

BIOLOGY AND ECOLOGY OF FERAL BURROS (EQUUS ASINUS)

AT GRAND CANYON NATIONAL PARK, ARIZONA

FINAL RESEARCH REPORT

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CHAPTER I

THE SETTING AND THE PROBLEM

G.A. Ruffner and A.M. Phillips, III

The burro (Equus asinus) has had a long and colorful history in North America. These animals were first introduced to this continent by Spanish explorers during the 1500's (Carothers et al. 1976) and have subsequently been the subject of religious and folk symbolism. Perhaps the best known example of this is the amazingly popular children's story, Brighty of the Grand Canyon (Henry 1953).

Recently the existence of feral burros on federal lands has been defended by a well-meaning but misinformed segment of the American public. In fact, some of the most vociferous proponents have acknowledged that these animals do cause management problems on public lands. V.B. "Wild Horse Annie" Johnston and M.J. Pontrelli (1969) stated that "...complete protection is not a panacea. Many observers agree that burros often seem too numerous."

Researchers, conservation organizations, resource managers and concerned citizens have become aware of another side of Brighty; that is, severe management problems associated with the introduction and subsequent "feralization" of burros in the southwestern United States. Perhaps this problem has been best addressed by McKnight (1964) who commented that "Man has a penchant for trying to improve on nature, and he has frequently demonstrated this proclivity by deliberately introducing exotic creatures into new habitats." Several authors (Dodge 1951; McKnight 1958, 1964; Hansen and Martin 1973; Spatz and Mueller-Dombois 1973; Koehler 1974; Bratton 1975; Carothers et al. 1976; Ruffner et al. 1976, 1977; National Parks and Conservation Association 1977; Norment and Douglas 1977; Potter and Berger 1977) have considered the problems of exotic organisms and the destruction they have wrought on many acres of National Park Service lands. Currently, in the southwestern United States, there are six National Parks,

National Monuments and National Recreation Areas which have management problems associated with feral burros (National Parks and Conservation Association 1977).

The situation at Grand Canyon National Park is typical of the problem throughout the Southwest. Initial feral burro management practices were designed merely to reduce the population densities to a number compatible with park resources. This objective was accomplished either primarily by shooting or secondarily by capture and removal of feral burros from the park. However, of the 2,860 animals eliminated between 1924 and 1969, only 252 or 9 percent were captured and removed (Carothers et al. 1976). Furthermore, all capture and removal operations were restricted to the more accessible Tonto Platform between Red Canyon and Bass Camp. Direct reduction by shooting has proven to be the most effective tool in the management of the Grand Canyon burros, since this method is not subject to topographic restraints.

Ruffner and Carothers (in press) have documented some of the changes in Grand Canyon feral burro populations that have occurred as a result of different management practices. They have found that young, rapidly expanding populations are the direct result of partial reduction of feral burros within Grand Canyon National Park (see Chapter VII). This conclusion is further supported by Park Service records of reduction efforts in two areas of the Grand Canyon between 1956 and 1969 (Table I-1). Although during the 14 year removal program 584 animals were eliminated between Tanner and Garnet Canyons and 59 in Shinumo Amphitheater, there are currently an estimated 100 animals in the Tanner Canyon to Garnet Canyon area and 40 animals in Shinumo Amphitheater (J. Walters, pers. comm.) These data emphasize the futility of a partial reduction program for feral burro populations. Thus, it appears that future management programs should either allow populations to stabilize or remove them entirely from the Park by the most effective method.

In this difficult and often emotional climate, the National Park Service has been directed by the Secretary of the Interior to develop an Environmental Impact Statement addressing the management of feral burros at Grand Canyon National Park. In response to criticisms of the Feral Burro Management Plan and Environmental Assessment (U.S.D.I. 1976), the following studies were designed and implemented by Museum of Northern Arizona biologists under contract with the National Park Service, Grand Canyon National Park. The objectives of this study were:

1. to assess the current distribution and population densities of feral burros;
2. to evaluate quantitatively the effects of feral burros on natural communities, including soils, vascular plants and small mammals;
3. to evaluate quantitatively the short-term recovery of natural communities following removal of feral burros;
4. to evaluate the growth of feral burro populations in relation to environmental alteration;
5. to review the age structure, condition, reproduction and diet of feral burros in Grand Canyon.

Table I-1.--Numbers of feral burros shot or removed from two areas of Grand Canyon National Park between 1956 and 1969.¹

<u>Year</u>	<u>Tanner Canyon to Garnet Canyon²</u>	<u>Shinumo Amphitheater</u>
1956	0	0
1957	125	0
1958	113	0
1959	51	0
1960	10	0
1961	1	0
1962	0	0
1963	101	0
1964	69	4
1965	32	33
1966	33	6
1967	0	0
1968	36	5
1969	13	11
	<u>584</u>	<u>59</u>

-
1. Data from National Park Service files, Grand Canyon National Park.
 2. Excludes any animals taken from Pasture Wash.

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CHAPTER II

DISTRIBUTION AND POPULATION DENSITIES OF FERAL BURROS, GRAND CANYON, ARIZONA

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A complete understanding of the distribution and population dynamics of feral burros at Grand Canyon is essential to an effective management program. Some of the problems of accurately censusing burros are exaggerated because of the topography of the study area. Shoemaker (1976) attempted to census feral burros from fixed-wing aircraft. This effort resulted in an accurate assessment of feral burro distribution, but censuses conducted from fixed-wing aircraft were of dubious value. More recently Park Service investigators, in cooperation with researchers from Arizona State University, have been successful in censusing feral burros from helicopters. This technique requires marking and subsequent recounting of marked and unmarked animals (J. Walters, pers. comm.).

Distribution of feral burros in Grand Canyon has been monitored infrequently for many years. Shoemaker's (1976) efforts represent the first systematic investigation of feral burro distribution in the Park. He identified three areas of the Canyon that support the highest densities of feral burros:

1. on the south side of the Colorado River from Red Canyon to Hermit Canyon;
2. on the north side of the Colorado River in Shinumo Amphitheater;
3. on the north side of the Colorado River from Parashant Canyon to 220 Mile Canyon.

Recently, Park Service investigations, conducted in cooperation with Arizona State University, tend to verify Shoemaker's (1976) findings. At least 100 feral burros are present from Tanner Canyon to Garnet Canyon; approximately

40 are found in the Shinumo Amphitheater area; and 150 occupy the area between Parashant Canyon and Bridge Canyon (J. Walters, pers. comm.).

No feral burros were sighted during Park Service census efforts in the Grand Wash Cliffs area although fresh sign was apparent (J. Walters, pers. comm.). Our observations in this vicinity suggest that the north bank of the Colorado River is occupied irregularly by a small population (approximately 6 to 15) of feral burros. Moreover, Hansen and Martin (1973) heard or observed feral burros in this area during their visit in March, 1972. These data suggest that in this section of the Grand Canyon feral burros move temporarily into the Park from adjacent B.L.M. and Lake Mead National Recreation Area lands.

The majority of feral burros in Grand Canyon National Park presently occupy the area below the Redwall Limestone (Shoemaker 1976; J. Walters, pers. comm.). Burros are present, or have been, in several areas above the Redwall Limestone including Pasture Wash and Darwin Plateau. Between 1956 and 1964, Park Service feral burro control records indicate that animals were shot in the vicinity of Pasture Wash during every month of the year except July, September and October. The largest number of kills were made in February, March and April. Nineteen animals from "around Darwin Plateau" were shot in 1968 (N.P.S. Feral Burro Control Records, G.C.N.P.). A Museum of Northern Arizona field party observed six feral burros near Darwin Plateau at the head of Garnet Canyon on 25 September 1977. We feel that feral burros are present infrequently on a seasonal basis in this pinyon-juniper woodland community of the Park. Water may be a limiting factor during the warmer months of the year in this community. Woodward and Ohmart (1976) reported a high degree of site fidelity in feral burro populations on the Lower Colorado River. During the driest and warmest months of the year burros were generally confined to habitat adjacent to the river.

In summary, feral burros are found on the south side of the Colorado River from Red Canyon to Hermit Canyon, on the north side of the Colorado River in Shinumo Amphitheater and on the north side of the Colorado River from Parashant Canyon to 220 Mile Canyon. Approximately 300 animals are present in these areas with highest densities in the Parashant to 220 Mile Canyon area. Pinyon-Juniper habitats above the Redwall Limestone are utilized on a seasonal basis by feral burros.

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CHAPTER III

DESCRIPTION OF STUDY SITES, GRAND CANYON, ARIZONA

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Plant communities in the Grand Canyon are distinctly zoned from rim to river and change according to differences in elevation and substrate. Previous burro impact studies in the Grand Canyon have been carried out within the low elevation Mohave Desert plant communities of the Inner Gorge, the most arid and fragile vegetation type in the Grand Canyon. These hot desert communities differ considerably in species composition, ecology, and origin from the high desert shrub community of the Tonto Platform and the pinyon-juniper woodland community of the high plateaus and rims of the canyon. Therefore, it is not valid to extrapolate impact of feral burros on one community from data obtained in another community.

Five major areas have been evaluated for burro impact during this study. These include the pinyon-juniper woodland community on the Esplanade, the blackbrush community on the Tonto Platform, the Mohave Desert community near Rampart Cave, the Inner Gorge Mohave desert and riparian communities between River Mile 124 and River Mile 210.5, and the Shinumo Creek area.

The pinyon-juniper woodland contains relatively few plant species in common with the Tonto Platform and the Inner Gorge. The blackbrush community of the Tonto Platform is a high desert shrub community differing considerably in species composition from the Mohave Desert community of the Inner Gorge. The Rampart Cave area at the western end of the Grand Canyon was selected to evaluate burro impact in a section of the canyon where no previous studies of this type had been done. The greatest diversity of Mohave Desert plant species

within the Inner Gorge occurs in this area. Burro use in the Rampart Cave area is infrequent compared to other Inner Gorge study sites. In addition, Hansen and Martin (1973) compared the diets of burros and bighorn sheep (Ovis canadensis) in this vicinity. Rampart Cave and the surrounding area, well studied with respect to modern and late Pleistocene floras (Phillips 1975, 1977), is the focal point for the question of whether the late Pleistocene Equus found there is ecologically and/or morphologically comparable to the modern feral burro.

The pinyon-juniper, blackbrush and Mohave Desert community sites were established in May, 1977, and re-analyzed subsequently in July and September. Control (burros absent) and impact (burros present) study sites were matched as closely as possible with respect to slope, aspect, soil and vegetation. Five permanent transects were established at each study site.

Eleven permanent vegetation transects were established by the Museum of Northern Arizona in September, 1976, in areas of the Inner Gorge. The transects were located in two areas, the Bedrock Canyon area (River Mile 124 to River Mile 128) and the Lower Canyon area (River Mile 198 to River Mile 210.5). In July of 1976 all feral burros were removed between River Mile 124.5 and Bedrock Canyon; they have not since re-invaded this area. Burro numbers were reduced between River Mile 198 (Parashant Canyon) and River Mile 210.5. Most of these transects were matched control and impact sites on opposite sides of the river; however, three had no matched control site. All were re-read in April and September, 1977.

Five permanent vegetation transects were established by the National Park Service in the Shinumo Creek area in May of 1965. Three were situated in the Mohave Desert community along the creek and two at higher elevations in the blackbrush community near Dox Castle. Burros were removed from the area during the late 1960's, but their populations have increased dramatically

since 1969. Burro activity in the Shinumo area today is largely confined to the Creek. These transects were located and re-analyzed in July, 1977.

The following study site descriptions indicate site location, elevation, appropriate U.S. Geological Survey topographic quadrangle map on which the transect is situated, slope, aspect, geologic formation serving as soil parent material, and general plant community. Colorado River mileage is measured from Lee's Ferry; abbreviations (R) and (L) refer to right and left sides of river (facing downstream).

Pinyon-Juniper control (original): [Grand Canyon National Park (GCNP), Coconino Co., Specter Terrace, elev. 1600 m (Powell Plateau 15 min. quadrangle)]. The vegetation transect, virtually level at this site, is situated on reddish sand originating from Esplanade sandstone of the Supai Group. The site is located in the pinyon-juniper woodland (Brown and Lowe, 1974), and consists of open pinyon woodland with only a few scattered junipers.

Pinyon-Juniper control (new): [GCNP, Coconino Co., Masonic Temple, elev. 1860 m (Powell Plateau 15 min. quadrangle)]. Slope is 1 to 3 degrees with a southern exposure. Soil parent material and vegetative community are similar to those of the original Pinyon-Juniper control site.

Pinyon-Juniper impact (original): [GCNP, Coconino Co., Tapeats Amphitheater S of Crazy Jug Point, 4.3 km S, 1.3 km W Big Saddle Camp, elev. 1770 m (Powell Plateau 15 min. quadrangle)]. Slope, aspect, soil, and general plant community are the same as the original Pinyon-Juniper control site. J. Walters (pers. comm.) noted that this transect is within an area that was a wintering pasture for approximately 40 head of horses and an undetermined

number of cattle until May, 1976. A new impact site was selected for the September pinyon-juniper sampling period.

Pinyon-Juniper impact (new): [GCNP, Coconino Co., Darwin Plateau SSE of Mt. Heuthawali, elev. 1650 m (Havasupai Point 15 min. quadrangle)]. Slope, aspect, soil, and plant community are equivalent to those of the new Pinyon-Juniper control site. This site displayed recent signs of burro activity and is not utilized by horses or cattle.

Tonto Platform control: [GCNP, Coconino Co., Tonto Platform SSW of Krishna Shrine, 16 km E Grand Canyon village, elev. 1280 m (Vishnu Temple 15 min. quadrangle)]. Slope of the transect is 5 to 8 degrees with a west-facing exposure. Soil parent material is Bright Angel shale with gradational contacts with Muav limestone and Tapeats sandstone. The vegetative community is a temperate desertscrub blackbrush community (Brown and Lowe 1974).

Tonto Platform impact: [GCNP, Coconino Co., Tonto Platform N of Horseshoe Mesa, 1.6 km S, 16.2 km E. Grand Canyon Village, elev. 1220 m (Vishnu Temple 15 min. quadrangle)]. Slope, aspect, soil, and plant community are similar to the Tonto Platform control site.

* Rampart Cave control: [GCNP, Mohave Co., 140 m below (ENE of) Rampart Cave, south side of Lake Mead, 1.6 km S, 6.4 km E Pearce Ferry, elev. 400 m (Columbine Falls 7 1/2 min. quadrangle)]. Slope of the east-facing hillside is 10 to 12 degrees. Soil parent material is Bright Angel shale overlain with Muav limestone. The vegetative community is Mohave desertscrub (Brown and Lowe 1974).

X Rampart Cave impact: [GCNP, Mohave Co., north side of Lake Mead, 0.8 km N, 7.2 km E Pearce Ferry, elev. 400 m (Columbine Falls 7 1/2 min. quadrangle)]. Slope of the west-facing hillside is 10 to 12 degrees. Soil parent material is Bright Angel shale with travertine overflow. Plant community is the same as the Rampart Cave control site.

Colorado River Mile 124.5(L) control: [GCNP, Coconino Co., 1.2 km S of mouth of Fossil Canyon, elev. 720 m (Kanab Point 15 min. quadrangle)]. Slope of the west-facing exposure is 25-27 degrees. Soil consists of Recent river deposits - mud, sand and silt. The vegetative community is characteristic of Mohave desertscrub (Brown and Lowe 1974).

Colorado River Mile 124.5(R) impact: [GCNP, Coconino Co., 1 km SSW of mouth of Fossil Canyon, elev. 720 m (Kanab Point 15 min. quadrangle)]. Slope of the east-facing exposure is 25-27 degrees. Soil and vegetative community are similar to those of River Mile 124.5(L) control site. All feral burros were removed from this area in July, 1976.

Colorado River Mile 128(L) control: [GCNP, Coconino Co., 0.6 km W of mouth of Specter Chasm, elev. 800 m (Powell Plateau 15 min. quadrangle)]. Slope of the east-facing exposure is 12-15 degrees. Parent material is Muav limestone. The vegetative community is Mohave desertscrub (Brown and Lowe 1974).

Colorado River Mile 126.5(R) impact: [GCNP, Coconino Co., 1.2 km SW of mouth of One Hundred and Twenty-eight Mile Creek, elev. 800 m (Powell Plateau 15 min. quadrangle)]. Slope of the west-facing exposure is 12-15 degrees.

Soil parent material is Bright Angel shale with gradational contacts with the Muav limestone. The vegetative community is Mohave desertscrub (Brown and Lowe 1974). All feral burros were removed from this area in July, 1976.

Parashant Canyon Beach (R) impact: [(no matched control site) Colorado River Mile 198, GCNP, Mohave Co., beach at mouth of Parashant Canyon 50 m from river, elev. 460 m (Whitmore Point SE 7 1/2 min. quadrangle)]. The slope of this south-facing exposure is less than 5 degrees and the soil consists of alluvial river deposits. The vegetation type is Mohave desertscrub (Brown and Lowe 1974).

Parashant Canyon (L) control: [Colorado River Mile 198, GCNP, Coconino Co., opposite mouth of Parashant Canyon, elev. 510 m (Whitmore Point SE 7 1/2 min. quadrangle)]. This site has northwest-facing exposure with a slope of 30-32 degrees. Soil parent material is Muav limestone and the vegetation is Mohave desertscrub (Brown and Lowe 1974).

Parashant Canyon (R) impact: [Colorado River Mile 198, GCNP, Mohave Co. W side at the mouth of Parashant Canyon, elev. 510 m (Whitmore Point SE 7 1/2 min. quadrangle)]. The site has an east-facing exposure with a slope of 30-32 degrees. Substrate and vegetation are similar to that at Parashant Wash (L) control site.

Spring Canyon (R) impact: [(no matched control site) Colorado River Mile 204.5, GCNP, 0.5 km N of mouth of Spring Canyon, elev. 520 m (Whitmore Point SE 7 1/2 min. quadrangle)]. The slope of the east-facing hillside is 13-15 degrees. Soil parent material is Bright Angel shale. The vegetation type is Mohave desertscrub (Brown and Lowe 1974). The Spring Canyon area is

apparently heavily used by burros as freshly used trails and fresh droppings were abundant in the sampling area.

Colorado River Mile 208(L) control: [Hualapai Indian Reservation, Coconino Co., 1.1 km NW of mouth of Two Hundred and Nine Mile Canyon, elev. 470 m (Granite Park 7 1/2 min. quadrangle)]. The slope faces southwest with an inclination of 8-10 degrees. Soil consists of alluvial deposits, mainly beach sand. The vegetation type is old pre-dam upper floodline riparian community, dominated by Acacia greggii (catclaw) and Prosopis juliflora var. torreyana (mesquite), usually intermixed.

Indian Canyon impact: [Colorado River Mile 207.5(R), Mohave Co., 1 km SSE of mouth of Indian Canyon, elev. 470 m (Granite Park 7 1/2 min. quadrangle)]. The slope of this east-facing beach is 13-15 degrees. Soil and plant community are similar to those of River Mile 208(L) control site.

Colorado River Mile 210.5(R) impact: [(no matched control site) GCNP, Mohave Co., 1.7 km N of mouth of Fall Canyon, elev. 440 m (Granite Park 7 1/2 min. quadrangle)]. This east-facing slope is inclined at an angle of 10-12 degrees. Substrate is of alluvial deposits. Vegetation type is Mohave desertscrub (Brown and Lowe 1974).

Shinumo 401 impact: [GCNP, Coconino Co., 0.5 km SW of middle of saddle on Dox Castle, elev. 1195 m (Havasupaid Point 15 min. quadrangle)]. Inclination of this south-facing slope is 7-9 degrees. The substrate is Bright Angel shale with gradational contacts in the Muav limestone and Tapeats sandstone. Vegetation is typical of the blackbrush community (Brown and Lowe 1974).

Shinumo 402 impact: [GCNP, Coconino Co., 0.6 km W of middle of saddle on Dox Castle, elev. 1170 m (Havasupai Point 15 min. quadrangle)]. There is no slope but the site has a northern exposure. The substrate and vegetation type are similar to the Shinumo 401 impact site.

Shinumo Creek 403 impact: [GCNP, Coconino Co., 1.4 km NW of middle of saddle on Dox Castle, elev. 835 m (Powell Plateau 15 min. quadrangle)]. There is no slope but the site has a northeast exposure. The soil parent material is Shinumo quartzite. The vegetation is a streambed riparian community.

Shinumo Creek 404 impact: [GCNP, Coconino Co., 1.2 km NW of the middle of the saddle on Dox Castle, elev. 845 m (Powell Plateau 15 min. quadrangle)]. There is a slope of 15-20 degrees on this west-facing hillside. The substrate is Shinumo quartzite. The vegetation is typical of the Mohave desertscrub (Brown and Lowe 1974).

Shinumo Creek 405 impact: [GCNP, Coconino Co., 1.1 km NW of middle of saddle on Dox Castle, elev. 850 m (Powell Plateau 15 min. quadrangle)]. The slope of this west-facing hillside is 30-35 degrees. The soil parent material and the vegetation are similar to the Shinumo Creek 404 impact site.

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CHAPTER IV

INVESTIGATIONS OF FERAL BURRO IMPACT ON PLANT COMMUNITIES,
GRAND CANYON, ARIZONA

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Introduction

The influence of the feral burro on natural communities in the southwestern United States has received considerable attention. McKnight (1958) made qualitative observations of habitat modifications attributed to the activities of feral burros. Carothers et al. (1976) quantitatively evaluated the impact of feral burros on plant and small mammal communities in Grand Canyon. Recently, other investigators have addressed the effects of feral burros on plant communities in Grand Canyon (Ruffner et al. 1976, Ruffner et al. 1977) and elsewhere throughout the Southwest (Koehler 1974, Woodward and Ohmart 1976, Hanley and Brady 1977a and 1977b, Norment and Douglas 1977, Potter and Berger 1977).

Changes in plant community structure resulting from the activities of feral burros are comparable to the effects of browsing and grazing attributed to several other species of livestock in the West (Humphrey 1958, Schmutz and Smith 1976, Young et al. 1976). In general, alterations in plant community structure favor an increase in unpalatable or resilient native shrubs, an increase in "weed" species adapted to intensive grazing, and a reduction in palatable forbs and grasses.

