. W., F. Jaenike, and G. W. Workman. 1977. The amphibians and reptiles of Canyonlands National Park, Utah. Dept. of Wildlife Science, Utah State University, Logan, Utah. 18 pp.

Activities and Interests:

Intramural archery champion, 1973, 1974
Intramural trap and skeet champion, 1974
Intramural basketball champions, 1973, 1978
Illinois State canoe champion, 1973
Intramural weightlifting, track, swimming, softball, badminton, basketball, 1972 - 1978

Enjoy essentially all sports, outdoor recreation, research, writing, and photography.

Personal: Age 23, unmarried Excellent health

References: Utah State University Placement Center