Studies of seeds and the organisms that interact with them (e.g., ants, rodents) have traditionally concerned themselves with the effects of seed predators on seed germination (Abbott and Quink 1970, Janzen 1971, Reichman 1976, 1977), seed distribution (Reichman 1977, Reichman and Oberstein 1977),

seed density (Reichman 1977, Reichman and Oberstein 1977), or with the responses of plants to protect themselves from seed predation (Smith 1970, Janzen 1971). Recently, some authors (Carothers et al. 1976, Woodward and Ohmart 1976) have made qualitative observations concerning the fate of seeds in habitats occupied by feral burros that interact indirectly with seeds. Seeds are extremely important in determining the structure and composition of future plant assemblages within a community. As such, they are a unique and valuable indicator of potential plant community structure.

The purposes of our study were to evaluate the effects of feral burros on Tortula, and to identify and evaluate the impacts of feral burros on structure of Grand Canyon plant communities. In addition, we measured the long-term trends of plant community structure in areas inhabited by feral burros, determined short-term recovery rates of plant communities modified by feral burros and measured seed production of vascular plants to evaluate the influence of feral burros on vascular plant reproduction.

Materials and Methods

Vegetation Analysis

For the Inner Gorge transects, frequency, density, cover (dominance), and importance value were determined for all plant species encountered at each sampling site. A line transect 100 m in length was run at each site to determine coverage of woody plants using the line intercept method (Canfield 1941). Circular plots 25m^2 in area were set up at four places along the transect at 10, 40, 60, and 90 m from the origin, giving a total of 100m^2 for each transect. Only perennial plants were counted in these

plots, yielding data for calculating frequency and density. Annual species were analyzed by placing a 1 m^2 plot frame at ten points every 10 m along the left-hand side of the transect, giving a total area of 10 m^2 . Frequency and density were determined by counting the number of individuals of each species falling within the frame. Cover was estimated for each annual species using the canopy coverage method (Daubenmire 1959). The species in each plot were placed in one of six coverage classes according to the percent of the frame covered by its canopy. The six classes are: 1) 0-5%; 2) 5-25%; 3) 25-50%; 4) 50-75%; 5) 75-95%; 6) 95-100%. In analysis of the data, the midpoint of each of the percentage classes was used.

The values for frequency, density, and cover generated for each species were converted to relative values (based on 100) for each parameter as follows (Mueller-Dombois and Ellenberg 1974):

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

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

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

The Importance Value is defined as the sum of the above relative values (Curtis 1959). This is converted to an "importance percentage" (based on 100 instead of 300) by dividing by 3 (Risser and Rice 1971). In the text, importance value refers to the value after division by 3 (ie. I.V./3).

The importance percentage calculated for each species allowed comparison of a given species between sampling area. Data collected from the transects and circular plots for perennials must be analyzed separately from data

obtained for annuals from 1 m^2 plot frames because of difference in size of the sampling area. During the September 1977 readings of transects at River Mile 207R and 208L, we sampled 50 mesquites and 50 catclaw acacias at each site for mistletoe infestation. This was done by recording infestation in the first 50 trees of each species encountered while walking upstream from the transect.

Several modifications in the sampling procedure were used in the Pinyon-Juniper, Tonto Platform, and Rampart area transects established in May, 1977. A 50 m base line was selected in the impact and in the control area. Five 50 m long transects were set up perpendicular to the base line at 10 m intervals, the first at 5 m and the last at 45 m, giving a total length of 250 m at each site.

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

Annual plant species and mosses were sampled in 0.1 m^2 plots by placing a plot frame at the beginning of each of the belt segments. Ten plots were measured along each transect, giving a total area sampled of 5.0 m^2 at each site.

For analysis, the data from each of the five transects at each site were combined. Relative frequency, density, and cover and importance percentage were calculated as described above for each species. Cover data from the transects are compatible for all species; however, since

the plot size was different it was necessary to compute importance percentages separately for annuals and perennials as was done above.

The Shinumo Area Ground Cover transects were read using the same method employed by National Park Service personnel when the sites were established in 1965. A 100-foot tape was stretched tightly between two plot stakes marking the ends of the transects. A plumb-bob was dropped from each foot mark and the dominant vegetation or ground cover was noted within a 4-inch circle. If the plumb fell within the normal diameter of a large plant, it was considered a "hit" on that plant. If it hit a dead portion of a live plant, it was listed as dead. Data were collected on form GCNP 15-3-R (5/12/59) entitled Ground Cover Composition Survey Form. Each of the 100 points thus sampled on each transect was considered as 1%, and the total "hits" for each species or surface type was considered as the percent ground cover.

Seed Analysis

Seed analyses were conducted in the Pinyon-Juniper, Tonto Platform and Rampart Cave study sites. Fifty circular soil samples (.002 meters in area) were collected at 2 meter intervals along the vegetation transect base line at each site during all three sampling periods. In the July and September sampling periods, we were careful to take soil samples from

previously unsampled points along the base line. Each soil sample was placed in consecutively numbered coin envelopes and returned to the laboratory.

In the laboratory, each sample was opened and weighed to the nearest 0.1 g. It was then placed in a beaker, washed by adding 250 ml of H_2O , and stirred. The filtrate was poured through a piece of organza cloth in a Buchner funnel connected to a vacuum pump. This step, repeated four times, removed about 40% of the sample weight. After the organza cloth is used five times it was discarded, since it stretches easily and the mesh dimensions become unreliable. To float the seeds, a saturated solution of K_2CO_3 (density 1.56, 113 K_2CO_3 per 100 ml distilled water) was used. We have found this density to be sufficient to float off most of the organic material in the sample. The funnel was moved to a second flask and the beaker with the sample was filled to 200 ml with the K_2CO_3 solution. It was stirred thoroughly and the dirt was allowed to settle to the bottom. The filtrate was then poured through the funnel and the organic material was trapped by the organza cloth. This step was repeated to catch any organic material that remained in the beaker. The funnel was then moved to a third flask and washed twice with water as in the second step. This washing removed any K_2CO_3 from the seed to facilitate identification. The organza cloth containing the organic material was removed from the funnel and set aside to dry for about 24 hours. If there

was dust left in the sample after drying, it was shaken through the organza cloth. The sample was then placed under a stereoscope microscope (power 10X) and the seeds were picked out with forceps, identified and counted.

In our analysis of the data, we assumed that the number of seeds increased linearly as sample area increased. Furthermore, comparison of samples from impact and control sites within a given habitat and sampling period required that soil sample weights not differ significantly. This relationship was tested using the Student's t test (Sokal and Rohlf 1969). We found no significant differences in weights of soil samples for any pair of impact and control sites within a given habitat and sampling period.

Results

Inner Gorge Transects

There were striking differences in species composition between the matched control and impact sites at River Mile 124.5 R and L. On the burro impacted side, the most important species were Encelia farinosa, Ephedra nevadensis and Opuntia basilaris (Tables IV-1 - IV-2). On the control transect, Hilaria rigida (big galleta) was the highest in importance value during both sampling periods. Big galleta was much lower in importance value on the impact side. Other key species on the control side include Ephedra nevadensis and Encelia farinosa and an unknown grass (Tables IV-4 - IV-5).

Total cover figures for annuals were considerably greater on the control side (55% and 28%) than on the impact side (31% and 16%) for both sampling periods (Table IV-1, IV-2, IV-4, IV-5). Annual cover on both sides decreased by about one-half between April and September, 1977, an unusually dry period in the Grand Canyon during which there was not sufficient rainfall for germination. Tortula, a moss forming a crust on the soil surface in undisturbed areas, had a much higher ground cover on the control side (about 40%), where it formed a uniform cover on bare soil, than on the impact side (6% or less), where it was present mainly under shrubs. Its abundance was not affected by drought conditions.

Table IV-7 compares absolute density and cover figures for select perennial species on both sites at all three sampling periods. Although the absolute densities of Mormon-tea were similar between the control and impact sites, there was greater cover of Mormon-tea on the impact side. Both density and cover of brittlebush were usually greater on the impact than on the control site. However, the perennial grasses and Haplopappus spinulosus (goldenbush) were dense and contributed more to cover at the control site.

The new transects showed basically the same trends as the original transects, with some variations (Table IV-3 and Table IV-6). The main differences were the greater importance values for Gutierrezia lucida (snakeweed) and big galleta on the impact site on the new transect than on the original transect.

The results of matched transects at River Mile 126R and 128L are shown in Tables IV-8 to IV-11. Brittlebush was the most important species on the control site (I.V. 46.3%); it was absent from the impact side. Mormon-tea was most important on the impact side (I.V. 31.9%); it was third on the control side (I.V. 10.2%). Plant cover was very low at both control and impact sites, ranging from seven to ten percent.

At the site on the bench at the mouth of Parashant Canyon (River Mile 198R), only three perennial species accounted for 90% of the importance value (Tables IV-12 and IV-13). These were Larrea tridentata (creosotebush; I.V. 63.1%), Opuntia basilaris (beavertail cactus; I.V. 17.5%), and Acacia greggii (catclaw; I.V. 14.9%). Cover of annuals decreased from 14% to 4% between April and September, 1977. Tortula cover remained at about 7% and it was confined to areas under shrubs.

The transects on hillsides on opposite sides of the river at Parashant Creek displayed a different species composition from the transect at the creek. At the impact site, brittlebush, creosotebush, beavertail cactus, and Mormon-tea made up 74.2% of the importance value in September; they were joined by Allionia incarnata (trailing four-o'clock) to make up 78.2% of the importance value in April (Tables IV-14 and IV-15). Cover of annuals was low for both sampling periods (6% and 8%). However, Tortula cover increased from 10 to 20 percent from April to September 1977. At the control site, big galleta was first and bush muhly was in the top ten in importance value (Tables IV-16 and IV-17); both were missing from the impact site.

In general, density and cover were greater for selected species on the control than on the burro impacted site during all sampling periods at River Mile 198 (Parashant Canyon). The one exception, brittlebush, was present in greater densities on the impact than on the control site. However, cover values were similar for both areas. In contrast, several perennial grasses were present on the control and essentially absent on the impact site (Table IV-18).

On the single transect established in a burro impacted area on the north side of the Colorado River at River Mile 204R, brittlebush and creosotebush strongly predominated, making up 71% of the importance value, but total cover

of perennials was only 9.5%. Seedlings and mature plants of brittlebush had about the same importance value when they were counted separately during the April, 1977, sampling period, with a value of about 21% for each. When seedlings and mature plants of brittlebush were lumped during the September sampling period, the importance value for the species was about 50%.

The results of the transects run in the old upper floodline of the Colorado River at Indian Canyon (River Mile 207R and 208L) are shown in Tables IV-21 to IV-24. The most striking difference between the two areas was in total cover. The area impacted by feral burros had a cover of perennials ranging from 29% to 31% (Tables IV-21 and IV-22), while the cover on the control side ranged from 65% to 69%. The transect on the impact side was more open and had a higher species diversity. Creosotebush had a higher importance value than mesquite or catclaw on the impact site. The control transect ran through a mature, dense mesquite bosque forming a pure stand with a closed canopy along the first two-thirds of the transect. On the site impacted by feral burros, 20% of the mesquites and 36% of the catclaws contained mistletoe (Phoradendron californicum), while on the control site only 2% of the mesquites and 12% of the catclaws were infested.

An unpaired transect at River Mile 210.5R ran across an active sand dune with scattered catclaw, mesquite, creosotebush, and other shrubs. The results are shown in Tables IV-25 and IV-26. The cover of annual plants dropped from 15 to 7 percent between April and September 1977. Tortula cover (2% and 4%) remained low at this site.

Pinyon-Juniper Sites

The species diversity at the original Pinyon-Juniper sites during the May, 1977, sampling period was higher than at any other sites in this study,

with 36 perennial species on the impact site and 29 on the control site (Tables IV-27 to IV-30). Grasses were important at both sites, with three among the top ten species in importance value at the control site and two among the top ten at the impact site. Bouteloua gracilis was first in importance value (about 22%) on the impact site during both sampling periods. The shrubs found in the two sites were notably different, with Arctostaphylos pungens (manzanita), Ceanothus greggii (buckbrush), Cowania mexicana (cliffrose) and Quercus turbinella (shrub live oak) present on the impact site and absent on the control site; Chrysothamnus nauseosus (rabbitbrush) and Haplopappus spinulosus (goldenweed) were present on the control site and absent from the impact site. However, all shrubs, except manzanita, were lower than tenth in importance value. Manzanita was second at the impact site.

The major difference between the sites established in September, 1977, was the abundance of perennial grasses at the control site and their paucity at the impact site (Tables IV-31 and IV-32). Stipa neomexicana, Poa cf. fendleriana, and Bouteloua gracilis ranked first, second, and fifth in importance value at the control site and had a combined importance value of 32.4%. Only Stipa was present, in very small quantities, on the impact site. The only grass among the top ten in importance value at the impact site was Sporobolus flexuosus, which was lacking at the control site. The species with the highest importance value at the impact site was Gutierrezia sarothrae (snakeweed). The total cover of perennials at the impact site was 28%, compared with 51.7% at the control site.

Tonto Platform Sites

The results of vegetation studies at the impact site on the Tonto Platform are shown in Tables IV-33 to IV-35, and at the control site across the Colorado River are shown in Tables IV-36 to IV-38. The community on the impact site was dominated by Opuntia erinacea (prickly-pear), Ephedra nevadensis (Mormon-tea), and Brickellia sp. This differed somewhat from the control site, where prickly-pear, blackbrush, and Lycium andersonii (wolfberry) predominated. There was little change between sampling periods, as the dry summer of 1977 was not conducive to plant growth. Both areas showed rather sparse vegetation, with perennial species cover on the control side (19-25%) being somewhat higher than on the impact side (7-11%). The tables show the abundance of grasses to be higher on the impact side, but our field observations showed that grasses were heavily grazed throughout the area, with very little of the plants remaining above ground. About one-half of the prickly-pear plants were uprooted or dead at the impact site, whereas only a third of the plants were uprooted or dead at the control site. The importance value of the dead prickly-pear was about 25% on the impact site compared to 9% on the control. The total cover of perennials at the impact site was 8.3% compared with 21.7% at the control site. In contrast, cover of annuals was higher on the impact (10.3%) than the control (3%) site. Bromus, an exotic weedy species, contributed greatest to annual cover in the impact site. Its importance value of 46.8% contrasts with the importance value of Bromus of 11.7% on the control site. Native species were the predominant annuals on the control site. Several plant species, Mormon-tea, trailing four-o'clock, and fluffgrass, were absent on the control but were found on the impact site. However, the perennial shrubs, blackbrush and wolfberry, occurred in greater densities and with greater cover on the control than on the impact sites. Moreover,

although beavertail cacti were twice as dense on the control area as on the impact site, their cover was 50% greater on the impact site than on the control site. This suggests the occurrence of fewer young plants on the impact site. Both perennial shrubs, blackbrush and wolfberry, had greater density and cover values on the control site than on the impact site.

Rampart Cave Sites

The Rampart Cave impact and control sites are similar floristically, as indicated by the dominant species at the two sites. As shown in Tables IV-40 to IV-45, the dominant species on both sites were Tridens pulchellus (fluffgrass), and brittlebush, with combined importance values ranging from 49.5% on the impact site to 62.4% on the control site.

The most notable differences between the two sites are in Franseria dumosa (white bursage) and trailing four-o'clock. White bursage was consistently fourth in importance value at about 4.5% during the three sampling periods on the control site, while it was ninth or tenth at about 1% at each reading on the impact site. Trailing four-o'clock was third or fourth in importance value on the impact site (11-15%), while its importance value was always less than 1% on the control site. Cover of Tortula was greater at the control sites (26-32%) than at the impact site (17-20%). Cover of annuals was higher at the impact sites (4-19%) than at the control sites (3-8%); whereas cover of perennials was higher at the control sites (22-24%) than at the impact sites (12-14%).

A comparison of cover and density values for selected species revealed striking differences between the impact and control sites (Table IV-46). Both white bursage and Mormon-tea had decreased cover and density values on the impact site. In contrast, trailing four-o'clock and Euphorbia polycarpa

(spurge) occurred in greater densities and with greater cover on the impact site. Haplopappus spinulosus, absent on the impact site, occurred sparsely on the control site; whereas fluffgrass was more abundant on the impact than on the control site.

Shinumo Area Transects

The comparison between the 1965 and 1977 readings of the five Shinumo area transects is shown in Tables IV-47 and IV-48. The area was subjected to intensive burro removal between 1964 and 1969, and a total of 59 burros were shot during that period (see CHAPTER I). The current burro population for the entire Shinumo Amphitheater is estimated at 40 (see CHAPTER II). Our field observations indicated that burros probably have been absent from the transects in the blackbrush (401 and 402) at least since 1969. They are present at transect 403, the site closest to Shinumo Creek, and in lower densities at transects 404 and 405, on steep slopes near the creek (see CHAPTER III).

The increase in the number of points with vegetative cover ranged from 32% at 403 to 74% at 401, evidence that recovery has occurred since the original establishment of the transects. Transect 401 had the lowest vegetative cover in 1965; in the intervening 12 years each of the species on the original transect increased by one point except for Opuntia erinacea, which doubled from 13 to 26. No change in species diversity was noted. Transect 402 in the blackbrush community increased only 35% in species present since 1965, but its species diversity doubled from four to nine during the 12-year period. Transect 403 showed the smallest increase in vegetative cover (32%), much of which was accounted for by an increase of Ephedra viridis from 17 to 28 points. Seven new species appeared on the transects in 1977, but four species noted in 1965 were missing 12 years later. One of the casualties was Acacia

greggii, present at nine points in 1965 and found only as dead cover at three points in 1977. Species diversity increased from six to nine during the 12-year period. Transects 404 and 405 each showed slight increases in the dominant Encelia farinosa. Both showed annual grass and no Tridens pulchellus in 1965; and no annual grass and 18 points for Tridens pulchellus in 1977. It is possible that fluffgrass, a perennial, was mistaken for an annual in the original reading of the transects. Species diversity increased in both areas, from two to five in Transect 404, and from three to four in Transect 405.

Seed Analysis

Seed densities (number/m²) were greater on the Pinyon-Juniper control sites than on the impact sites at each sampling period with one exception (Table IV-49). Seed densities were, however, lower in the pinyon-juniper woodland than in any other habitat sampled. Gutierrezia, Festuca, Juniperus, Mammillaria and Phacelia were at higher densities on the control areas than on the impact. Cowania and Oryzopsis were found exclusively on the control, while Arctostaphylos, Atriplex, Echinocereus, Euphorbia and Sphaeralcea were recovered in low densities from the impact site. Densities and diversities of seeds from the May and July samples at the original Pinyon-Juniper sites were substantially different from the September samples at the new sites. Relatively few annual and perennial grass seeds were recovered in the pinyon-juniper woodland from all sampling periods.

Densities of seeds of perennial and annual species were greatest on the Tonto Control (Table IV-49). On the Tonto control, seeds of Echinocereus, Mentzelia and Phacelia were found in higher densities than on the impact and Mentzelia seeds were recovered exclusively on the control. Euphorbia seed density was greatest on the impact and Mammillaria was recovered there

exclusively. However, numbers of miscellaneous seeds (Astragalus and graminoids) were greater on the impact than on the control. Astragalus was not found on vegetation transects nor was it observed in the immediate vicinity of either Tonto Platform site. Seeds were found on both sites but were especially numerous on the impact site. One, two or three taxa of graminoids with similar seed morphology (Bromus, Hilaria, and/or Sitanion) were the most numerous seeds recovered on the impact site. The only grasses on the vegetation transects were Bromus (both sites) and Hilaria (impact only.). Bromus densities far exceeded those of Hilaria on the Tonto impact. Pianka (1974) noted that annual plants (e.g., Bromus) produce relatively high numbers of seeds each year while perennials (e.g., Hilaria) produce relatively few. A total of 16,710 seeds were recovered from the Tonto impact; of these 84% (14,100) were Astragalus or graminoids (probably Bromus).

Densities of perennial seeds were greatest on the control site at Rampart Cave while annual seeds were found in higher densities on the impact site (Table Iv-49). Larrea, Mammillaria, Phacelia, Tridens and Festuca were recovered in higher densities on the Rampart Control than on the impact. Seeds of Cryptantha, Ferocactus and Haplopappus were found exclusively on the control. Compositae, Euphorbia, Plantago and Sphaeralcea were the most abundant seeds on the impact site and Allionia and Cassia were found here exclusively. On the vegetation transects at the Rampart Cave sites, Plantago densities were highest on the impact site. Seeds of graminoids (Bromus, Hilaria and/or Sitanion) were much more abundant on the control site than on the impact. Vegetation transect data from both sites indicated that Bromus reaches higher densities on the control than on the impact while Hilaria and Sitanion were absent from the transects on both sites. Therefore, we assumed that Gramineae seeds recovered from the Rampart Cave sites were Bromus.

Discussion

There are three distinct plant associations below the rims of the Grand Canyon, all of which have been influenced in places by feral burros and have been included in our transects. At the higher elevations in the Canyon and extending onto the rims is a pinyon-juniper woodland (Merkle 1952). This woodland is widespread in the Intermountain Region (Cronquist et al. 1972).

Although there is considerable variability from place to place in the understory, ranging from nearly bare ground to a good mixture of shrubs, forbs, and grasses (Merkle 1952, Cronquist et al. 1972), our study sites, which are near the lower elevational limit for the vegetation type, show the latter characteristic. Highly palatable grasses (USDA 1973) dominated the Masonic Temple.

The next major plant community in the Grand Canyon is the high desert blackbrush community, found in the central part of the Canyon (e.g., Tonto Platform) and on the rims at the western end. It is a shrubby desert vegetation type intermediate between low elevation Mohave Desert communities dominated by creosotebush and Great Basin Desert communities dominated by shadscale (Atriplex confertifolia) and big sagebrush (Artemisia tridentata) (Cronquist et al. 1972, Beatley 1976). Blackbrush is often associated with galleta grass (Hilaria spp.) in the Canyon and elsewhere (Cronquist et al. 1972). Under moderate grazing, galleta generally increases, but under the combined effects of overgrazing and drought it may be eliminated (West et al. 1972).

The Inner Gorge of the Grand Canyon supports a well-developed Mohave Desert vegetation type, dominated by shrubs and succulents typical of hot desert areas west of the Grand Canyon (Beatley 1976). A number of species from the Sonoran Desert to the south also reach into the Grand Canyon along

the Colorado River (Hastings et al., 1972). The hottest, driest part of the Grand Canyon, the Inner Gorge, supports the most fragile community characterized by low plant densities.

Disturbed Communities

Burros have affected natural communities in all three vegetation types in the Grand Canyon. Since each plant community differs in origin, species composition and climate, the type and degree of habitat modification by feral burros are not the same in different areas of the Grand Canyon.

In the pinyon-juniper zone, grazing by burros has apparently greatly reduced perennial grasses, especially palatable species (USDA 1973), resulting in an increase in bare ground and in unpalatable shrubs such as snakeweed (Martin 1975, Schmutz and Smith 1976). This pattern was also noted in a pinyon-juniper woodland heavily grazed by burros at Bandelier National Monument (Potter and Berger 1977). Ecologically, as the most mesophytic community in the study, and historically, as the community most likely to have received impact in the late Pleistocene by large extinct herbivores including equines (see Chapter VII), this woodland is expected to be the vegetation type least influenced by grazing and browsing pressure. Nevertheless, the foraging activities of feral burros have led to a shift from palatable grasses to unpalatable shrubs in the pinyon-juniper community.

The grasses of the blackbrush community appear to be similarly affected. We noted extensive evidence of heavy burro impact on the Tonto Platform grasses. Almost every plant had been grazed nearly to ground level and few plants had seed heads.

However, we found no perennial grasses on the Tonto Platform control site. This site was characterized by desert pavement soils which have been shown to be a poor environment for seed germination and plant growth (Musick 1975). Therefore, the occurrence of grasses on the impact area can be attributed to the significant disturbance of desert pavement soils resulting in suitable sites for seedling establishment.

At the Shinumo Creek blackbrush sites, we have analyzed a community free of burros for up to eight years, following many years of impact. The 100% increase in species diversity at one site and 35% to 74% increase in number of points with vegetative cover indicate some recovery. Nevertheless, there was no indication of a return of palatable grasses.

The Inner Gorge sites showed the greatest amount of disturbance of the natural community because of the inherent fragile nature of the arid desert flora, the low species diversity at the upstream sites, and the concentrated impact of burros. The tremendous reduction of palatable grasses is the greatest change coupled with an increase in less palatable shrubs and succulents. In addition, there is a severe effect on the crustose mosses and lichens that protect the surface of the soil. The impact on grasses is more evident at the paired Inner Gorge sites at River Miles 124.5 and 198 than at Rampart Cave, where perennial grasses are less abundant and Mohave Desert shrubs and succulent diversity are higher (Phillips 1975). This greater plant species diversity coupled with the intermittent use by burros (see Chapter II) result in a lower level of disturbance in the natural community. Therefore, the impact at the upstream Inner Gorge sites cannot be extrapolated from the much lower level of disturbance at Rampart Cave.

Specific Effects of Burro Impact

The most widespread and obvious burro-related change in Grand Canyon plant communities is the reduction and local elimination of palatable grasses and their replacement by unpalatable shrubs. We have documented this change in all three of the major plant communities below the rims in the Grand Canyon. These effects parallel the patterns noted by others for changes in desert grassland caused by grazing of cattle. Long-term studies in southern Arizona have shown that unpalatable shrubs increase and desirable grasses decrease under heavy grazing pressure (Humphrey 1958, Martin 1975, Shmutz and Smith 1975). In the Great Basin, Young et al. (1976) noted that in extensive areas which were once sagebrush/grassland, perennial grasses have been reduced and native shrubs, generally those undesirable as browse, have increased. There seems to be widespread agreement that overgrazing in the Southwest leads to a replacement of grasses by shrubs (see discussion in Humphrey 1958). This is best demonstrated by our transect data from River Mile 124.5 and diet information from a previous study (Ruffner et al. 1977). On the impact site, perennial grasses had a low importance value (8%) while on the control, perennial grasses had a high importance value (50%). Data from July 1976 on the impact side showed that perennial grasses comprised almost 47.8% of burro diets. Moreover, at Rampart Cave, Hansen and Martin (1973) found burro fecal samples to contain 68.4% grasses in the annual diet. In the more arid lower Colorado River Valley, Woodward and Ohmart (1976) found only 3.9% grasses in the annual burro diet. In Death Valley, one of the most arid parts of the Mohave Desert, Browning (1960) found 10.0% grasses in the annual diet of feral burros. Perennial grasses are certainly over-

represented in burro diets in desert areas where they are available only in small quantities. The strong preference burros exhibit for grasses makes their scarcity in heavily impacted areas understandable and their future existence in such areas highly doubtful. Weaver (1972) and Woodward and Ohmart (1976) also suggested that perennial grasses have been eliminated by the foraging activities of feral burros.

The new Pinyon-Juniper area showed some striking differences, especially in grass composition between impact and control sites. We feel the differences are directly attributable to burro grazing. There were five perennial grasses present in large quantities on the control site and absent at the impact site. Two of the three grasses which were present at impact site and absent at control site (Aristida adscensionis [sixweek threeawn] and Sitanion hystrix [squirreltail]) increase in disturbed habitats (USDA 1973). In addition, the species with the highest importance value at the impact site was snakeweed, a species which is toxic to livestock and has a fibrous root system occupying the same soil levels as many perennial grasses (Martin 1975). Snakeweed is considered an invader and an indicator of poor range conditions (Schmutz and Smith 1975).

Another major effect of feral burro activity, especially in the Inner Gorge area, is the apparent increase in native shrubs which are known to be unpalatable or resilient under browsing pressure. Brittlebush is the best example of a native shrub not generally thought of as a weed species or disturbance indicator which does well in burro impacted areas. It is seldom utilized by feral burros (Hansen and Martin 1973, Woodward and Ohmart 1976, Ruffner et al. 1977) but is a dominant species in many parts of the Inner Gorge, especially on our transects at River Mile 124.5

and Rampart Cave. At River Mile 124.5R, the abundant brittlebush seedlings suggest that it has been increasing. Just why disturbance would have this effect is unclear, although it is known to reproduce readily and produce abundant seed (Shreve 1929, 1964). In addition, brittlebush chemically inhibits germination of potential competitors and creates a more favorable site for the establishment of its own seedlings (Bonner 1949).

Mormon-tea is more palatable, although it is not a major food source (Hansen and Martin 1973, Norment and Douglas 1977, Ruffner et al. 1977). The slight increase in cover on transects at River Mile 124.5R in September 1977 over readings a year earlier (Ruffner et al. 1976) may indicate recovery in the year since burros were removed from that area. Mormon-tea showed almost three times the cover on the impact site at River Mile 124.5 as was found on the control. However, densities of this species were similar on both sites. Wells (1961) found that Mormon-tea sprouts vigorously from the base when the tops are destroyed. The increased cover value on the impact site may be a response to the foraging activity of feral burros. Mormon-tea showed a similar response following release from browsing pressure in the long-term study at Shinumo Creek.

Among the shrubs that are heavily utilized by feral burros are white bursage, ocotillo, catclaw and mesquite. White bursage was found on our transects only at Rampart Cave, where it had a lower cover value on the impact site than on the control site. This was the only shrub species which showed heavy utilization by burros at Rampart Cave. While Hansen and Martin (1973) found little white bursage in burro diets in the lower Grand Canyon (1.8% in March), Norment and Douglas (1977) found its level

of utilization high enough to consider it in danger of eventual elimination from Wildrose Canyon in Death Valley. Ocotillo did not appear on any of our transects, but it was heavily damaged by burros in the Grand Canyon. Near our Indian Canyon site (River Mile 207R), we noted many ocotillos which were dead or had broken branches and bark stripped at the base. Woodward and Ohmart (1976) noted similar destruction of ocotillos. Catclaw and mesquite are favored browse species for burros where they are available (Hansen and Martin 1973, Woodward and Ohmart 1976, Ruffner et al. 1977, Appendix II). Our riparian zone transects at River Mile 207R (impact) and River Mile 208L (control) show striking effects of long-term browsing on the shrubs. While the open community at the impact site supports a greater diversity of shrubs, the two which are highest in importance value are the unpalatable brittlebush and creosote-bush. The focus, however, is on the contrast in development of mesquite and catclaw at the two sites. They are shorter in stature and show evidence of topping and basal sprouting on the impact site. The thicket is nearly impenetrable on the control site; it is necessary to crawl through and under lower limbs of dense mesquite trees as the vegetation is sampled. The mistletoe survey provides additional evidence that the plants on the impact site are less healthy. We attribute the much higher incidence of mistletoe on impact site trees to injury and reduced vigor caused by feral burro browsing (Carothers et al. 1976).

Two weedy species which increase with soil disturbance caused by burros are Bromus rubens (red brome) and trailing four-o'clock. Red brome is a species introduced from Europe characteristic of disturbed areas

(Kearney and Peebles 1960) and "especially abundant on overgrazed range-lands" (Gould 1951). Trailing four-o'clock is a native species characteristic of roadsides and other disturbed areas (Phillips 1976). Its increase in abundance at impact sites was evident at Parashant Creek and Rampart Cave in the Inner Gorge.

The most obvious effect of burro trampling on the vegetation was the consistent reduction of cover of Tortula. This crust-forming moss normally covers areas of bare soil in all three vegetation types, aiding in soil moisture retention, seedbed preparation, and erosion prevention (Loope and Gifford 1972). Its regrowth following destruction is apparently a lengthy process, but the time involved is unknown. On the areas most severely impacted by feral burros, it is present only under shrubs where burros do not walk, and in all areas its reduction is directly proportional to the amount of trampling and trail development.

Seed Analysis

Seeds of perennials were found in lower densities on the impact sites than on the control in all three habitat types. These observations, together with the vegetation transect data, suggest that many species of perennials (especially grasses) are being reduced by feral equines. Our previous studies on the diets of feral burros (APPENDIX II) also support this conclusion.

Graminoid seeds, probably Bromus, were recovered in the greater densities on the Tonto impact than on the control. Vegetation transect data at these sites indicated that densities of Bromus were greatest on the impact. However, desert pavement soils, like those on the Tonto control, have been identified as an unfavorable environment for seeds

and seedlings (Musick 1975); under these conditions plant germination and hence seed production were reduced on the Tonto control. These constraints made it difficult to effectively evaluate the influence of feral burros on seed production of Bromus at the Tonto sites. However, the situation at the Rampart Cave sites was more instructive because the substrates of the impact and control sites were more similar. On the control site densities of graminoid seeds, tentatively identified as Bromus, were higher than on the impact. Furthermore, the vegetative transect data indicated that Bromus densities were also greater on the control than on the impact. Almost 44% of the March diets of feral burros in the vicinity of the Rampart impact site was young, new Bromus (Hansen and Martin 1973). Intensive grazing has effectively reduced germination and seed production of Bromus at the impact site.

Plantago (an annual) seeds were recovered in greater densities from the Rampart impact site than from the control. Carothers et al. (1976) hypothesized that seeds of forbs, important in the diets of pocket mice, were reduced by the activities of feral burros. This suggestion was not applicable to Plantago at the Rampart Cave impact site. In contrast, Woodward and Ohmart (1976) stated that "Herbaceous [sic] species appear to prefer Plantago in a cured form, which appears to have little impact on seed dissemination." However, their diet data indicate that Plantago comprised only 11 percent or less of feral burro diets between July and January in the Chemehuevi Mountains (Woodward and Ohmart 1976).

In summary, there was a consistent reduction of Tortula ground cover as a result of trampling by feral burros. Densities of palatable perennials, especially grasses, were reduced on areas occupied by feral

burros. Moreover, certain unpalatable species, such as Gutierrezia and Encelia, increased in areas where feral burros were present. The habitat modifications induced by feral burros have produced important alterations in the structure of natural plant communities within Grand Canyon. This observation was further supported by the seed analysis. Seeds of perennial plants were recovered in greater densities on the control sites. Furthermore, although feral burros did not influence seed dissemination of annuals per se, their activities modified seed densities of at least two species of annual plants. The extent of these changes and the relative degree of impact at these sites are believed to be a direct function of feral burro densities, the length of time the sites have been occupied and the annual fluctuations in habitat use by feral burros.

Some of the effects of burro impact in the Grand Canyon are probably not irreversible if the level of damage is not allowed to further increase. While we have found no plant species to have been eliminated from the Grand Canyon, some of the shifts in abundance of palatable and unpalatable species may be essentially permanent. Young et al. (1976) believe that changes in abundance of perennial grasses and unpalatable shrubs under long-term pressure from domestic livestock are irreversible, and this may also be true of grasses in the Canyon. Potter and Berger (1977) noted discouraging rates of recovery in areas in New Mexico protected from grazing for 25 years. We have nevertheless seen some hopeful signs of recovery of native vegetation following burro removal, as with the increase in species diversity, cover, and soil stability at Shinumo Creek in 12 years and the apparent recovery of Mormon-tea in the Inner Gorge one year after removal.

With unchecked increasing burro population levels and a continued

series of dry seasons, large areas of the Grand Canyon will continue the trend toward instability. The inevitable result will be irreversible changes in the natural plant communities. As populations expand and forage decreases, areas now only lightly used by feral burros will receive greater impact. In many cases these are the most fragile habitats. Only a year ago population level estimates for feral burros in the Grand Canyon ranged as high as 3,000 animals; the official estimate after population studies in 1977 is 300 animals. This may encourage some, who see the problem as being only one-tenth as large as it was a year ago, but from the standpoint of the plant communities it is indeed unsettling. Estimates of impact caused per burro in the Grand Canyon must now be raised as much as ten times over previous levels. If 300 burros are doing the damage that 3,000 were once thought to have caused, the outlook for natural communities in the Canyon under rapidly increasing feral burro populations is indeed bleak unless immediate steps are taken to eliminate burros from the park.

Table IV-1. Mile 124.5R Impact vegetation studies (burros present).
22 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	10.3	24.0	35.4	23.2	1
<u>Ephedra nevadensis</u>	10.3	11.4	39.7	20.5	2
<u>Opuntia basilaris</u>	5.1	18.0	5.3	9.5	3
<u>Atriplex canescens</u>	5.1	4.5	9.0	6.2	4
<u>Sphaeralcea grossulariaefolia</u>	7.7	6.9	0	4.9	5
<u>Allionia incarnata</u>	2.6	8.4	0.5	3.8	6
<u>Ferocactus acanthodes</u>	5.1	2.4	2.6	3.4	7
<u>Gutierrezia lucida</u>	2.6	3.9	3.7	3.4	7
<u>Encelia farinosa</u>	5.1	3.0	0	2.7	9
<u>Tridens pulchellus</u>	5.1	3.0	0	2.7	10
<u>Acacia greggii</u>	5.1	1.5	0	2.2	
<u>Agave utahensis</u>	0	0	2.6	0.9	
<u>Dyssodia pentachaeta</u>	5.1	1.5	0	2.2	
<u>Encelia farinosa (dead)</u>	2.6	0.9	0	1.2	
<u>Ephedra nevadensis</u>	5.1	1.5	0	2.2	
<u>Ferocactus acanthodes</u>	2.6	0.9	0	1.2	
<u>Haplopappus acradenius</u>	2.6	1.5	0	1.4	
<u>Haplopappus spinulosus</u>	2.6	0.9	0	1.2	
<u>Hilaria jamesii</u>	0	0	0.5	0.2	
<u>Hilaria rigida</u>	5.1	2.4	0	2.5	
<u>Lycium andersonii</u>	2.6	0.9	0	1.2	
<u>Porophyllum gracile</u>	2.6	0.9	0	1.2	
<u>Sporobolus flexuosus</u>	5.1	1.5	0.5	2.4	

Total Cover = 19%

Annual Species:

<u>Bromus rubens</u>	38.5	57.0	55.4	50.3	1
<u>Plantago insularis</u>	26.9	42.1	36.8	35.3	2
<u>Lepidium lasiocarpum</u>	11.5	0.3	2.6	4.8	3
<u>Encelia farinosa (seedling)</u>	7.7	0.3	1.6	3.1	4
<u>Cryptantha spp.</u>	7.7	0.1	1.6	3.1	5
<u>Draba cuneifolia</u>	3.9	0.1	1.0	1.7	6
<u>Pectocarya sp.</u>	3.9	0.1	1.0	1.7	6

Total Cover = 31%

Tortula Average Cover = 1%

Table IV-2. Mile 124.5R Impact vegetation studies (burros present).
12 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	14.3	35.3	29.6	26.4	1
<u>Ephedra nevadensis</u>	10.7	12.9	42.5	22.0	2
<u>Opuntia basilaris</u>	7.1	12.9	3.2	7.7	3
<u>Acacia greggii</u>	7.1	2.4	10.8	6.7	4
<u>Sphaeralcea grossulariaefolia</u>	10.7	7.1	0	5.9	5
<u>Atriplex canescens</u>	7.1	3.5	6.5	5.7	6
<u>Hilaria rigida</u>	7.1	3.5	1.1	3.9	7
<u>Gutierrezia lucida</u>	3.6	7.1	0.5	3.7	8
<u>Dyssodia pentachaeta</u>	7.1	3.5	0	3.5	9
<u>Agave utahensis</u>	3.6	3.5	3.2	3.4	10
<u>Allionia incarnata</u>	3.6	1.2	0	1.6	
<u>Ferocactus acanthodes</u>	3.6	1.2	2.2	2.3	
<u>Haplopappus acradenius</u>	3.6	1.2	0.5	1.8	
<u>Lycium andersonii</u>	3.6	1.2	0	1.6	
<u>Tridens pulchellus</u>	3.6	2.4	0	2.0	
Unknown #1	3.6	1.2	0	1.6	

Total Cover = 19%

Annual Species:

Grass	60.0	85.8	82.5	76.1	1
<u>Plantago insularis</u>	26.7	13.8	14.3	18.3	2
<u>Cryptantha</u> sp.	6.7	0.3	1.6	2.9	3
<u>Pectocarya</u> sp.	6.7	0.2	1.6	2.8	4

Total Cover = 16%

Tortula Average Cover = 6%

Table IV-3. Mile 124.5R Impact vegetation studies (burros present).
250 m transects established 12 September 1977.

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Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	21.8	28.2	26.8	25.6	1
<u>Ephedra nevadensis</u>	11.2	6.5	26.3	14.6	2
<u>Gutierrezia lucida</u>	7.6	15.5	8.3	10.5	3
<u>Hilaria rigida</u>	10.4	12.0	3.3	8.6	4
<u>Atriplex canescens</u>	8.1	5.3	10.7	8.1	5
<u>Sphaeralcea grossulariaefolia</u>	10.7	10.2	0.7	7.2	6
<u>Ferocactus acanthodes</u>	6.1	4.2	7.6	5.9	7
<u>Haplopappus acradenius</u>	4.1	3.5	7.9	5.2	8
<u>Tridens pulchellus</u>	4.6	5.8	0.6	3.7	9
<u>Opuntia basilaris</u>	2.5	2.3	1.8	2.2	10
<u>Acacia greggii</u>	1.0	0.5	4.1	8.9	
<u>Agave utahensis</u>	1.0	1.2	1.8	1.3	
<u>Cheilanthes sp.</u>	0	0	0.2	0.1	
<u>Dyssodia pentachaeta</u>	4.1	2.5	0	2.2	
<u>Echinocereus engelmannii</u>	0.5	0.2	0	0.3	
<u>Galium stellatum</u>	0.5	0.2	0	0.3	
<u>Mammillaria sp.</u>	1.0	0.5	0	0.5	
<u>Muhlenbergia porteri</u>	1.0	0.5	0	0.5	
<u>Porophyllum gracile</u>	0.5	0.2	0	0.3	
Unknown grass	0.5	0.2	0	0.3	

Total Cover = 15%

Annual Species:

Grass	81.4	98.9	96.7	92.3	1
<u>Plantago insularis</u>	18.6	1.1	3.4	7.7	2

Total Cover = 13%

Tortula Average Cover = 6%

Table IV-4. Mile 124.5L Control vegetation studies (burros not present).
22 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Hilaria rigida</u>	8.7	27.5	22.6	19.6	1
<u>Ephedra nevadensis</u>	6.5	5.1	21.0	10.9	2
<u>Encelia farinosa</u>	6.5	2.5	16.5	8.5	3
<u>Opuntia erinacea</u>	4.3	2.2	18.0	8.2	4
<u>Haplopappus spinulosus</u>	6.5	14.4	2.3	7.7	5
<u>Sporobolus flexuosus</u>	6.5	10.6	0	5.7	6
<u>Muhlenbergia porteri</u>	6.5	9.0	0	5.2	7
<u>Sphaeralcea grossulariaefolia</u>	6.5	4.2	1.5	4.1	8
<u>Arabis perennans</u>	4.3	7.3	0	3.9	9
<u>Ferocactus acanthodes</u>	6.5	2.5	0	3.0	10
<u>Gutierrezia lucida</u>	2.2	1.4	5.3	3.0	10
<u>Acacia greggii</u>	2.2	0.5	0	0.9	
<u>Agave utahensis</u>	0	0	3.9	1.3	
<u>Aristida adscensionis</u>	2.2	0.5	0.8	1.2	
<u>Dyssodia pentachaeta</u>	2.2	2.2	0	1.5	
<u>Echinocereus engelmannii</u>	4.3	2.5	0.8	2.5	
<u>Echinocereus engelmannii</u> (dead)	2.2	0.5	0	0.9	
<u>Encelia farinosa</u>	4.3	1.4	3.0	2.9	
<u>Eriogonum inflatum</u>	2.2	0.5	4.5	2.4	
<u>Fern</u>	2.2	0.8	0	1.0	
<u>Mammillaria sp.</u>	4.3	1.4	0	1.9	
<u>Porophyllum gracile</u>	2.2	0.5	3.8	2.2	
<u>Tridens pulchellus</u>	2.2	0.8	0	1.0	
<u>Unknown composite</u>	4.8	1.7	0	2.0	

Total Cover = 18%

Annual Species:

<u>Plantago insularis</u>	27.3	51.8	45.3	41.5	1
<u>Bromus rubens</u>	30.3	41.4	41.3	37.7	2
<u>Lepidium lasiocarpum</u>	30.3	6.3	11.4	16.0	3
<u>Astragalus sp.</u>	9.1	0.4	1.4	3.6	4
<u>Cryptantha sp.</u>	3.0	0.1	0.5	1.2	5

Total Cover = 55%

Tortula Average Cover = 44%

Table IV-5. Mile 124.5L Control vegetation studies (burros not present).
11 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Hilaria rigida</u>	13.4	31.9	27.6	24.3	1
Unknown #1	10.0	14.4	16.7	13.7	2
<u>Haplopappus spinulosus</u>	10.0	21.3	7.9	13.1	3
<u>Encelia farinosa</u>	10.0	3.1	15.3	9.5	4
<u>Muhlenbergia porteri</u>	10.0	8.8	9.4	9.4	5
<u>Ephedra nevadensis</u>	10.0	5.0	7.4	7.5	6
<u>Ferocactus acanthodes</u>	10.0	3.1	7.4	6.9	7
<u>Gutierrezia lucida</u>	6.7	6.3	5.4	6.1	8
<u>Opuntia erinacea</u>	6.7	1.9	0.5	3.0	9
<u>Tridens pulchellus</u>	6.7	1.9	0.5	3.0	9
<u>Aristida adscensionis</u>	3.4	1.9	0.5	1.9	10
<u>Eriogonum inflatum</u>	3.4	0.6	1.5	1.8	

Total Cover = 20%

Annual Species:

Annual grass	40.0	77.0	77.5	64.8	1
<u>Plantago insularis</u>	32.0	20.5	16.2	22.9	2
<u>Ledpidium lasiocarpum</u>	24.0	2.5	5.4	10.6	3
<u>Cryptantha</u> sp.	4.0	0.1	0.9	1.7	4

Total Cover 28%

Tortula Average Cover = 37%

Table IV-6. Mile 124L Control vegetation studies (burros not present).
250 m transects established 12 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Hilaria rigida</u>	21.1	38.1	19.2	26.1	1
Unknown grass #1	13.3	23.4	13.3	16.7	2
<u>Ephedra nevadensis</u>	8.9	3.4	36.1	16.1	3
<u>Encelia farinosa</u>	13.3	5.9	13.5	10.9	4
<u>Haplopappus spinulosus</u>	7.2	8.9	2.3	6.1	5
<u>Ferocactus acanthodes</u>	6.1	2.3	4.4	4.3	6
<u>Tridens pulchellus</u>	5.0	6.0	1.0	4.0	7
<u>Muhlenbergia porteri</u>	3.9	2.7	4.2	3.6	8
<u>Sphaeralcea grossulariaefolia</u>	6.1	2.8	0.9	3.3	9
<u>Eriogonum inflatum</u>	5.0	2.5	0.8	2.8	10
<u>Agave utahensis</u>	1.1	0.9	2.6	1.6	
<u>Dyssodia pentachaeta</u>	0.6	0.2	0	0.3	
<u>Echinocereus engelmannii</u>	2.8	0.9	0	1.2	
<u>Echinocereus triglochidictus</u>	0.6	0.2	0	0.3	
<u>Galium stellatum</u>	1.1	0.5	0	0.6	
<u>Gutierrezia lucida</u>	0.6	0.2	0	0.3	
<u>Mammillaria</u> sp.	1.1	0.4	0	0.5	
<u>Opuntia erinacea</u>	1.1	0.4	0	0.5	
<u>Peucephyllum schottii</u>	0.6	0.4	0	0.3	
<u>Porophyllum gracile</u>	0.6	0.2	1.5	0.8	

Total Cover = 12%

Annual Species:

Grass	52.0	86.6	81.5	73.4	1
<u>Plantago insularis</u>	28.0	10.9	11.6	16.8	2
<u>Lepidium lasiocarpum</u>	14.7	1.9	5.2	9.0	3
<u>Cryptantha</u> sp. (dead)	2.7	0.5	0.9	1.4	4
<u>Oenothera cavernae</u>	2.7	0.2	0.9	1.2	5

Total Cover = 12%

Tortula Average Cover = 19%

Table IV-7. Comparison of density (D=plants/100m²) and cover (C=cm/100m²) for selected species on burro impacted and control sites at three sampling periods at Mile 124.5, Right and Left.

	Sept '76		Apr '77		Sept '77	
	Impact D/C	Control D/C	Impact D/C	Control D/C	Impact D/C	Control D/C
<u>Ephedra nevadensis</u>	12/700	16/260	15.2/750	12/280	11/790	8/150
<u>Encelia farinosa</u>	32.8/850	6/140	32/670	60/310	30/550	5/310
<u>Haplopappus spinulosus</u>	1/0	40.8/80	1.2/0	34/30	0/0	34/160
<u>Hilaria rigida</u>	2/0	207.2/620	3.2/0	65.2/300	3/20	51/56
<u>Muhlenbergia porteri</u>	0/0	8/180	0/0	21.3/70	0/0	14/190
<u>Tridens pulchellus</u>	0/0	2/0	4/0	2/0	2/0	3/10

Table IV-8. Mile 126.5R Impact vegetation studies (burros present).
21 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Ephedra nevadensis</u>	15.8	13.7	53.4	27.6	1
<u>Eriogonum inflatum</u>	21.0	28.3	9.6	19.6	2
<u>Sphaeralcea grossulariaefolia</u>	15.8	38.0	1.5	18.4	3
<u>Hilaria rigida</u>	10.5	8.8	4.1	7.8	4
<u>Ferocactus acanthodes</u>	10.5	3.9	5.5	6.6	5
<u>Lycium andersonii</u>	5.3	1.5	9.6	5.5	6
<u>Ephedra nevadensis</u> (dead)	10.5	2.4	0	4.3	7
<u>Gutierrezia lucida</u>	5.3	1.5	1.4	2.7	8
<u>Mammillaria tetrancistra</u>	5.3	1.5	0	2.3	9
<u>Sphaeralcea grossulariaefolia</u> (dead)	0	0	1.4	0.5	10

Total Cover = 7%

Annual Species:

<u>Bromus rubens</u>	77.8	96.3	83.3	85.8	1
<u>Erodium cicutarium</u>	11.1	1.9	8.3	7.1	2
<u>Lepidium lasiocarpum</u>	11.1	1.9	8.3	7.1	2

Total Cover = 4%

Table IV-9. Mile 126.5R Impact vegetation studies (burros present).
13 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Ephedra nevadensis</u>	15.8	16.4	76.3	36.2	1
<u>Sphaeralcea grossulariaefolia</u>	15.8	36.0	14.0	21.9	2
<u>Hilaria rigida</u>	15.8	21.3	0	12.4	3
<u>Eriogonum inflatum</u>	15.8	11.5	8.6	12.0	4
<u>Ferocactus acanthodes</u>	15.8	8.2	0	8.0	5
<u>Gutierrezia lucida</u>	5.3	1.6	1.1	2.7	6
<u>Lycium andersonii</u>	5.3	1.6	0	2.3	7
<u>Mammillaria</u> sp.	5.3	1.6	0	2.3	7
<u>Porophyllum gracile</u>	5.3	1.6	0	2.3	7

Total Cover = 9%

Annual Species:

Grass	66.7	98.2	55.6	73.5	1
<u>Cryptantha</u> sp.	20.0	1.3	41.7	21.0	2
<u>Oenothera cavernae</u>	13.3	0.5	2.8	5.5	3

Total Cover = 18%

Table IV-10. Mile 128L Control vegetation studies (burros not present).
21 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	17.4	70.6	55.2	47.1	1
<u>Hilaria rigida</u>	13.0	8.1	19.8	13.5	2
<u>Ephedra nevadensis</u>	17.4	2.0	11.5	10.0	3
<u>Gutierrezia lucida</u>	8.7	5.1	1.0	4.8	4
<u>Ferocactus acanthodes</u>	4.3	1.0	0	3.1	5
<u>Eriogonum inflatum</u>	4.3	5.1	0	3.1	6
Unknown composite	4.3	1.0	0	3.1	7
<u>Ferocactus acanthodes</u> (dead)	4.3	0.6	0	3.0	8
<u>Encelia farinosa</u>	8.7	4.1	7.3	2.8	9
<u>Tridens pulchellus</u>	8.7	2.0	0	2.1	10
<u>Ditaxis neomexicana</u>	4.3	0.6	0	1.6	
<u>Ephedra nevadensis</u> (dead)	0	0	2.1	0.7	
<u>Gutierrezia sarothrae</u>	0	0	1.0	0.4	
<u>Haplopappus spinulosus</u>	0	0	2.1	0.7	
Woody plant (dead)	4.3	0.6	0	1.6	

Total Coverage 10%

Annual Species:

<u>Tridens pulchellus</u> (seedlings)	33.3	40.0	33.3	35.5	1
<u>Cryptantha</u> sp.	33.3	40.0	33.3	35.5	1
<u>Bromus rubens</u>	33.3	20.0	33.3	28.9	2

Total Cover = 1%

Table IV-11. Mile 128L Control vegetation studies (burros not present).
13 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	21.1	63.0	52.2	45.4	1
<u>Hilaria rigida</u>	15.8	20.2	33.3	23.1	2
<u>Ephedra nevadensis</u>	21.1	2.3	7.8	10.4	3
<u>Gutierrezia lucida</u>	10.5	6.4	2.2	6.4	4
<u>Eriogonum inflatum</u>	10.5	5.2	0	5.2	5
<u>Haplopappus spinulosus</u>	5.3	0.6	4.4	3.4	6
<u>Tridens pulchellus</u>	5.3	1.2	0	2.2	7
<u>Ditaxis neomexicana</u>	5.3	0.6	0	2.0	8
<u>Ferocactus acanthodes</u>	5.3	0.6	0	2.0	8

Total Cover = 9%

Annual Species:

Grass	56.3	89.6	73.1	73.0	1
<u>Cryptantha</u> sp.	31.3	9.2	19.2	19.9	2
<u>Eriogonum</u> sp.	12.5	1.2	7.7	7.1	3

Total Cover = 7%

Table IV-12. Mile 198R Parashont #1 Flats Impact (burros present).
19 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Larrea tridentata</u>	37.5	59.4	82.0	59.6	1
<u>Acacia greggii</u>	25.0	15.6	8.1	16.2	2
<u>Opuntia basilaris</u>	25.0	20.3	1.1	15.5	3
<u>Acacia greggii</u> (dead)	12.5	4.7	1.5	6.2	4
<u>Prosopis juliflora</u>	0	0	7.4	2.5	5

Total Cover = 27%

Annual Species:

<u>Bromus rubens</u>	62.5	81.4	79.7	74.5	1
<u>Plantago insularis</u>	18.8	17.5	14.5	16.9	2
<u>Larrea tridentata</u>	12.5	0.4	3.6	5.5	3
<u>Pectocarya</u> sp.	6.3	0.7	2.2	3.1	4

Total Cover = 14%

Tortula Average Cover = 7%

Table IV-13. Parashont #1 Flats, Mile 198R, Impact vegetation studies (burros present). 16 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Larrea tridentata</u>	37.5	65.0	97.7	66.7	1
<u>Opuntia basilaris</u>	37.5	20.0	0.9	19.5	2
<u>Acacia greggii</u>	25.0	15.0	0.9	13.6	3
<u>Opuntia phaeacantha</u>	0	0	0.5	0.2	4

Total Cover = 22%

Annual Species:

Grass	80.0	91.3	86.7	86.0	1
<u>Plantago insularis</u>	20.0	8.7	13.3	14.0	2

Total Cover = 4%

Tortula Average Cover = 8%

Table IV-14. Mile 198R Parashont #2 Hillside Impact (burros present).
19 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	14.3	37.3	24.2	25.3	1
<u>Allionia incarnata</u>	10.7	36.4	1.6	16.2	2
<u>Larrea tridentata</u>	10.7	3.3	34.4	16.1	3
<u>Opuntia basilaris</u>	14.3	12.7	12.9	13.3	4
<u>Ephedra nevadensis</u>	7.1	1.3	13.4	7.3	5
<u>Opuntia whipplei</u>	7.1	2.1	7.5	5.6	6
<u>Echinocereus engelmannii</u>	7.1	1.6	0	2.9	7
<u>Cassia covesii</u>	7.1	0.8	0	2.6	8
<u>Acacia greggii</u>	3.6	0.5	0.5	1.5	9
<u>Sphaeralcea grossulariaefolia</u>	3.6	1.3	1.1	2.0	10
<u>Dyssodia pentachaeta</u>	3.6	0.5	0	1.4	
<u>Encelia farinosa</u> (dead)	3.6	0.8	0	1.5	
<u>Ephedra nevadensis</u> (dead)	0	0	3.8	1.3	
Ferns	3.6	0.8	0	1.5	
<u>Fouquieria splendens</u>	3.6	0.5	0	1.4	
<u>Mammillaria tetrancistra</u>	0	0	0.5	0.2	

Total Cover = 18%

Annual Species:

<u>Plantago insularis</u>	36.0	67.2	45.5	49.6	1
<u>Bromus rubens</u>	28.0	26.3	23.4	25.9	2
<u>Lepidium lasiocarpum</u>	12.0	3.0	10.4	8.5	3
<u>Encelia farinosa</u> (seedling)	8.0	1.0	6.5	5.2	4
Unknown dicot	8.0	1.0	6.5	5.2	4
<u>Larrea tridentata</u> (seedling)	4.0	1.0	3.9	3.0	5
<u>Acacia greggii</u> (seedling)	4.0	0.5	3.9	2.8	6

Total Cover = 8%

Tortula Average Cover = 10%

Table IV-15. Parashont #2 Hillside, Mile 198R, Impact vegetation studies (burros present). 16 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	16.0	43.2	32.1	30.4	1
<u>Larrea tridentata</u>	12.0	8.4	37.2	19.2	2
<u>Opuntia basilaris</u>	16.0	22.1	10.3	16.1	3
<u>Ephedra nevadensis</u>	8.0	2.1	15.4	8.5	4
<u>Tridens pulchellus</u>	12.0	8.4	0	6.8	5
<u>Opuntia whipplei</u>	8.0	5.3	4.5	5.9	6
<u>Echinocereus engelmannii</u>	8.0	3.2	0.6	3.9	7
<u>Allionia incarnata</u>	8.0	3.2	0	3.7	8
<u>Sphaeralcea grossulariaefolia</u>	4.0	2.1	0	2.0	9
<u>Dyssodia pentachaeta</u>	4.0	1.1	0	1.7	10
<u>Ferocactus acanthodes</u>	4.0	1.1	0	1.7	10

Total Cover = 16%

Annual Species:

Grass	47.4	69.7	58.3	58.5	1
<u>Plantago insularis</u>	42.1	28.4	33.3	34.6	2
<u>Cryptantha</u> sp.	5.3	1.5	4.2	3.7	3
<u>Lepidium lasiocarpum</u>	5.3	0.5	4.2	3.3	4

Total Cover = 6%

Tortula Average Cover = 20%

Table IV-16. Mile 198L Parashont #3 Hillside Control (burros not present).
19 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Hilaria rigida</u>	10.8	35.6	7.4	17.9	1
<u>Sphaeralcea grossulariaefolia</u>	10.8	14.2	23.0	16.0	2
<u>Larrea tridentata</u>	8.1	2.7	32.4	14.4	3
<u>Encelia farinosa</u>	8.1	8.0	22.5	12.9	4
<u>Muhlenbergia porteri</u>	10.8	4.8	7.4	7.7	5
Fern	8.1	12.8	0	7.0	6
<u>Encelia farinosa</u> (dead)	10.8	5.3	2.0	6.0	7
<u>Mirabilis bigelovii</u>	5.4	3.5	0	3.0	8
<u>Viguiera deltoidea</u>	2.7	4.0	2.0	2.9	9
<u>Tridens pulchellus</u>	5.4	2.7	0	2.7	10
<u>Andropogon</u> sp.	2.7	0.8	1.0	1.5	
<u>Ferocactus acanthodes</u>	0	0	1.5	0.5	
<u>Gutierrezia lucida</u>	2.7	1.3	0	1.3	
<u>Haplopappus spinulosus</u>	5.4	1.3	0	2.2	
<u>Mammillaria microcarpa</u>	2.7	0.8	0	1.2	
<u>Opuntia whipplei</u> (dead)	0	0	1.0	0.3	
<u>Porophyllum gracile</u>	2.7	1.3	0	1.3	
Unknown	2.7	0.8	0	1.2	

Total Cover = 20%

Annual Species:

<u>Bromus rubens</u>	27.3	48.1	22.7	32.7	1
Unknown grass	18.2	26.6	34.8	26.5	2
Dicot seedling	18.2	5.1	15.2	12.8	3
<u>Lepidium lasiocarpum</u>	13.6	12.7	7.6	11.3	4
<u>Plantago insularis</u>	9.1	3.8	7.6	6.8	5
<u>Cryptantha</u> sp.	9.1	2.5	7.6	6.4	6
<u>Encelia farinosa</u> seedling	4.5	1.3	4.5	3.4	7

Total Cover = 7%

Tortula Average Cover = 18%

Table IV-17. Parashont #3 Hillside, Mile 198L, Control vegetation studies (burros not present). 17 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Hilaria rigida</u>	12.9	53.6	25.3	30.6	1
<u>Encelia farinosa</u>	9.7	5.9	31.5	15.7	2
<u>Sphaeralcea grossulariaefolia</u>	12.9	10.8	16.3	13.3	3
<u>Tridens pulchellus</u>	12.9	22.1	0	11.7	4
<u>Larrea tridentata</u>	12.9	2.3	7.9	7.7	5
<u>Ephedra nevadensis</u>	3.2	0.5	11.8	5.2	6
<u>Gutierrezia lucida</u>	6.5	0.9	3.4	3.6	7
<u>Haplopappus spinulosus</u>	6.5	0.9	0	2.5	8
<u>Ferocactus acanthodes</u>	3.2	0.5	2.8	2.2	9
<u>Muhlenbergia porteri</u>	3.2	0.5	0.6	1.4	10
<u>Aristida adscensionis</u>	3.2	0.5	0	1.2	
<u>Dyssodia pentachaeta</u>	3.2	0.5	0	1.2	
<u>Eriogonum inflatum</u>	3.2	0.5	0	1.2	
<u>Fouquieria splendens</u>	0	0	0.6	0.2	
<u>Mammillaria sp.</u>	3.2	0.5	0	1.2	
<u>Yucca whipplei</u>	3.2	0.5	0	1.2	

Total Cover = 18%

Annual Species:

Grasses	47.6	89.4	73.2	70.1	1
<u>Cryptantha sp.</u>	33.3	6.8	17.1	19.1	2
<u>Lepidium lasiocarpum</u>	9.5	3.1	4.9	5.8	3
<u>Plantago insularis</u>	9.5	0.7	4.9	5.0	4

Total Cover = 10%

Tortula Average Cover = 31%

Table IV-18. Comparison of density (D=plants/100m²) and cover (C=cm/100m²) for selected species on burro impacted and control sites at three sampling periods at Mile 198, Parashont Creek.

	Sept '76		Apr '77		Sept '77	
	Impact D/C	Control D/C	Impact D/C	Control D/C	Impact D/C	Control D/C
<u>Encelia farinosa</u>	80/630	15/890	90/450	12/460	41/500	13/560
<u>Sphaeralcea</u> <u>grossulariaefolia</u>	4/0	19/350	3.2/20	21.2/470	2/0	24/290
<u>Haplopappus spinulosus</u>	0/0	2/30	0/0	2/0	0/0	2/0
<u>Hilaria rigida</u>	0/0	110/120	0/0	53.2/150	0/0	119/450
<u>Muhlenbergia porteri</u>	0/0	5/80	0/0	7.2/150	0/0	1/10
<u>Tridens pulchellus</u>	0/0	1/0	0/0	1/0	2/0	49/0

Table IV-19. Mile 204R Impact vegetation studies (burros present).
21 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Larrea tridentata</u>	11.1	4.5	57.4	24.3	1
<u>Encelia farinosa</u> (seedling)	11.1	49.3	2.0	20.8	2
<u>Encelia farinosa</u>	16.7	13.1	31.6	20.5	3
<u>Allionia incarnata</u>	5.6	14.8	2.0	7.5	4
<u>Tridens pulchellus</u>	11.1	7.9	0	6.3	5
<u>Fouquieria splendens</u>	5.6	1.0	3.0	3.2	6
<u>Ferocactus acanthodes</u>	5.6	1.7	2.0	3.1	7
<u>Krameria parviflora</u>	5.6	1.7	2.0	3.1	7
Unknown grass	5.6	1.7	0	2.4	8
<u>Acacia greggii</u>	5.6	1.0	0	2.2	9
<u>Cassia covesii</u>	5.6	1.0	0	2.2	9
<u>Ephedra nevadensis</u>	5.6	1.0	0	2.2	9
<u>Fouquieria splendens</u>	5.6	1.0	0	2.2	9

Total Cover = 10%

Annual Species:

<u>Plantago insularis</u>	50.0	93.7	82.9	75.5	1
<u>Larrea tridentata</u> seedling	25.0	3.1	8.6	12.2	2
Dicot seedling	16.7	2.1	5.7	8.2	3
<u>Cassia covesii</u> seedling	8.3	1.1	2.9	4.1	4

Total Cover = 10%

Tortula Average Cover = 2%

Table IV-20. Mile 204R Impact vegetation studies (burros present).
17 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	30.0	79.7	31.5	47.1	1
<u>Larrea tridentata</u>	20.0	6.8	60.7	29.2	2
<u>Tridens pulchellus</u>	10.0	5.1	0	5.0	3
<u>Krameria parviflora</u>	10.0	3.4	0	4.5	4
<u>Aristida adscensionis</u>	10.0	1.7	0	3.9	5
<u>Ephedra nevadensis</u>	10.0	1.7	0	3.9	5
<u>Ferocactus acanthodes</u>	10.0	1.7	0	3.9	5
<u>Fouquieria splendens</u>	0	0	7.9	2.6	6

Total Cover = 9%

<u>Plantago insularis</u>	33.3	64.5	33.3	43.7	1
Grasses	25.0	16.1	25.0	22.0	2
<u>Encelia farinosa</u> seedling	16.7	9.7	16.7	14.4	3
<u>Cassia covesii</u> seedling	8.3	3.2	8.3	6.6	4
<u>Cryptantha</u> sp.	8.3	3.2	8.3	6.6	4
<u>Larrea tridentata</u> seedling	8.3	3.2	8.3	6.6	4

Total Cover = 3%

Tortula Average Cover = 4%

Table IV-21. Mile 207R Impact vegetation studies (burros present).
20 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V. /3	Rank
<u>Larrea tridentata</u>	27.3	16.0	58.4	33.9	1
<u>Encelia farinosa</u> (seedling)	9.1	34.6	0	14.6	2
<u>Acacia greggii</u>	9.1	3.7	25.3	12.7	3
<u>Larrea tridentata</u>	9.1	24.7	0	11.3	4
<u>Prosopis juliflora</u>	9.1	6.2	14.0	9.8	5
<u>Echinocereus triglochidictus</u>	9.1	3.7	2.3	5.0	6
<u>Condalia lycioides</u>	9.1	3.7	0	4.3	7
<u>Encelia farinosa</u>	9.1	3.7	0	4.3	7
<u>Haplopappus acradenius</u> (seedling)	9.1	3.7	0	4.3	7

Total Cover = 31%

Annual Species:

<u>Bromus rubens</u>	32.0	57.4	16.3	35.2	1
<u>Plantago insularis</u>	16.0	25.2	49.6	30.3	2
<u>Festuca octoflora</u>	8.0	6.6	12.8	9.1	3
<u>Lepidium lasiocarpum</u>	12.0	5.3	5.7	7.7	4
<u>Larrea tridentata</u> seedling	12.0	1.2	5.7	6.3	5
<u>Descuriania pinnata</u>	8.0	0.3	2.2	3.5	6
<u>Eriophyllum lanosum</u>	4.0	3.7	2.1	3.3	7
<u>Thelypodium</u> sp.	4.0	0.1	2.1	2.1	8
<u>Encelia farinosa</u> seedling	4.0	0.1	2.1	2.1	8

Total Cover = 14%

Table IV-22. Mile 207R Impact vegetation studies (burros present).
18 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Larrea tridentata</u>	33.3	41.7	64.2	46.4	1
<u>Encelia farinosa</u>	22.2	25.0	0	15.7	2
<u>Acacia greggii</u>	11.1	8.3	19.1	12.8	3
<u>Prosopis juliflora</u>	11.1	8.3	16.7	12.0	4
<u>Condalia lycioides</u>	11.1	8.3	0	6.5	5
<u>Echinocereus triglochidictus</u>	11.1	8.3	0	6.5	5

Total Cover = 29%

Annual Species:

<u>Plantago insularis</u>	25.0	56.3	45.7	42.3	1
Grasses	56.3	40.5	17.3	38.0	2
<u>Lepidium lasiocarpum</u>	18.8	3.2	37.0	19.6	3

Total Cover = 20%

Tortula Average Cover = 2%

Table IV-23. Mile 208L Control vegetation studies (burros not present).
20 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Prosopis juliflora</u>	60.0	75.0	92.3	75.8	1
<u>Atriplex canescens</u>	20.0	12.5	0	10.8	2
<u>Larrea tridentata</u> (dead)	20.0	12.5	0	10.8	2
<u>Prosopis juliflora</u>	0	0	7.3	2.4	3
<u>Larrea tridentata</u>	0	0	0.5	0.2	4

Total Cover = 65%

Annual Species:

<u>Bromus rubens</u>	42.9	95.7	79.6	72.7	1
<u>Descuriania pinnata</u>	42.9	3.7	14.8	20.5	2
<u>Chaenactis fremontii</u>	14.3	0.6	5.6	6.8	3

Total Cover = 5%

Tortula Average Cover = 6%

Table IV-24. Mile 208L Control vegetation studies (burros not present).
19 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Prosopis juliflora</u>	75.0	87.5	100.0	87.5	1
<u>Atriplex canescens</u>	25.0	12.5	0	12.5	2

Total Cover = 69%

Annual Species:

Grasses	80.0	99.3	95.8	91.7	1
<u>Descurainia pinnata</u>	20.0	0.7	4.2	8.3	2

Total Cover = 6%

Tortula Average Cover = 7%

Table IV-25. Mile 210.5R Impact vegetation studies (burros present).
20 April 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Haplopappus acradenius</u>	11.8	38.5	5.0	18.4	1
<u>Oenothera pallida</u>	17.6	33.3	0	17.0	2
<u>Encelia farinosa</u>	17.6	9.2	12.6	13.1	3
<u>Prosopis juliflora</u>	0	0	31.1	10.4	4
<u>Acacia greggii</u>	5.9	1.5	21.8	9.7	5
<u>Larrea tridentata</u>	5.9	1.5	21.0	9.5	6
<u>Porophyllum gracile</u>	5.9	2.6	8.4	5.6	7
<u>Baccharis sarothroides</u>	11.8	2.6	0	4.8	8
<u>Acacia greggii</u>	5.9	4.1	0	3.3	9
<u>Cassia covesii</u>	5.9	2.6	0	2.8	10
<u>Dyssodia pentachaeta</u>	5.9	2.6	0	2.8	
<u>Opuntia basilaris</u>	0	0	0.1	0	
Unknown grass #1	5.9	1.5	0	2.5	

Total Cover = 12%

Annual Species:

<u>Bromus rubens</u>	31.2	12.6	48.0	30.1	1
<u>Plantago insularis</u>	12.5	33.8	12.0	19.4	2
<u>Chaenactis fremontii</u> (dead)	6.2	42.9	2.0	17.0	3
Unknown Cruciferae	12.5	9.1	26.6	16.0	4
<u>Astragalus</u> sp.	18.8	7.8	5.3	10.6	5
<u>Ditaxis neomexicana</u>	6.2	1.3	2.0	3.1	6
<u>Funastrum heterophyllum</u>	6.2	1.3	2.0	3.1	6
<u>Haplopappus acradenius</u>	6.2	1.3	2.0	3.1	6

Total Cover = 15%

Tortula Average Cover = 2%

Table IV-26. Mile 210.5R Impact vegetation studies (burros present).
19 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Acacia greggii</u>	4.5	1.4	46.5	17.5	1
<u>Haplopappus acradenius</u>	13.6	33.8	4.2	17.2	2
<u>Encelia farinosa</u>	13.6	11.3	9.7	11.5	3
<u>Larrea tridentata</u>	4.5	1.4	18.8	8.2	4
<u>Cassia covesii</u>	4.5	5.6	5.6	5.2	5
Grass sp.	9.1	5.6	0	4.9	6
<u>Cassia covesii</u>	4.5	9.9	0	4.8	7
<u>Dyssodia pentachaeta</u>	4.5	9.9	0	4.8	7
<u>Ditaxis neomexicana</u>	4.5	7.0	0	3.8	8
<u>Prosopis juliflora</u>	0	0	9.7	3.2	9
<u>Porophyllum gracile</u>	4.5	2.8	0	2.4	10
Unknown #1	4.5	2.8	0	2.4	10
<u>Acacia greggii</u> (seedling)	4.5	1.4	0	2.0	
<u>Allionia incarnata</u>	4.5	1.4	0	2.0	
<u>Baccharis sarothroides</u>	4.5	1.4	0	2.0	
<u>Funastrum heterophyllum</u>	0	0	4.9	1.6	
<u>Funastrum</u> sp.	4.5	1.4	0	2.0	
<u>Mentzelia</u> sp.	4.5	1.4	0	2.0	
<u>Opuntia basilaris</u>	0	0	0.7	0.2	
<u>Porophyllum gracile</u>	4.5	1.4	0	2.0	

Total Cover = 14%

Annual Species:

Grasses	70.0	93.2	72.4	78.5	1
Cruciferae	10.0	4.8	20.7	11.8	2
<u>Plantago insularis</u>	10.0	1.6	3.4	5.0	3
<u>Descurainia pinnata</u>	10.0	0.4	3.4	4.6	4

Total Cover = 7%

Tortula Average Cover = 4%

Table IV-27. Tapeats Amphitheater Pinyon-Juniper Impact vegetation studies (burros present). 24 May 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Bouteloua gracilis</u>	10.5	47.1	5.5	21.0	1
<u>Arctostaphylos pungens</u>	6.8	8.7	34.0	16.5	2
<u>Pinus edulis</u>	5.9	1.3	35.1	14.1	3
<u>Gutierrezia sarothrae</u>	13.6	6.1	1.7	7.1	4
<u>Poa fendleriana</u>	11.8	8.3	.3	6.8	5
<u>Opuntia phaeacantha</u>	9.1	4.2	2.2	5.2	6
<u>Aristida purpurea</u>	3.6	5.1	2.2	3.6	7
<u>Yucca baccata</u>	4.5	2.9	2.9	3.4	8
<u>Zigadenus paniculatus</u>	4.1	3.2	.4	2.6	9
<u>Lepidium montanum</u>	4.1	2.9	.1	2.4	10
<u>Agave sp.</u>	.9	.3	0	.4	
<u>Arceuthobium sp.</u>	0	0	.1	0	
<u>Artemisia tridentata</u>	0	0	.4	.1	
<u>Berberis fremontii</u>	.5	0	.7	.4	
<u>Carex sp.</u>	.5	0	0	.2	
<u>Ceanothus greggii</u>	1.8	.3	1.1	1.1	
<u>Commandra pallida</u>	1.8	2.6	.2	1.5	
<u>Coryphantha vivipara</u>	.5	0	0	.2	
<u>Cowania mexicana</u>	.9	.3	4.5	1.9	
<u>Ephedra viridis</u>	.5	.3	.6	.5	
<u>Eriogonum alatum</u>	.9	.3	.2	.5	
<u>Erigeron concinnus</u>	.5	0	0	.2	
<u>Eriogonum hieracifolium</u>	1.8	.6	0	.8	
<u>Eriogonum (mat grower)</u>	.5	.3	0	.3	
<u>Eurotia lanata</u>	.9	.3	0	.4	
<u>Forsellesia nevadensis</u>	.9	.3	.4	.5	
<u>Gilia sp.</u>	1.4	.3	0	.6	
<u>Juniperus osteosperma</u>	1.8	.3	2.0	1.4	
<u>Opuntia phaeacantha</u>	.5	0	.2	.2	
<u>Penstemon eatoni</u>	1.8	.6	0	.8	
<u>Phlox austromontana</u>	.5	0	.1	.2	
<u>Pinus monophylla</u>	0	0	2.3	.8	
<u>Quercus turbinella</u>	1.8	2.6	2.5	2.3	
<u>Shrub seedling</u>	1.4	.3	0	.6	
<u>Sitanion hystrix</u>	.9	.3	0	.4	
<u>Swertia albomarginata</u>	.5	0	0	.2	
<u>Townsendia incana</u>	.9	0	0	.3	
<u>Unknown Compositae</u>	.5	0	0	.2	
<u>Unknown (grass)</u>	1.4	0	0	.5	

Total Cover = 39%

Annual Species:

<u>Festuca octoflora</u>	68.4	94.1	29.2	64.0	1
<u>Pine stump</u>	5.3	0	54.2	19.8	2
<u>Draba cuneifolia</u>	10.5	5.9	4.2	6.9	3
<u>Bromus rubens</u>	5.3	0	4.2	3.2	4
<u>Cryptantha pectocarya</u>	5.3	0	4.2	3.2	4
<u>Gilia sp. (seedling)</u>	5.3	0	4.2	3.2	4

Total Cover = 2%

Tortula Average Cover = 27%

Litter = 38%

Table IV-28. Pinyon-Juniper Impact vegetation studies (burros present).
11 July 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Bouteloua gracilis</u>	11.4	55.4	3.6	23.5	1
<u>Arctostaphylos pungens</u>	11.8	14.0	25.3	17.0	2
<u>Poa fendleriana</u>	12.4	6.1	2.2	6.9	3
<u>Pinus edulis</u>	2.0	0.3	16.8	6.4	4
<u>Gutierrezia sarothrae</u>	12.9	5.4	0.7	6.3	5
<u>Opuntia phaeacantha</u>	10.4	5.1	1.3	5.6	6
<u>Ephedra viridis</u>	0.5	0	10.9	3.8	7
<u>Pinus edulis</u> (dead)	0	0	10.9	3.6	8
<u>Yucca baccata</u>	5.0	1.6	2.9	3.2	9
<u>Lepidium montanum</u>	5.0	3.2	0	2.7	10
<u>Agave utahensis</u>	0	0	0	0	
<u>Allium</u> sp. (dead)	0	0	0.1	0	
<u>Arctostaphylos pungens</u> (dead)	0	0	6.9	2.3	
<u>Artemisia tridentata</u>	1.0	0.3	0.5	0.6	
<u>Berberis fremontii</u>	0.5	0	0	0.2	
<u>Bouteloua gracilis</u> (dead)	0	0	2.3	0.8	
<u>Carex</u> sp.	1.0	0.3	0	0.4	
<u>Ceanothus greggii</u>	1.5	0.3	0.7	0.8	
<u>Ceanothus greggii</u> (seedling)	1.0	0.3	0	0.4	
<u>Ceanothus greggii</u> (dead)	0	0	0.9	0.3	
<u>Cercocarpus montanus</u>	0.5	0	0	0.2	
<u>Commandra pallida</u>	2.0	2.2	0.1	1.4	
Compositae (unknown.)	0.5	0	0	0.2	
<u>Cowania mexicana</u>	2.0	0.3	3.9	2.1	
<u>Cowania mexicana</u>	0	0	1.9	0.6	
<u>Eriogonum hieracifolium</u>	2.5	1.0	0.4	1.3	
<u>Forsellesia nevadensis</u>	1.0	0	0.4	0.5	
<u>Forsellesia nevadensis</u> (dead)	0	0	0.3	0.1	
<u>Gilia</u> sp.	0	0	0	0	
<u>Gutierrezia sarothrae</u>	0	0	0.7	0.2	
<u>Juniperus osteosperma</u>	1.0	0	1.9	1.0	
<u>Juniperus osteosperma</u> (seedling)	1.0	0	0	0.3	
<u>Opuntia phaeacantha</u> (dead)	1.5	0.3	1.4	1.1	
<u>Penstemon eatonii</u>	2.0	0.6	0	0.9	
<u>Phlox austromontanus</u>	1.0	0	0	0.3	
<u>Pinus edulis</u> (seedling)	3.0	0.6	0	1.2	
<u>Pinus monophylla</u>	0.5	0	0	0.2	
<u>Quercus turbinella</u>	2.0	1.9	2.1	2.0	
<u>Quercus turbinella</u> (dead)	0	0	0.2	0.1	
<u>Sitanion hystrix</u>	0.5	0	0	0.2	
<u>Swertia albomarginata</u>	0.5	0	0	0.2	
<u>Townsendia incana</u>	1.5	0.3	0	0.6	
<u>Tricetum spicatum</u>	0.5	0	0.3	0.3	
Unknown grass	1.5	0.3	0	0.6	
<u>Yucca baccata</u>	0	0	0.5	0.2	

Total Cover = 48%

Table IV-28. Pinyon-Juniper Impact, 11 July 1977. (continued)

Annual Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Festuca</u> sp.	89.5	100.0	81.8	90.4	1
<u>Arctostaphylos pungens</u> (seedling)	5.3	0	9.1	4.8	2
<u>Opuntia phaeacantha</u> (seedling)	5.3	0	9.1	4.8	2

Total Cover = 1%

Tortula = 23%

Table IV-29. Specter Pinyon-Juniper Control vegetation studies (burros not present).
23 May 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Opuntia erinacea</u>	12.9	22.7	7.0	14.2	1
<u>Oryzopsis hymenoides</u>	14.9	18.2	5.3	12.8	2
<u>Gutierrezia sarothrae</u>	15.3	11.9	10.2	12.5	3
<u>Pinus edulis</u>	1.0	.4	29.7	10.4	4
<u>Juniperus osteosperma</u>	2.4	.7	26.7	9.9	5
<u>Bouteloua gracilis</u>	8.1	12.6	1.7	7.5	6
<u>Yucca baccata</u>	5.1	5.9	7.8	6.3	7
<u>Lepidium montanum</u>	5.1	7.4	2.9	5.1	8
<u>Bouteloua eriopoda</u>	6.1	5.9	1.0	4.3	9
<u>Eriogonum hieracifolium</u>	5.8	2.6	.8	3.1	10
<u>Ephedra viridis</u>	4.1	2.6	2.2	3.0	
<u>Artemisia tridentata</u>	1.0	.4	.2	.5	
<u>Aster arenosus</u>	1.0	1.1	0	.7	
<u>Berberis fremontii</u>	.3	0	1.4	.6	
<u>Chrysothamnus nauseosus</u>	.3	0	1.1	.5	
<u>Commandra sp.</u>	.3	1.5	.2	.7	
<u>Erigeron concinnus</u>	.3	0	0	.1	
<u>Haplopappus spinulosus</u>	3.1	1.9	.2	1.7	
<u>Lesquerella intermedia</u>	.7	0	0	.2	
<u>Opuntia erinacea</u>	2.0	.4	.5	1.0	
<u>Psilostrophe sparsiflora</u>	3.4	1.1	.2	1.6	
<u>Sitanion hystrix</u>	2.4	1.5	.4	1.4	
<u>Sphaeralcea sp.</u>	.3	0	0	.1	
<u>Swertia albomarginata</u>	.7	.4	0	.4	
<u>Thamnosma montana</u>	.7	0	.6	.4	
<u>Townsendia incana</u>	2.7	.7	0	1.1	

Total Cover = 33%

Annual Species:

<u>Bromus rubens</u>	93.8	100.0	71.4	88.4	1
<u>Juniper (trunk)</u>	6.3	0	28.6	11.6	2

Total Cover = 3%

Tortula Average Cover = 20%

Detritus = 29%

Table IV-30. Specter Pinyon-Juniper Control vegetation studies (burros not present).
10 July 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Juniperus osteosperma</u>	1.3	.4	44.4	15.4	1
<u>Opuntia erinacea</u>	12.3	23.2	5.0	13.5	2
<u>Gutierrezia sarothrae</u>	13.3	11.1	11.9	12.1	3
<u>Oryzopsis hymenoides</u>	13.6	15.1	6.7	11.8	3
<u>Bouteloua gracilis</u>	7.5	14.0	2.4	8.0	4
<u>Yucca baccata</u>	4.9	5.5	7.3	5.9	5
<u>Bouteloua eriopoda</u>	5.8	7.4	1.3	4.8	6
<u>Lepidium montanum</u>	5.2	7.4	1.5	4.7	7
<u>Opuntia erinacea</u> (dead)	4.9	1.8	2.5	3.1	8
<u>Ephedra viridis</u>	3.9	1.8	1.8	2.5	9
<u>Gutierrezia sarothrae</u> dead	2.3	1.1	3.9	2.4	10
<u>Haplopappus spinulosus</u>	3.9	1.5	1.7	2.4	10
<u>Artemisia tridentata</u>	1.0	.4	.5	.6	
<u>Artemisia tridentata</u> (dead)	0	0	.6	.2	
<u>Aster arenosus</u>	.6	.7	0	.4	
<u>Berberis fremontii</u>	0	0	.6	.2	
<u>Bouteloua eriopoda</u> (dead)	0	0	.2	.1	
<u>Bouteloua gracilis</u> (dead)	0	0	1.5	.5	
<u>Chrysothamnus nauseosus</u>	0	0	.6	.2	
<u>Commandra</u> sp.	.1	.7	.1	.3	
<u>Erigeron concinnus</u>	1.0	.4	.2	.5	
<u>Eriogonum</u> (basal rosette)	0	0	0	0	
<u>Eriogonum hieracifolium</u>	4.2	1.5	1.2	2.3	
<u>Haplopappus spinulosus</u> (dead)	0	0	.1	0	
<u>Lesquerella</u> sp.	1.6	2.2	0	1.3	
<u>Lesquerella</u> (dead)	0	0	.7	.2	
<u>Muhlenbergia porteri</u>	0	0	.1	0	
<u>Oryzopsis hymenoides</u> (dead)	0	0	.1	0	
<u>Psilostrophe sparsiflora</u>	3.2	1.1	0	1.4	
<u>Sitanion hystrix</u>	2.6	1.1	.1	1.3	
<u>Sphaeralcea</u> sp.	0	0	0	0	
<u>Stipa neomexicana</u>	1.9	.7	.3	1.0	
<u>Swertia albamarginata</u>	.1	.4	0	.2	
<u>Thamnosma montana</u>	0	0	.4	.1	
<u>Townsendia incana</u>	1.6	.4	.2	.7	
Unknown Compositae	0	0	.3	.1	
<u>Yucca baccata</u>	0	0	1.8	.6	

Total Cover = 37%

Annual Species:

<u>Bromus rubens</u>	94.4	100.0	70.4	88.3	1
Juniper trunk	5.6	0	29.6	11.7	2

Cover annuals = 3%

Tortula Average Cover = 25%

Table. IV-31. Darwin Plateau Pinyon-Juniper Impact (burros present).
24 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Gutierrezia sarothrae</u>	21.2	38.3	15.6	25.0	1
<u>Lepidium montanum</u>	11.3	26.8	0.1	13.0	2
<u>Pinus edulis</u>	1.5	0.4	28.3	10.1	3
<u>Coleogyne ramosissima</u>	7.9	2.8	14.0	8.2	4
<u>Yucca baccata</u>	5.4	5.5	13.1	8.0	5
<u>Forsellesia nevadensis</u>	8.4	2.3	8.3	6.4	6
<u>Ephedra viridis</u>	6.9	3.7	1.8	4.2	7
<u>Ceanothus greggii</u>	3.5	1.3	5.1	3.3	8
<u>Aster arenosus</u>	3.5	4.4	0.2	2.7	9
<u>Sporobolus flexuosus</u>	3.9	3.4	0.3	2.6	10
<u>Agave utahensis</u>	2.5	1.3	0.1	1.3	
<u>Aristida adscensionis</u>	0.5	0.1	0.1	0.3	
<u>Artemisia sp.</u>	2.0	0.5	0.4	0.9	
<u>Castilleja sp.</u>	1.0	0.6	0	0.5	
<u>Cercocarpus intricatus</u>	0.5	0.1	0.9	0.5	
<u>Cowania mexicana</u>	0	0	0.9	0.3	
<u>Erigeron sp.</u>	0.5	0.1	0	0.2	
<u>Eriogonum fasciculatum</u>	3.0	2.6	1.4	2.3	
<u>Gutierrezia sarothrae</u> (dead)	2.0	0.9	0	1.0	
<u>Haplopappus spinulosus</u>	1.0	0.4	0	0.4	
<u>Hymenoxys acaulis</u>	1.5	0.2	0	0.6	
<u>Juniperus osteosperma</u>	0	0	3.5	1.2	
<u>Opuntia phaeacantha</u>	2.5	0.9	2.4	1.9	
<u>Quercus turbinella</u>	0.5	0.1	2.4	1.0	
<u>Sitanion hystrix</u>	0.5	0.4	0.2	0.3	
<u>Sphaeralcea grossulariaefolia</u>	1.0	0.4	0	0.5	
<u>Stipa neomexicana</u>	3.5	0.9	0	1.5	
<u>Swertia albomarginata</u>	1.5	0.9	0.0	0.8	
<u>Thamnosma montana</u>	0	0	0.2	0.1	
<u>Townsendia incana</u>	0.5	0.1	0	0.2	
Unknown #1	2.0	0.5	0	1.5	
Unknown #2	0.5	0.1	0	0.2	
Total Cover = 28%					
Annual Species:					
<u>Bromus rubens</u>	60.0	63.8	44.8	56.2	1
Grass	20.0	34.5	51.7	35.4	2
<u>Lepidium lasiocarpum</u>	20.0	1.7	3.4	8.4	3
Total Cover = 1%					
Tortula average cover = 11%					

Table IV-32. Masonic Point Pinyon-Juniper Control vegetation studies (no burros present). 26 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Stipa neomexicana</u>	12.2	21.8	11.0	15.0	11
<u>Poa sp.</u>	11.2	14.9	6.0	10.6	2
<u>Pinus edulis</u>	2.1	0.4	26.3	9.6	3
<u>Gutierrezia sarothrae</u>	9.4	5.5	5.8	6.9	4
<u>Bouteloua gracilis</u>	4.7	14.2	1.5	6.8	5
<u>Aster arenosus</u>	5.5	12.7	0.9	6.4	6
<u>Juniperus osteosperma</u>	1.3	0.2	14.8	5.5	7
<u>Eriogonum fasciculatum</u>	6.8	5.2	3.6	5.2	8
<u>Quercus undulata</u>	2.3	1.6	11.2	5.0	9
<u>Hymenoxys acaulis</u>	5.0	4.8	0.4	3.4	10
<u>Agave utahensis</u>	0.5	0.1	0	0.2	
<u>Artemisia sp.</u>	0.8	0.2	0.4	0.4	
<u>Berberis fremontii</u>	0.5	0.1	0.4	0.3	
<u>Cercocarpus montanus</u>	1.6	0.5	0.1	0.7	
<u>Coryphantha vivipara</u>	0.3	0	0	0.1	
<u>Echinocereus engelmannii</u>	0.3	0	0	0.1	
<u>Ephedra viridis</u>	5.0	1.4	2.2	2.8	
<u>Forsellesia nevadensis</u>	3.1	0.5	6.0	3.2	
<u>Hilaria jamesii</u>	4.4	4.7	0.5	3.2	
<u>Linum neomexicanum</u>	4.4	3.4	0.2	2.6	
<u>Opuntia erinacea</u>	5.2	3.0	1.0	3.0	
<u>Opuntia phaeacantha</u>	3.9	0.9	1.5	2.1	
<u>Oryzopsis hymenoides</u>	0.3	0	0.5	0.3	
<u>Penstemon sp.</u>	0.3	0	0	0.1	
<u>Phlox sp.</u>	6.3	3.0	0.2	3.1	
<u>Quercus turbinella</u>	0.3	0.1	0.6	0.3	
<u>Stipa arida</u>	0.8	0.3	4.1	1.7	
<u>Swertia albomarginata</u>	0.8	0.1	0	0.3	
<u>Yucca baccata</u>	1.0	0.6	1.0	0.9	

Total Cover = 51.67%

No annuals present

Tortula Average Cover = 12%

Table IV-33. Tonto Platform Impact vegetation studies (burros present).
17 May 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Opuntia erinacea</u> (uprooted)	20.8	63.4	1.7	28.6	1
<u>Opuntia erinacea</u>	23.5	14.4	30.6	22.8	2
<u>Ephedra nevadensis</u>	12.8	2.6	38.3	17.9	3
<u>Brickellia</u> sp.	10.7	3.3	5.0	6.3	4
<u>Opuntia phaeacantha</u>	3.4	1.3	9.4	4.7	5
<u>Lycium</u> sp.	4.7	1.3	7.2	4.4	6
<u>Coleogyne ramosissima</u>	4.7	.7	5.6	3.7	7
<u>Hilaria rigida</u>	3.4	5.2	1.1	3.2	8
<u>Opuntia phaeacantha</u> (uprooted)	2.0	4.6	0	2.2	9
<u>Echinocereus</u> spp.	4.0	.7	0	1.6	10
<u>Spaeralcea grossulariaefolia</u>	3.4	1.3	0	1.6	10
<u>Stipa</u> sp.	2.7	.7	.6	1.3	
<u>Tridens pulchellus</u>	2.0	.7	.6	1.1	
<u>Coleogyne ramosissima</u> (dead)	.7	0	0	.2	
<u>Gutierrezia sarothrae</u>	.7	0	0	.2	
<u>Muhlenbergia porteri</u>	.7	0	0	.2	

Total Cover = 7%

Annual Species:

<u>Bromus rubens</u>	38.0	66.1	52.9	52.3	1
<u>Euphorbia</u> spp.	37.2	23.3	28.7	29.7	2
<u>Plantago</u> spp.	22.3	10.6	16.1	16.3	3
<u>Cryptantha</u> spp.	1.7	0	1.1	.9	4
<u>Eriogonum racemosum</u>	.8	0	1.1	.6	5

Total Cover = 9%

Table IV-34. Tonto Platform Impact vegetation studies (burros present).
15 July 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Opuntia erinacea</u> (dead)	19.4	37.7	25.0	27.4	1
<u>Opuntia erinacea</u>	20.0	23.7	25.0	22.9	2
<u>Ephedra nevadensis</u>	9.4	3.5	20.1	11.0	3
<u>Brickellia</u> sp.	12.8	6.1	3.4	7.4	4
<u>Hilaria rigida</u>	3.9	9.6	2.2	5.2	5
<u>Opuntia phaeacantha</u> (dead)	2.8	1.8	7.1	3.9	6
Unknown grass	4.4	6.1	0	3.5	7
<u>Coleogyne ramosissima</u>	5.0	1.8	3.5	3.4	8
<u>Opuntia phaeacantha</u>	2.8	1.8	4.1	2.9	9
<u>Tridens pulchellus</u>	3.3	3.5	0.3	2.4	10
<u>Allionia incarnata</u>	1.7	0.9	0	0.9	
<u>Coleogyne ramosissima</u> (dead)	0.6	0	0	0.2	
<u>Echinocereus engelmannii</u>	3.9	0.9	0	1.6	
<u>Ephedra nevadensis</u> (dead)	0	0	0.7	0.2	
<u>Ephedra viridis</u>	1.1	0	4.8	2.0	
Grass (dead)	0.6	0	0.3	0.3	
<u>Gutierrezia sarothrae</u>	0.6	0	0	0.2	
<u>Lycium andersonii</u>	1.7	0.9	2.1	1.5	
<u>Muhlenbergia porteri</u>	2.8	0.9	1.2	1.6	
<u>Spaeralcea grossulariaefolia</u>	2.8	0.9	0.1	1.3	
<u>Stipa arida</u>	0.6	0	0	0.2	

Total Cover = 11%

Annual Species:

<u>Bromus rubens</u>	33.3	48.7	48.4	43.5	1
<u>Euphorbia polycarpa</u>	30.5	17.5	22.7	23.6	2
<u>Plantago insularis</u>	21.3	17.5	12.5	17.1	3
<u>Bromus rubens</u> — dead?	7.1	10.7	10.2	9.3	4
<u>Bouteloua simplex</u>	2.1	4.7	3.1	3.3	5
<u>Eriogonum deflexum</u>	5.7	0.9	3.1	3.2	6

Total Cover = 13%

Table IV-35. Tonto Platform Impact vegetation studies (burros present).
4 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Opuntia erinacea</u>	17.6	24.8	24.2	22.2	1
<u>Opuntia erinacea</u> (dead)	19.2	36.7	9.0	21.7	2
<u>Ephedra nevadensis</u>	9.3	3.3	21.8	11.5	3
<u>Brickellia sp.</u>	9.9	4.7	4.6	6.4	4
<u>Ephedra torreyana</u>	0	0	16.5	5.5	5
<u>Hilaria rigida</u>	3.3	9.5	2.7	5.2	6
<u>Allionia incarnata</u>	7.7	4.0	1.5	4.4	7
<u>Tridens muticus</u>	6.6	5.2	0.3	4.0	8
<u>Coleogyne ramosissima</u>	5.5	1.7	4.5	3.9	9
<u>Opuntia phaeacantha</u>	3.3	2.1	5.1	3.5	10
<u>Echinocereus engelmannii</u>	3.3	1.2	0	1.5	
<u>Ephedra nevadensis</u> (dead)	0	0	1.2	0.4	
<u>Eriogonum deflexum</u>	0	0	0.3	0.1	
<u>Gutierrezia sarothrae</u>	0.5	0.2	0	0.2	
<u>Lycium andersonii</u>	1.6	0.5	6.1	2.8	
<u>Muhlenbergia porteri</u>	3.8	1.2	1.1	2.1	
<u>Opuntia phaeacantha</u> (dead)	2.7	1.9	0.9	1.9	
<u>Sphaeralcea grossulariaefolia</u>	2.7	1.0	0.2	1.3	
<u>Tridens pulchellus</u>	2.7	1.9	0	1.6	

Total Cover = 7%

Annual Species:

<u>Bromus rubens</u>	42.0	55.4	36.5	44.6	1
<u>Euphorbia polycarpa</u>	27.2	16.9	40.9	28.3	2
<u>Bouteloua simplex</u>	9.9	16.9	9.7	12.2	3
<u>Plantago insularis</u>	14.8	9.2	6.5	10.2	4
<u>Eriogonum deflexum</u>	4.9	1.5	5.4	3.9	5
<u>Sphaeralcea grossulariaefolia</u> (seedling)	1.2	0.3	1.1	0.9	6

Total Cover = 9%

Table IV-36. Tonto Platform Control vegetation studies (burros not present).
18 May 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Coleogyne ramosissima</u>	25.3	16.7	40.4	27.5	1
<u>Opuntia erinacea</u>	26.5	43.1	7.7	25.8	2
<u>Lycium andersonii</u>	14.1	10.8	40.2	21.7	3
<u>Opuntia erinacea</u> (uprooted)	7.1	17.6	.6	8.4	4
<u>Echinocereus engelmannii</u>	12.9	6.9	3.7	7.8	5
<u>Yucca baccata</u>	5.9	2.9	4.7	4.5	6
<u>Ephedra nevadensis</u>	1.8	1.0	1.5	1.4	7
<u>Brickellia</u> sp.	1.8	1.0	0	.9	8
<u>Dyssodia porophylloides</u>	.6	0	1.1	.6	9
<u>Eriogonum inflatum</u>	1.2	0	0	.4	10
<u>Opuntia phaeacantha</u>	1.2	0	0	.4	10
<u>Echinocereus engelmannii</u> (uprtd)	.6	0	0	.2	
<u>Gutierrezia sarothrae</u>	.6	0	0	.2	
<u>Tridens muticus</u>	.6	0	0	.2	

Total Cover = 19%

Annual Species:

<u>Cryptantha</u> spp.	52.6	30.1	53.1	45.3	1
<u>Bromus rubens</u>	7.0	47.0	6.3	20.1	2
<u>Cryptantha</u> seedling	19.3	13.3	18.8	17.1	3
<u>Plantago</u> spp.	19.3	9.6	18.8	15.9	4
<u>Eriogonum racemosum</u>	1.8	0	3.1	1.6	5

Total Cover = 3%

Table IV-37. Tonto Platform Control vegetation studies (burros not present).
14 July 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Opuntia erinacea</u>	20.8	44.2	6.2	23.7	1
<u>Coleogyne ramosissima</u>	19.8	17.3	30.9	22.7	2
<u>Lycium andersonii</u>	10.8	8.7	28.3	15.9	3
<u>Opuntia erinacea</u> (dead)	14.6	9.6	6.6	10.3	4
<u>Echinocereus engelmannii</u>	10.8	6.7	3.7	7.1	5
<u>Coleogyne ramosissima</u> (dead)	2.8	1.9	11.0	5.2	6
<u>Yucca baccata</u>	4.7	2.9	4.9	4.2	7
<u>Echinocereus engelmannii</u> (dead)	5.7	3.8	0.2	3.2	8
<u>Yucca baccata</u> (dead)	2.8	1.0	2.2	2.0	9
<u>Lycium andersonii</u> (dead)	0.5	0	2.2	0.9	10
<u>Bouteloua eriopoda</u>	0.5	1.0	0	0.5	
<u>Brickellia</u> sp.	1.4	1.0	0	0.8	
<u>Dyssodia porophylloides</u>	0.5	0	1.1	0.5	
<u>Ephedra viridis</u>	0.9	0	1.6	0.8	
<u>Ephedra viridis</u> (dead)	0	0	0.1	0	
<u>Eriogonum deflexum</u>	0	0	0.1	0	
<u>Eriogonum deflexum</u> (dead)	0	0	0	0	
<u>Eriogonum inflatum</u>	0.9	1.0	0.3	0.7	
<u>Gutierrezia sarothrae</u>	0.5	0	0	0.2	
<u>Opuntia phaeacantha</u>	0.9	1.0	0.4	0.8	
<u>Opuntia phaeacantha</u> (dead)	0.5	0	0.2	0.2	
<u>Tridens muticus</u>	0.9	0	0	0.3	

Total Cover = 25%

Annual Species:

<u>Plantago insularis</u>	42.9	56.7	37.9	45.8	1
<u>Eriogonum deflexum</u>	24.5	16.7	20.7	20.6	2
<u>Bouteloua simplex</u>	16.3	16.7	24.1	19.0	3
<u>Cryptantha</u> sp.	8.2	3.3	6.9	6.1	4
<u>Bromus rubens</u>	6.1	3.3	6.9	5.4	5
<u>Bromus rubens</u> (dead)	2.0	3.3	3.4	2.9	6

Total Cover = 3%

Table IV-38. Tonto Platform Control vegetation studies (burros not present).
3 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Opuntia erinacea</u>	24.9	48.3	8.3	27.2	1
<u>Coleogyne ramosissima</u>	19.3	15.9	45.0	26.7	2
<u>Lycium andersonii</u>	12.7	9.0	32.8	18.2	3
<u>Opuntia erinacea</u> (dead)	12.7	11.8	0.6	8.4	4
<u>Echinocereus engelmannii</u>	14.4	7.2	2.4	8.0	5
<u>Yucca baccata</u>	5.0	2.6	6.0	4.5	6
<u>Echinocereus engelmannii</u> (dead)	3.9	2.0	0	2.0	7
<u>Ephedra viridis</u>	1.1	0.4	1.9	1.1	8
<u>Opuntia phaeacantha</u>	1.1	0.9	0.4	0.8	9
<u>Dyssodia porophylloides</u>	1.1	0.4	0.7	0.7	10
<u>Brickellia</u> sp.	1.1	0.4	0	0.5	
<u>Eriogonum inflatum</u>	1.1	0.6	0.1	0.6	
<u>Gutierrezia sarothrae</u>	0.6	0.2	0	0.2	
<u>Tridens muticus</u>	1.1	0.4	0	0.5	
<u>Yucca baccata</u> (dead)	0	0	1.8	0.6	

Total Cover = 21%

Annual Species:

<u>Eriogonum deflexum</u>	29.8	31.8	32.3	31.3	1
<u>Plantago insularis</u>	31.9	27.3	25.8	28.3	2
<u>Cryptantha</u> sp. (seedling)	14.9	13.6	12.9	13.8	3
<u>Bouteloua simplex</u>	10.6	13.6	16.1	13.4	4
<u>Bromus rubens</u>	10.6	9.1	9.7	9.8	5
<u>Echinocereus engelmannii</u> (seedling)	2.1	4.5	3.2	3.3	6

Total Cover = 3%

Table IV-39. Comparison of density (D=plants/100m²) and cover (C=cm/100m²) for selected species on burro impacted and control sites at three sampling periods on the Tonto Platform.

	May		July		Sept	
	Impact D/C	Control D/C	Impact D/C	Control D/C	Impact D/C	Control D/C
<u>Ephedra nevadensis</u>	8/276	0/0	8/227.6	0/0	7.6/134.8	0/0
<u>Opuntia erinacea</u>	44/220	88/144	54/282.8	92/152.8	58/167.2	104/169.2
<u>Coleogyne ramosissima</u>	2/40	34/752	4/40	36/765.2	4/31.2	34/912.8
<u>Lycium andersonii</u>	4/52	22/748	2/23.6	18/700	2/42	20/666
<u>Allionia incarnata</u>	0/0	0/0	2/0	0/0	10/10.4	0/0
<u>Tridens pulchellus</u>	2/4	0/0	8/3.6	0/0	4/0	0/0

Table IV-40. Rampart Impact vegetation studies (burros present).
27 May 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Tridens pulchellus</u>	21.0	55.8	5.6	27.5	1
<u>Encelia farinosa</u>	15.5	2.3	46.2	21.3	2
<u>Allionia incarnata</u>	17.2	27.3	1.7	15.4	3
<u>Larrea tridentata</u>	2.9	.4	34.6	12.6	4
<u>Cassia covesii</u>	13.4	3.2	2.4	6.3	5
<u>Euphorbia polycarpa</u>	6.3	6.5	2.2	5.0	6
<u>Ditaxis neomexicana</u>	7.1	2.7	.3	3.4	7
<u>Sphaeralcea ambigua</u>	4.6	.5	2.2	2.4	8
<u>Ephedra nevadensis</u>	1.3	.2	2.3	1.3	9
<u>Franseria dumosa</u>	2.9	.4	.6	1.3	9
<u>Krameria parviflora</u>	1.3	.2	1.2	.9	10
<u>Coldenia hispidissima</u>	.8	0	.1	.3	
<u>Dyssodia sp.</u>	.4	0	0	.1	
<u>Echinocereus engelmannii</u>	1.7	.2	0	.6	
<u>Ephedra torreyana</u>	1.7	.2	0	.6	
<u>Eriogonum inflatum</u>	1.3	.2	0	.5	
<u>Opuntia basilaris</u>	.4	0	.6	.3	

Total Cover = 14%

Annual Species:

<u>Plantago insularis</u>	62.3	95.5	89.0	82.3	1
<u>Bromus rubens</u>	14.3	2.8	4.9	7.3	2
<u>Cassia covesii</u>	7.8	.7	1.8	3.4	3
<u>Aristida adscendionis</u>	7.6	.3	1.2	3.0	4
<u>Encelia farinosa</u>	5.2	.3	1.2	2.2	5
<u>Ledpidium lasiocarpum</u>	2.6	.3	.6	1.2	6
<u>Opuntia basilaris</u>	1.3	0	.6	.6	7
<u>Sphaeralcea (seedling)</u>	1.3	0	.6	.6	7

Cover = 16%

Tortula Average Cover = 20%

Table IV-41. Rampart Impact vegetation studies (burros present).
7 July 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Tridens pulchellus</u>	21.0	68.1	9.5	32.9	1
<u>Encelia farinosa</u>	15.5	2.5	41.1	19.7	2
<u>Larrea tridentata</u>	3.8	0.4	32.1	12.1	3
<u>Allionia incarnata</u>	16.3	13.2	3.0	10.8	4
<u>Euphorbia polycarpa</u>	8.4	8.0	1.0	5.8	5
<u>Cassia covesii</u>	9.6	2.1	5.2	5.6	6
<u>Ditaxis neomexicana</u>	6.7	3.5	0.1	3.4	7
<u>Sphaeralcea ambigua</u>	4.2	0.4	3.0	2.5	8
<u>Ephedra nevadensis</u>	1.3	0.2	2.9	1.5	9
<u>Franseria dumosa</u>	3.3	0.4	0.5	1.4	10
<u>Coldenia hispidissima</u>	0.8	0	0.2	0.3	
<u>Dyssodia thurberi</u>	1.3	0.2	0	0.5	
<u>Echinocereus engelmannii</u>	2.1	0.2	0	0.8	
<u>Ephedra torreyana</u>	1.7	0.2	0	0.6	
<u>Eriogonum inflatum</u>	0.8	0.2	0.1	0.4	
<u>Krameria parviflora</u>	1.3	0.2	1.1	0.9	
<u>Opuntia basilaris</u>	1.3	0.2	0	0.5	

Total Cover = 12%

Annual Species:

<u>Plantago insularis</u>	63.6	92.6	51.3	69.2	1
<u>Bromus rubens</u>	20.8	5.5	28.2	18.2	2
<u>Cassia covesii</u> (seedling)	9.1	1.4	10.3	6.9	3
<u>Aristida adscendionis</u>	3.9	0.5	5.1	3.2	4
<u>Encelia farinosa</u>	1.3	0	2.6	1.3	5
<u>Sphaeralcea ambigua</u> (seedling)	1.3	0	2.6	1.3	5

Total Cover = 4%

Tortula average cover = 17%

Table IV-42. Rampart Impact vegetation studies (burros present).
18 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Tridens pulchellus</u>	21.6	57.1	6.7	28.5	1
<u>Encelia farinosa</u>	13.4	2.2	39.8	18.5	2
<u>Allionia incarnata</u>	18.1	21.5	1.8	13.8	3
<u>Euphorbia polycarpa</u>	7.8	33.0	0.4	13.8	4
<u>Larrea tridentata</u>	2.6	0.3	37.7	13.5	5
<u>Cassia covesii</u>	13.4	3.2	3.2	6.6	6
<u>Ditaxis neomexicana</u>	6.9	3.7	0	3.5	7
<u>Sphaeralcea ambigua</u>	3.9	0.5	2.5	2.3	8
<u>Aristida adscensionis</u>	0.9	0.1	3.6	1.5	9
<u>Franseria dumosa</u>	2.6	0.4	0.5	1.1	10
<u>Coldenia hispidissima</u>	0.9	0.1	0	0.3	
<u>Dyssodia pentachaeta</u>	0.4	0.1	0	0.2	
<u>Echinocereus engelmannii</u>	1.7	0.2	0	0.6	
<u>Ephedra nevadensis</u>	2.6	0.3	2.1	1.7	
<u>Ephedra torreyana</u>	0.4	0.1	0	0.2	
<u>Eriogonum inflatum</u>	1.7	0.3	0.2	0.8	
<u>Krameria parviflora</u>	1.3	0.1	0.2	0.9	
<u>Opuntia basilaris</u>	0.9	0.1	0.5	0.5	

Total Cover = 14%

Annual Species:

<u>Plantago insularis</u>	58.0	96.0	94.0	82.7	1
<u>Bromus rubens</u>	30.4	2.9	3.9	12.4	2
<u>Lepidium lasiocarpum</u>	5.8	0.5	1.1	2.5	3
<u>Cassia covesii</u>	4.4	0.3	0.5	1.7	4
<u>Encelia farinosa</u>	2.9	0.3	0.5	1.2	5

Total Cover = 19%

Tortula Average Cover = 17%

Table IV-43. Rampart Control vegetation studies (burros not present).
28 May 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	24.7	14.9	56.0	31.9	1
<u>Tridens pulchellus</u>	21.5	64.6	1.8	29.3	2
<u>Larrea tridentata</u>	4.3	1.1	21.0	8.8	3
<u>Franseria dumosa</u>	5.4	2.3	4.9	4.2	4
<u>Ephedra nevadensis</u>	5.4	1.1	5.9	4.1	5
<u>Eriogonum inflatum</u>	6.5	3.4	.4	3.4	6
<u>Cheilanthes parryi</u>	6.5	3.4	0	3.3	7
<u>Opuntia basilaris</u>	5.4	1.1	1.6	2.7	8
<u>Sphaeralcea ambigua</u>	3.2	1.1	1.9	2.1	9
<u>Ditaxis neomexicana</u>	4.3	1.7	0	2.0	10
<u>Opuntia acanthocarpa</u>	2.2	.6	3.1	2.0	10
<u>Allionia incarnata</u>	1.1	1.1	0	.7	
<u>Dyssodia pentachaeta</u>	1.1	0	0	.4	
<u>Echinocereus engelmannii</u>	.5	0	.4	.3	
<u>Euphorbia polycarpa</u>	3.2	2.3	0	1.8	
<u>Fouquieria splendens</u>	2.7	.6	1.6	1.6	
<u>Haplopappus spinulosus</u>	1.1	.6	.2	.6	
<u>Krameria parviflora</u>	.5	0	1.2	.6	
<u>Mammillaria microcarpa</u>	.5	0	0	.2	

Total Cover = 23%

Annual Species:

<u>Bromus rubens</u>	51.9	70.5	45.3	55.9	1
<u>Plantago insularis</u>	25.9	26.9	18.7	23.8	2
<u>Encelia farinosa</u>	13.0	2.6	5.3	7.0	3
Barrel cactus (dead)	1.9	0	17.3	6.4	4
<u>Fouquieria splendens</u>	1.9	0	10.7	4.2	5
<u>Cryptantha</u> (dead)	3.7	0	1.3	1.7	6
<u>Sphaeralcea ambigua</u> (seedling)	1.9	0	1.3	1.1	7

Total Cover = 8%

Tortula Average Cover = 32%

Table IV-44. Rampart Control vegetation studies (burros not present).
6 July 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	25.8	17.6	58.0	33.8	1
<u>Tridens pulchellus</u>	22.5	64.8	1.8	29.7	2
<u>Larrea tridentata</u>	3.9	0.6	19.5	8.0	3
<u>Franseria dumosa</u>	6.7	2.3	4.6	4.5	4
<u>Ephedra nevadensis</u>	5.1	1.1	5.9	4.0	5
<u>Eriogonum inflatum</u>	6.7	3.4	0.9	3.7	6
<u>Cheilanthes parryi</u>	7.3	2.8	0.1	3.4	7
<u>Opuntia basilaris</u>	5.6	1.1	1.0	2.6	8
<u>Ditaxis neomexicana</u>	4.5	1.1	0.1	1.9	9
<u>Euphorbia polycarpa</u>	3.4	2.3	0	1.9	9
<u>Opuntia acanthocarpa</u>	2.2	0.6	2.9	1.9	9
<u>Sphaeralcea ambigua</u>	2.8	1.1	1.8	1.9	9
<u>Fouquieria splendens</u>	1.1	0	1.6	0.9	10
<u>Allionia incarnata</u>	0.6	0.6	0	0.4	
<u>Dyssodia pentachaeta</u>	0	0	0	0	
<u>Echinocereus engelmannii</u>	0.6	0	0.4	0.3	
<u>Haplopappus spinulosus</u>	0.6	0.6	0.2	0.5	
<u>Krameria parviflora</u>	0.6	0	1.2	0.6	
<u>Mammillaria microcarpa</u>	0	0	0	0	

Total Cover = 24%

Annual Species:

<u>Bromus rubens</u>	50.9	70.2	53.2	58.1	1
<u>Plantago insularis</u>	39.6	27.0	21.0	29.2	2
Barrel cactus (dead)	1.9	0	21.0	7.6	3
<u>Encelia farinosa</u>	3.7	2.7	1.6	2.7	4
<u>Cryptantha</u> sp. (dead)	1.9	0	1.6	1.2	5
<u>Fouquieria splendens</u>	1.9	0	1.6	1.2	5

Total Cover = 6%

Tortula average cover - 28%

Table IV-45. Rampart Control vegetation studies (burros not present).
16 September 1977.

Perennial Species:	Rel. Freq. %	Rel. Dens. %	Rel. Cover %	I.V./3	Rank
<u>Encelia farinosa</u>	26.0	16.5	54.0	32.2	1
<u>Tridens pulchellus</u>	22.7	66.2	2.2	30.3	2
<u>Larrea tridentata</u>	4.4	1.0	20.6	8.7	3
<u>Franseria dumosa</u>	6.6	2.3	6.8	5.2	4
<u>Ephedra nevadensis</u>	5.5	1.4	6.3	4.4	5
<u>Cheilanthes sp.</u>	7.2	3.2	0.2	3.5	6
<u>Eriogonum inflatum</u>	5.5	2.7	0.4	2.8	7
<u>Opuntia basilaris</u>	5.5	1.3	1.5	2.8	8
<u>Opuntia acanthocarpa</u>	2.2	0.5	3.1	1.9	9
<u>Euphorbia polycarpa</u>	3.3	2.2	0.1	1.9	10
<u>Ditaxis neomexicana</u>	3.9	1.0	0.1	1.7	
<u>Echinocereus engelmannii</u>	0.6	0.1	0.4	0.4	
<u>Fouquieria splendens</u>	1.7	0.4	1.6	1.2	
<u>Haplopappus spinulosus</u>	1.1	0.5	0.7	0.8	
<u>Krameria parviflora</u>	0.6	0.1	1.0	0.6	
<u>Mammillaria microcarpa</u>	1.1	0.2	0	0.4	
<u>Sphaeralcea ambigua</u>	2.2	0.6	1.2	1.3	

Total Cover = 22%

Annual Species:

Grasses	54.2	56.7	60.9	57.2	1
<u>Plantago insularis</u>	31.3	39.1	21.7	30.7	2
<u>Sphaeralcea ambigua</u> (seedling)	6.3	2.6	4.4	4.4	3
<u>Eriogonum deflexum</u>	2.1	0.4	8.7	3.7	4
<u>Cryptantha sp.</u>	2.1	0.4	1.5	1.3	5
<u>Encelia farinosa</u>	2.1	0.4	1.5	1.3	5
Unknown #1	2.1	0.4	1.5	1.3	5

Annual Cover = 3%

Tortula Average Cover = 26%

Table IV- 46 Comparison of density (D=plants/100m²) and cover (C=cm/100m²) for selected species on burro impacted and control sites at three sampling periods at the Rampart Cave Area.

	May		July		Sept	
	Impact D/C	Control D/C	Impact D/C	Control D/C	Impact D/C	Control D/C
<u>Ephedra nevadensis</u>	2/276	4/134	2/34.4	4/140.8	24/29.2	48/139.2
<u>Franseria dumosa</u>	4/8.4	8/111.6	4/6.4	8/110.4	3.2/6.4	8/151.2
<u>Sphaeralcea ambigua</u>	6/30.8	4/43.6	4/35.6	4/43.6	4.4/34.8	2/26
<u>Haplopappus spinulosus</u>	0/0	2/3.6	0/0	2/4.4	0/0	1.6/16.4
<u>Tridens pulchellus</u>	622/80	226/40	662/113.2	228/43.2	484/94.4	230/48
<u>Allionia incarnata</u>	304/24	4/.4	128/36	2/0	182.4/24.8	0/0
<u>Euphorbia polycarpa</u>	72/32	8/.8	78/12.4	8/0	83.2/5.6	7.6/1.2

Table IV-47. Shinumo area transects: the long-term effects of burro browsing on vegetation. Comparison of original 1965 readings and 1977 re-readings, using NPS ground cover composition survey method. Readings are percent of ground cover.

	401		402		403		404		405	
	'65	'77	'65	'77	'65	'77	'65	'77	'65	'77
NON-PRODUCTIVE:										
Bare soil	15	1	1	-	26	16	13	10	-	1
Erosion pavement	34	25	62	53	1	-	16	-	45	24
Rock	11	17	7	6	20	28	32	26	20	12
Litter	3	-	1	-	16	3	1	7	3	9
VEGETATIVE COVER:										
Annual grass	-	-	-	-	3	-	17	-	4	-
Annual forbs	-	-	-	2	6	-	1	-	6	-
<u>Acacia greggii</u>	-	-	-	-	9	-	-	-	-	-
<u>Agave utahensis</u>	-	-	2	3	-	-	-	-	-	-
<u>Cassia covesii</u>	-	-	-	-	-	-	-	4	-	-
<u>Chrysothamnus nauseosus</u>	-	-	5	7	-	-	-	-	-	-
<u>Coleogyne ramosissima</u>	2	3	17	16	-	-	-	-	-	-
<u>Dyssodia pentachaeta</u>	-	-	-	-	-	5	-	-	-	6
<u>Echinocereus engelmannii</u>	-	-	-	-	-	1	-	-	-	-
<u>E. triglochidiatus</u>	1	2	-	-	-	-	-	-	-	-
<u>Encelia farinosa</u>	-	-	-	-	-	-	10	18	10	12
<u>Ephedra nevadensis</u>	-	-	-	-	-	2	-	-	-	-
<u>E. viridis</u>	5	6	2	2	17	28	9	11	9	9
<u>Erodium cicutarium</u>	-	-	-	-	1	-	-	-	-	-
<u>Gutierrezia sarothrae</u>	-	-	-	1	-	6	-	-	-	-
<u>Opuntia erinacea</u>	13	26	-	-	-	1	-	-	-	-
<u>Porophyllum gracile</u>	-	-	-	-	-	4	-	-	-	-
<u>Sphaeralcea</u>	-	-	-	-	-	-	-	-	-	-
<u>grossulariaefolia</u>	-	-	-	-	1	1	-	-	-	-
<u>Stipa</u> sp.	-	-	-	2	-	-	-	-	-	-
<u>Thamnosma montana</u>	-	-	-	1	-	-	-	-	-	-
<u>Tridens muticus</u>	-	-	-	-	-	1	-	1	-	-
<u>Tridens pulchellus</u>	-	-	-	1	-	-	-	18	-	18
<u>Yucca baccata</u>	2	3	-	-	-	-	-	-	-	-
Unk. perennial forb	-	-	-	-	-	-	-	-	1	-
DEAD COVER:										
<u>Acacia greggii</u>	-	-	-	-	-	3	-	-	-	-
<u>Agave utahensis</u>	-	-	1	2	-	-	-	-	-	-
<u>Coleogyne ramosissima</u>	3	2	2	4	-	-	-	-	-	-
<u>Dyssodia pentachaeta</u>	-	-	-	-	-	1	-	-	-	1
<u>Encelia farinosa</u>	-	-	-	-	-	-	1	3	1	7
<u>Ephedra viridis</u>	-	-	-	-	-	-	-	-	1	1
<u>Opuntia erinacea</u>	6	12	-	-	-	-	-	-	-	-
<u>Tridens pulchellus</u>	-	-	-	-	-	-	-	2	-	-
<u>Yucca baccata</u>	5	3	-	-	-	-	-	-	-	-

Table IV-49.--Seed density (number/m²) on control and impact sites during three sampling periods in three habitat types, Grand Canyon, Arizona.

PINYON-JUNIPER CONTROL	<u>May</u>	<u>July</u>	<u>September</u>
Perennials			
<u>Cowania mexicana</u>	30	10	
<u>Gutierrezia</u> spp.	830	80	
<u>Juniperus osteosperma</u>	270	330	
<u>Mammillaria</u> spp.	260	40	100
<u>Opuntia</u> spp.			60
<u>Oryzopsis hymenoides</u>	130	10	
<u>Phacelia fremonti</u>	40	230	60
Total Perennials	1560	700	230
Annuals			
<u>Cryptantha angustifolia</u>			10
<u>Festuca octoflora</u>	2320	3060	
<u>Plantago insularis</u>			30
Total Annuals	2320	3060	40
Miscellaneous			
Cruciferae ²	20	10	20
Gramineae			220
<u>Ledpidium</u> spp.	180	100	600
<u>Phacelia</u> spp.	90	250	
<u>Sporobolus</u> spp.	10		
Unknown	20	10	70
Total Miscellaneous	320	370	910
PINYON-JUNIPER IMPACT			
Perennials			
<u>Arctostaphylos pungens</u>	50	40	
<u>Atriplex canescens</u>	10		10
<u>Echinocereus</u> spp.		10	
<u>Euphorbia</u> spp.			50
<u>Gutierrezia</u> spp.		30	
<u>Juniperus osteosperma</u>	20		
<u>Mammillaria</u> spp.			60
<u>Opuntia</u> spp.	20	10	
<u>Phacelia fremonti</u>		10	
<u>Sphaeralcea</u> spp.			10
Total Perennials	100	100	130

Table IV-49.--continued

	<u>May</u>	<u>July</u>	<u>September</u>
Annuals			
<u>Festuca octoflora</u>	80	10	
<u>Philostoma auritum</u>	10		
Total Annuals	90	10	0
Miscellaneous			
Cruciferae ²			20
<u>Lepidium</u> spp.	20		1090
<u>Phacelia</u> spp.	170	20	
<u>Sporobolus</u> spp.			10
Unknown	60		40
Total Miscellaneous	250	30	1160
TONTA PLATFORM CONTROL			
Perennials			
<u>Echinocereus</u> spp.	100	800	30
<u>Euphorbia</u> spp. ¹	10	10	
<u>Mentzelia</u> spp.	580	10	500
<u>Phacelia fremontii</u>	830	40	430
Total Perennials	1520	860	960
Annuals			
<u>Amsinkia tessellata</u>			20
<u>Cryptantha angustifolia</u>	70	10	50
<u>Cryptantha pterocarya</u>	80	240	140
<u>Pholistoma auritum</u>	200		40
Total Annuals	350	250	250
Miscellaneous			
<u>Astragalus</u> spp.	500	420	530
Cruciferae ²	10		10
<u>Cryptantha</u> spp.	40		20
<u>Dyssodia</u> spp.	20		10
<u>Erodium</u> spp.	10		
Gramineae	90	30	60
Gramineae ⁴	10		
Leguminosae	50	120	40
<u>Lepidium</u> spp.	30		
<u>Phacelia</u> spp.	10		20
Unknown	170		10
Total Miscellaneous	940	570	710

Table IV-49.--continued

	<u>May</u>	<u>July</u>	<u>September</u>
TONTTO PLATFORM IMPACT			
Perennials			
Compositae 3		20	
<u>Echinocereus spp.</u>	30	240	160
<u>Euphorbia spp.</u>	400	130	40
<u>Mammillaria spp.</u>	480	120	10
<u>Opuntia spp.</u>	50	20	
<u>Phacelia fremontii</u>	50	80	
<u>Sphaeralcea spp.</u>	10		
Total Perennials	1020	610	210
Annuals			
<u>Cryptantha pterocarya</u>			20
<u>Festuca octoflora</u>		10	
Total Annuals	0	10	20
Miscellaneous			
<u>Astragalus spp.</u>	3330	2410	1300
Cruciferae 2	50	70	
<u>Dyssodia spp.</u>			10
<u>Erodium spp.</u>	240	180	100
Gramineae	50	20	
Gramineae 4	4150	1730	1180
Unknown	20		
Total Miscellaneous	7840	4410	2590
RAMPART CONTROL			
Perennials			
Compositae 3	240	160	280
<u>Cryptantha angustifolia</u>		90	
<u>Euphorbia spp.</u> 1	30		
<u>Ferocactus spp.</u>	10		1190
<u>Haplopappus acredenius</u>	10		
<u>Larrea tridentata</u>		60	
<u>Mammillaria spp.</u>	1120	2110	1640
<u>Phacelia fremontii</u>	1580	5870	3650
<u>Sphaeralcea spp.</u>		30	
<u>Tridens pulchellus</u>	20	180	20
Total Perennials	3010	8500	6780
Annuals			
<u>Festuca octoflora</u>	980	1560	510
<u>Pectocarya spp.</u>		20	
<u>Pholistoma auritum</u>	20		20
<u>Plantago insularis</u>	180	270	240
Total Annuals	1180	1850	770

Table IV-49.--continued

	<u>May</u>	<u>July</u>	<u>September</u>
Miscellaneous			
<u>Boerhavia</u> spp.	20		
<u>Cruciferae</u> ²	80	170	20
<u>Cryptantha</u> spp.		10	40
<u>Ditaxis neomexicana</u>		90	100
<u>Dyssodia</u> spp.	190	600	530
<u>Gramineae</u>	40	80	
<u>Gramineae</u> ⁴	90	320	30
<u>Lepidium</u> spp.		10	
<u>Phacelia</u> spp.	10	30	20
Unknown	<u>2300</u>	<u>2030</u>	<u>1070</u>
Total Miscellaneous	2730	3340	1810
 RAMPART IMPACT			
Perennials			
<u>Allionia</u> spp.	40	10	
<u>Cassia covesii</u>	10	50	20
<u>Compositae</u> ³	240	340	300
<u>Euphorbia</u> spp. ¹	30	10	20
<u>Larrea tridentata</u>		30	
<u>Mammillaria</u> spp.	80	20	120
<u>Phacelia fremontii</u>	80	20	50
<u>Sphaeralcea</u> spp.	30	60	60
<u>Tridens pulchellus</u>	<u>120</u>	<u>70</u>	
Total Perennials	630	610	570
 Annuals			
<u>Cryptantha pterocarya</u>	10		
<u>Festuca octoflora</u>	30		
<u>Plantago insularis</u>	<u>1440</u>	<u>3180</u>	<u>1390</u>
Total Annuals	1480	3180	1390
 Miscellaneous			
<u>Astragalus</u> spp.			10
<u>Cruciferae</u> ²	20	50	20
<u>Dyssodia</u> spp.	60	60	
<u>Gramineae</u>		50	
<u>Gramineae</u> ⁴	10	30	
<u>Lepidium</u> spp.	50	20	
<u>Phacelia</u> spp.		10	
Unknown	<u>120</u>	<u>10</u>	
Total Miscellaneous	260	230	30

-
1. Euphorbia spp. = Euphorbia fendleri or E. polycarpa.
 2. Cruciferae = Arabis spp., Lepidium lasiocarpum or Lesquerella intermedia.
 3. Compositae = Encelia spp. or Viguiera spp.
 4. Gramineae = Bromus rubens, Hilaria rigida or Sitanion hystrix.

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CHAPTER V

INVESTIGATIONS ON SOIL MOISTURE, SOIL COMPACTION AND TRAIL DEFLATION
IN THREE HABITAT TYPES, GRAND CANYON, ARIZONA

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Introduction

Grazing pressures have been shown to influence soil properties, including soil moisture (Linnartz et al. 1966), soil compaction (Fuller 1958, Linnartz et al. 1966) and soil loss (trail deflation) as a result of trail formation (Earth Environmental Associates 1974). Consequently, changes in these properties influence associated vegetation.

Linnartz et al. (1966) indicated that heavy grazing adversely affected several important watershed properties of soils. They suggested that because of soil compaction caused by grazing herbivores, a substantial proportion of moisture might be lost as runoff even if the soil moisture content was low. On heavily grazed areas, runoff surpassed that of ungrazed areas by about 50 percent.

Fuller (1958) found that compacted soils affected vegetation by reducing seed germination rates, root aeration, root feeding area, and the amount of water available to plants. Foin et al. (1977) found that trails were more likely to be formed in areas of dry soil and sparse vegetation rather than areas with wet soil and dense vegetation. They indicated that the rate of use of trails is directly proportional to trail width, which is dependent on the fragility of vegetation and the nature of soils.

The purpose of the study was to determine the effects of feral burros on soil characteristics in three different habitats within the Grand

Canyon. Soil moisture, soil compaction, and trail deflation were analyzed and compared between areas where burros were present and absent.

Methods and Materials

Soil Moisture

During each sampling period, soil samples used in determining soil moisture were taken with a hand trowel at two-meter intervals along a 50 m baseline at each study site. Soil was placed in seamless cans, sealed, and returned to the laboratory.

Moisture content was determined by the gravimetric method (Brady 1972). Tape was removed from cans and samples were weighed to the nearest 0.1 gram. The cans were uncovered, and samples were placed in a drying oven for 24 hours at 100°C, recovered and reweighed. Moisture loss was calculated as percent of weight of a given sample.

Soil Compaction

Soil compaction was measured with a Soiltest, Inc., pocket penetrometer CL-700. Using this instrument, a calibrated spring is compressed until sufficient force is exerted to force a blunt rod affixed to the spring into the soil a standard distance. The amount the spring is compressed is proportional to the degree of soil compaction (measured in kilograms per centimeter²). A total of 500 readings were taken on bare soil at each study site during all sample periods. One hundred points, at 0.5 m (approximate) intervals, were sampled along each of five 50 m vegetation transects at each site. For each study site the mean, standard deviation, and standard error of the mean were calculated for each sampling period. Data were analyzed using a Student's t test (Sokal and Rohlf 1969).

Trail Deflation

We quantified the volume of soil lost (trail deflation) within trail systems used by feral burros and native ungulates on each of the Pinyon-Juniper, Tonto Platform and Rampart Cave sites. A 50 meter² plot was established adjacent to the fifth vegetation line transect at each site. Within each sample plot, all visible trails were mapped and measured linearly in meters. In addition, the depth at the middle of the trail and trail width were measured at randomly selected points within each sample plot. From these data, mean values of trail depth and width were calculated. Total linear meters of trail, mean trail width and depth were used to estimate the meters³ of soil lost, or trail deflation, within each plot. This computation slightly overestimates the actual trail deflation on each plot.

Results

Soil Moisture

Due to sporadic rainfall both prior to and during selected sampling periods, the moisture content of soils from the study sites varied as a function of rainfall and not as a function of the impact of feral burros. Therefore, the data gathered on this soil parameter were rendered inconclusive.

Soil Compaction

Comparisons of soil compaction demonstrated that compaction was greater on the impact areas for all three sampling periods at the Tonto Platform and Rampart Cave Study sites (Table V-1). During the July sampling period, the same relationship was observed on the Pinyon-Juniper areas; however, there were no significant differences during the May and September sampling periods in this habitat type (Table V-1).

Trail depth and trail width varied little between the four impact plots (Table V-2). The average depth and width of the burro trails we measured was about 3 cm and 35 cm respectively.

Trail Deflation

Total trail deflation, measured as cubic meters of soil lost per hectare, was greatest on the original Pinyon-Juniper study site. This is not surprising as it has been established that this area has a history of intensive use by domestic livestock, as well as by the feral burro (see CHAPTER III). The Rampart Cave study area also showed extensive trail deflation. The Tonto Platform site and the new Pinyon-Juniper site had the least amount of trail deflation. It is important to note that trail deflation is influenced by the slope of the terrain and the intensity of use. With the exception of the original Pinyon-Juniper site where domestic livestock were historically grazed, there is a linear relationship between slope and the total length of trail systems. The new Pinyon-Juniper area is essentially level and has the fewest meters of trail, while the Tonto Platform, intermediate in trail length, has a slope of 5 to 8 degrees and the Rampart Cave site, with more meters of trail than any of the other study sites, also has the greatest slope at 10 to 12 degrees.

Discussion

Soil Compaction

Our study has shown that the presence of burros on the Tonto Platform and Rampart Cave study sites has a significant effect on increasing soil compaction. On the Tonto Platform area, the compaction may have been accentuated through the erosion of desert pavement soils by the presence of the feral burros. Desert pavement, consisting of gravel and small stones

and almost devoid of fine material, was observed on the Tonto control. Dregne (1968) found that desert pavement forms a rather firm crust capable of bearing some weight, but rarely strong enough to withstand the weight of even a man. He suggested that this layer serves to break the force of raindrops striking the soil, thereby reducing soil compaction.

Feral burro activity in the Pinyon-Juniper habitat type is infrequent (see CHAPTER II). Infrequent use is not sufficient to cause sustained differences in soil compaction on the Pinyon-Juniper sites.

Additionally, an increase in soil compaction may result in a decrease in perennial vegetation. Annual plants were not considered because Bromus rubens, an exotic weedy species, occurred in the areas and behaves as an invader species; therefore, it is found frequently in greater numbers in disturbed rather than undisturbed habitats (see CHAPTER V) and would have biased our data. A decrease in perennial vegetation appears to have occurred at the impact sites of the Tonto Platform and Rampart Cave. According to Fuller (1958), increased soil compaction leads to a decrease in vegetation by reducing the amount of root aeration, available water for plants, seed germination, emergence of seedlings, and root feeding area. However, in the September sampling of the Pinyon-Juniper areas, the perennial cover was greater on the control site where soil compaction was higher than on the impact site.

Trail Deflation

Measurable alteration of existing natural communities results from trail deflation by feral burros in Grand Canyon. Moreover, erosion is accelerated by the development of deflated trail systems.

Foin et al. (1977) found that hiking trails traversing difficult terrain were most likely to follow the least difficult route. In habitats

at Grand Canyon, we found that as slope increased, the total length of trail systems increased. Feral burros then follow the least difficult route by switching back on steeper slopes (e.g., Rampart Cave) more often than on gentler grades (e.g., Tonto Platform).

Trail deflation measurements showed that soil loss was greatest on the original Pinyon-Juniper site. This site was utilized by domestic livestock as well as feral burros. The data indicate that soil loss continues for at least several years following the removal of non-native ungulates. In Bandelier National Monument burro trails were shown to be highly susceptible to erosion (U.S.D.I. 1976). Almost 36 tons of soil per acre per year have been lost at Bandelier, "a rate far too high to be accounted for by a gradual decrease in precipitation alone" (Earth Environmental Associates 1974). The high trail deflation value at Rampart Cave was probably a function of the total length of the trail system. However, we expect that soil loss here has been accentuated by slope. Since runoff of precipitation increases on grazed ranges (Linnartz et al. 1966) and on steeper slopes, there is undoubtedly a greater propensity for soil erosion.

On the Tonto Platform, we encountered trails that may have been influenced by hikers. However, data from several recent studies (Tivy 1974, Foil et al. 1977) indicate that hikers generally confine their activities to a single well-defined trail. Furthermore, our sample plot was located 100 to 125 meters north of the main Tonto Trail as indicated on the Geological Survey topographic map for the quadrangle. From these observations, we concluded that trail deflation on the Tonto Platform study site is a result of the activities of feral burros.

In summary, the data indicate that the feral burros in the Grand Canyon have an adverse effect on soil characteristics. Feral burro activities have been responsible for increasing soil compaction and accelerating soil loss. Feral burros established an extensive trail system in the areas which they inhabited. In general, there was a direct relationship between the slope of the site and total length of trails, that is, burros tended to follow the least difficult route by switching back on steeper slopes more often than on gentler grades. Moreover, trail deflation (soil loss) was directly related to feral burro activity and erosion was intensified in areas with a steep slope and where desert pavement soils or Tortula was removed.

Table V-1.--Soil compaction (kilograms/centimeter²) in three habitat types, Grand Canyon National Park, Arizona.

	Tonto		Pinyon-Juniper		Rampart	
	Impact	Control	Impact	Control	Impact	Control
May 1977 ¹						
Mean	1.11	.25	~~2.00~~ 0.12	~~1.00~~ .05	1.74	1.62
Std. Dev. ²	.74	.32	~~26.00~~ .21	~~18.61~~ .13	.83	.76
Std. Error ³	.33	.014	~~1.00~~ .01	~~0.32~~ .01	.037	.034
Range	2.5-4.5	0-1.5	0-1.0	0-1.0	.25-5.0	.25-3.75
t Value	10.79*		-.53		13.06*	
July 1977						
Mean	2.18	.56	~~2.00~~ .32	~~1.00~~ .10	2.15	1.33
Std. Dev.	1.04	.53	~~2.00~~ .51	~~1.00~~ .23	1.05	.67
Std. Error	.047	.024	~~1.00~~ .02	~~0.32~~ .01	.047	.030
Range	.50-4.75	0-2.75	0-4.25	0-1.75	.25-5.0	.25-3.75
t Value	15.09*		4.40*		7.49*	
September 1977 ⁴						
Mean	2.17	.75	.31	.35	2.98	2.34
Std. Dev.	.97	.50	.30	.41	1.11	1.02
Std. Error	.043	.022	.013	.018	.050	.046
Range	.25-5.0	0-3.5	0-1.75	0-2.25	.50-5.0	.25-5.0
t Value	13.96*		-.36		2.65*	

* Significant $P < .01$

1. Original Pinyon-Juniper study site locations: Control, Specter Terrace; Impact, Tapeats Amphitheater.

2. Std. Dev. = standard deviation ($n - 1$)

3. Std. Error = standard error

4. New Pinyon-Juniper study site locations: Control, Masonic Temple; Impact, Darwin Plateau.

Table V-2 .--Physical characteristics of burro trails in three habitat types, Grand Canyon National Park, Arizona.

	<u>Tonto Platform</u>	<u>Original Pinyon-Juniper</u>	<u>New Pinyon-Juniper</u>	<u>Rampart Cave</u>
Total Length (meters/.25 hectare)	108.70	296.25	153.00	308.30
Mean Depth (meters)	0.02 (n=50)	0.04 (n=50)	0.01 (n=49)	0.03 (n=37)
Mean Width (meters)	0.42 (n=50)	0.34 (n=50)	0.30 (n=49)	0.38 (n=37)
Existing Trail Deflation (cubic meters/hectare)	3.65	16.12	1.84	14.06

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CHAPTER VI

INVESTIGATIONS ON SMALL MAMMAL COMMUNITIES IN THREE HABITAT TYPES, GRAND CANYON, ARIZONA

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Feral burros alter communities in numerous ways, as documented by various research programs within the National Park System (McKnight 1958, Koehler 1974, Carothers et al. 1976, Norment and Douglas 1977). Competition between feral burros and native ungulates has been investigated by several authors (McMichael 1964, St. John 1965, Hansen and Martin 1973) but burro impact on small mammals remains largely unknown. Only two previous studies known to us have dealt with the effects of feral burros on rodent populations. Carothers et al. (1976) and Norment and Douglas (1977) found that burros caused decreases in both rodent densities and rodent species diversity. Their studies were undertaken in the Mohave desertscrub vegetative community of the Inner Gorge of Grand Canyon and the creosote bush-scrub community of Death Valley, respectively.

The present study was designed to investigate the effects of feral asses on rodent populations in three different habitat types in Grand Canyon National Park. Those habitat types investigated were the pinyon-juniper woodland, the blackbrush community of the Tonto Platform, and the Mohave desertscrub of the lower end of the Canyon.

Methods

Small mammal populations were sampled by snap-trapping with Museum Specials and rat traps. Between 895 and 1100 traps were set at each study site

during each sampling period (Table VI-1). Poor weather limited the number of traps set on the original Pinyon-Juniper impact site (Tapeats Amphitheater) in May. Lines of approximately 200 traps at seven-meter intervals were set. In setting traps, an effort was made to stay within the same vegetation type as occurred in the vegetation transect at that particular study site. However, topography sometimes forced us to set traps in a different vegetation type. When this occurred, trapping effort in each vegetation type was equivalent on impact and control areas.

For tabulation of data, absolute numbers of a rodent species trapped were divided by the total number of traps set, giving the number of one species collected per 100 trap-nights or the percent trapping success for that species. Relative abundance (species composition) was determined by dividing the number of individuals of a species trapped by the total number of individuals of all species trapped at each site during each sampling period. The mean relative abundance value for each species over the entire study period was calculated by averaging the relative abundance values for each of three sampling periods. Family composition is a summation of mean relative abundances of all species of a family. Family composition data from Tonto Platform and Rampart Cave study areas were subjected to a χ^2 analysis (Sokal and Rohlf 1969). Pinyon-Juniper study areas were very similar with respect to family composition and therefore were not analyzed statistically.

Results

Pinyon-Juniper Sites

The pinyon mouse (Peromyscus truei), a form characteristic of pinyon-juniper woodlands in the Southwest (Hall and Kelson 1959, Douglas 1969), was the most abundant rodent species on all pinyon-juniper sites. It was somewhat more abundant on impact than on control sites (Table VI-2). No apparent

difference in overall abundance of rodents existed between impact and control sites. There was a weak trend indicating that woodrats (Neotoma spp.) were more common on the control sites, but the difference is probably unimportant.

Pocket mice (Perognathus spp.) were absent from all pinyon-juniper sites during the study with the exception of a single juvenile rock pocket mouse (Perognathus intermedius) taken on the impact site in September.

Alpha species diversity totaled nine species on impact sites and five on controls. Differences resulted from the presence of one individual each of the rock pocket mouse, deer mouse (Peromyscus maniculatus), and Stephens' woodrat (Neotoma stephensi), and three cactus mice (Peromyscus eremicus) on the impact sites.

Tonto Platform Sites

Cactus mouse relative abundance was greater on the impact than on the control site during every trapping period (Table VI-2). Differences in relative abundance between canyon mice (Peromyscus crinitus) and cactus mice were of greater magnitude on the impact site. Cactus mice accounted for 29% of the rodent community on the control site but made up 75% on the impact site. Their greater abundance appeared to occur at the expense of the canyon mouse, which accounted for 32% of the rodent fauna on the control area but only 4% on the impact site (Table VI-2, Figure VI-1).

No differences in relative abundance of desert woodrats (Neotoma lepida) or white-throated woodrats (Neotoma albigula) were evident between impact and control sites. Similarly there were no impact-related differences apparent in relative abundance of pocket mice. The rock pocket mouse (a species occurring only on the south side of the Colorado River, Hoffmeister 1971) was simply a more abundant mouse than the long-tailed pocket mouse (Perognathus formosus, which is restricted to the north side of the river) in the habitats we sampled-- independent of the presence or absence of burros (Figure VI-2). Relative

abundance of all small mammals was greater on impact than on control throughout the study (Table VI-2).

Alpha species diversity was six on the impact site and seven on the control site. The difference is probably inconsequential in that it results from the capture of one deer mouse.

Rampart Cave Sites

Relative abundance of canyon mice was slightly higher on the Rampart Cave impact than on the control site. Cactus mice were completely absent from both sites during all sampling periods with the exception of the September sample on the impact site.

Two species of pocket mice were the most abundant rodents on both sites. The lower relative abundance of long-tailed pocket mice on the impact site may be due to measurable differences in normal population densities between long-tailed and rock pocket mice in similar habitats, rather than a result of the presence of feral burros. Recall that on the Tonto Platform desertscrub, rock pocket mice occurred on the impact site in greater numbers than long-tailed pocket mice did on the control site (Figure VI-2).

There were no large differences in relative abundance of woodrats between the two sites. However, two species were found on the control site while only one was found on the impact site.

Very little difference existed between the sites in numbers of rodents caught. Six rodent species were taken on the impact site and four species were taken on the control. Merriam's kangaroo rats (Dipodomys merriami) were taken in a sandy flat covered with creosotebush (Larrea tridentata) on the impact site. A similar area was sampled on the control side yet no kangaroo rats were collected even though we have previously captured them on the south side of the river near Grapevine Wash, 6.5 airline km to the west. No cactus mice or white-tailed antelope squirrels (Ammospermophilus leucurus) were caught

on the control site and no white-throated woodrats were caught on the impact site.

Three families of rodents occurred on Pinyon-Juniper study sites where no burro-influenced differences in familial composition were apparent. Cricetids (native rats and mice) was the predominant family, comprising 95% of the rodent community on the control sites and 96% on the impact sites. The families Heteromyidae (pocket mice and kangaroo rats) and Sciuridae (chipmunks and squirrels) were of minor importance. Heteromyids were represented by one individual in 5468 trap-nights in pinyon-juniper woodland while sciurids were represented by four cliff chipmunks (Eutamias dorsalis) on control and two least chipmunks (Eutamias minimus) on impact sites.

Two families, Heteromyidae and Cricetidae, accounted for 99% of the rodent faunas at Tonto Platform and Rampart Cave areas. On both areas, the proportion of cricetids was greater on the impact than on the control site, while the proportion of heteromyids was lower on impact than on control sites (Table VI-3). Chi-squared (χ^2) analyses of these data revealed these differences in familial composition to be significant for both pairs of sites.

Discussion

From the results presented above, it is clear that feral burros affect the rodent populations of different habitats in different ways. Carothers et al. (1976) found a decrease in numbers of rodents on burro-impacted areas in the desertscrub-riparian habitat of the Inner Gorge of the Grand Canyon. In our studies in the pinyon-juniper community of the canyon, burro presence had little or no observable effect on the rodent fauna. However, burro use is infrequent in pinyon-juniper woodland communities of the Park (see CHAPTER II). Burro impact showed up most dramatically in the Tonto Platform desertscrub where

total numbers of rodents were much higher on impact areas (cf. Carothers et al. 1976) and where cactus mice and canyon mice acted as indicators of environmental quality. Ecologically, the cactus mouse is a generalist (Ruffner and Tomko 1976), and as such, is probably better adapted to utilizing disturbed areas than other more specialized rodents such as canyon mice.

In the desertscrub habitats of the Tonto Platform and Rampart Cave areas, the effect of feral burro impact is revealed in the imbalance in rodent family composition. Cricetids increase in importance as the heteromyids decrease. With this in mind, a look at the seed data (see CHAPTER IV) is instructive.

Heteromyids rely heavily upon seeds for a large portion of their diets (Reichman 1975). The near absence of heteromyids on the Pinyon-Juniper woodland sites is probably due in large part to the paucity of seeds available on soils in that habitat (see CHAPTER IV). Near Rampart Cave, burros apparently caused a decrease in the amount of seeds available to the seed-dependent Heteromyidae. At that study area, more seeds and more heteromyids were found on the control site than on the impact site. In contrast, on the Tonto Platform, heteromyids are present in higher absolute numbers on the impact site than on the control (even though they decrease in percent of family composition on the impact site). However, burro impact on the Tonto seems to have increased rather than decreased the number of seeds found there; the majority (84%) of seeds found on the impact site were of Astragalus and probably Bromus. On both Rampart Cave and Tonto Platform study areas, results are complicated by apparently normal differences in population levels between Perognathus formosus and Perognathus intermedius.

Several authors (Vorhies and Taylor 1933, 1940; Taylor, Vorhies, and Lister 1935; Phillips 1936; Smith 1940a) have found that moderate amounts of livestock grazing cause an increase in the abundance of small mammals, while in areas that have been heavily overgrazed, the number of small mammals decrease

(Phillips 1936, Smith 1940a). These are exactly the trends resulting from burro infestation that have occurred in Grand Canyon National Park. In the pinyon-juniper woodland where impact is infrequent, and at Rampart Cave where burro use is light, rodent abundance on impact sites approximates that of control sites. On the Tonto Platform, where the effects of grazing are greater, small mammal numbers are much higher on impact than control sites. Within the riparian community of the Inner Gorge, where burro damage is most severe, numbers of small mammals are reduced (Carothers et al. 1976). Feral burros, then, upset the normal population levels of rodents found in Grand Canyon communities by grazing-induced alterations of plant community structure (see CHAPTER IV).

In summary, burro impact affected rodent populations of different vegetative communities differently. Burro presence had the least effect on rodents of the pinyon-juniper community, where overall abundance of all rodent species was slightly higher on control and alpha species diversity was higher in impact. On Tonto Platform desertscrub, burro impact resulted in a large increase in the abundance of cactus mice and a decrease in the abundance of canyon mice. Rock pocket mice were more abundant than long-tailed pocket mice on both Tonto Platform and Rampart Cave study areas, apparently independent of burro presence. Burro presence adversely affected familial composition on Tonto and Rampart study sites by causing an increase in the proportion of cricetids with a corresponding decrease in the proportion of heteromyids. Feral burros alter plant communities and consequently induce changes in rodent communities at Grand Canyon.

Table VI-1.--Numbers of trap-nights set on three pairs of study sites.

	Pinyon-Juniper		Tonto Platform		Rampart Cave	
	<u>Impact</u>	<u>Control</u>	<u>Impact</u>	<u>Control</u>	<u>Impact</u>	<u>Control</u>
May	648	900	910	895	900	900
July	1010	1010	1010	1010	1025	1100
September	950	950	972	972	972	972

Table VI-2.--Numbers of rodents collected per 100 trap-nights and relative abundance of rodents in three habitat types, Grand Canyon National Park, Arizona (total number of trap-nights = 17,106).

PINYON-JUNIPER WOODLAND
IMPACT

<u>Species</u>	Number per 100 Trap-nights			Relative Abundance (percent)			
	<u>May</u>	<u>July</u>	<u>Sept.</u>	<u>May</u>	<u>July</u>	<u>Sept.</u>	<u>X</u>
<u>Eutamias minimus</u>	0.00	0.20	0.00	00.0	05.0	00.0	01.7
<u>Perognathus intermedius</u>	0.00	0.00	0.10	00.0	00.0	08.0	02.7
<u>Peromyscus crinitus</u>	0.15	0.00	0.32	08.0	00.0	23.0	10.3
<u>Peromyscus eremicus</u>	0.00	0.00	0.32	00.0	00.0	23.0	07.7
<u>Peromyscus maniculatus</u>	0.00	0.10	0.10	00.0	03.0	08.0	03.7
<u>Peromyscus truei</u>	1.54	1.78	0.42	83.0	49.0	31.0	54.3
<u>Peromyscus boylei</u>	0.00	1.29	0.00	00.0	35.0	00.0	11.7
<u>Peromyscus spp.*</u>	0.00	0.10	0.00	00.0	03.0	00.0	01.0
<u>Neotoma lepida</u>	0.15	0.20	0.00	08.0	06.0	00.0	04.7
<u>Neotoma stephensi</u>	0.00	0.00	0.11	00.0	00.0	08.0	02.7
TOTAL	1.84	3.67	1.37	99.0	101.0	101.0	100.5

Average absolute number of rodents caught = 20.7

CONTROL

<u>Eutamias dorsalis</u>	0.00	0.30	0.10	00.0	10.0	03.0	04.3
<u>Peromyscus crinitus</u>	0.78	0.40	0.32	30.0	14.0	09.0	16.7
<u>Peromyscus truei</u>	1.44	0.59	0.63	57.0	21.0	18.0	32.0
<u>Peromyscus boylei</u>	0.00	0.79	1.79	00.0	28.0	52.0	26.7
<u>Peromyscus spp.*</u>	0.00	0.50	0.00	00.0	17.0	00.0	05.7
<u>Neotoma lepida</u>	0.33	0.30	0.63	13.0	10.0	18.0	13.7
TOTAL	2.55	2.88	3.47	100.0	100.0	100.0	99.1

Average absolute number of rodents caught = 28.7

Table VI-2.--continued

TONTO PLATFORM DESERTSCRUB
IMPACT

<u>Species</u>	Number per 100 Trap-nights			Relative Abundance (percent)			
	<u>May</u>	<u>July</u>	<u>Sept.</u>	<u>May</u>	<u>July</u>	<u>Sept.</u>	<u>X</u>
<u>Ammospermophilus leucurus</u>	0.00	0.00	0.10	00.0	00.0	01.0	00.3
<u>Perognathus intermedius</u>	0.22	2.77	1.75	04.0	21.0	22.0	15.7
<u>Peromyscus crinitus</u>	0.55	0.10	0.00	10.0	01.0	00.0	03.7
<u>Peromyscus eremicus</u>	4.18	9.40	6.17	76.0	73.0	76.0	75.0
<u>Neotoma albigula</u>	0.44	0.40	0.10	08.0	03.0	01.0	04.0
<u>Neotoma lepida</u>	0.11	0.30	0.00	02.0	02.0	00.0	01.3
TOTAL	5.50	12.97	8.12	100.0	100.0	100.0	100.0

Average absolute number of rodents caught = 86.7

CONTROL

<u>Ammospermophilus leucurus</u>	0.00	0.10	0.00	00.0	02.0	00.0	00.7
<u>Perognathus formosus</u>	0.11	1.68	1.75	03.0	37.0	52.0	30.7
<u>Peromyscus crinitus</u>	0.89	2.18	0.72	26.0	48.0	21.0	31.7
<u>Peromyscus eremicus</u>	2.01	0.20	0.82	58.0	04.0	24.0	28.6
<u>Peromyscus maniculatus</u>	0.00	0.00	0.10	00.0	00.0	03.0	01.0
<u>Neotoma albigula</u>	0.34	0.00	0.00	10.0	00.0	00.0	03.3
<u>Neotoma lepida</u>	0.11	0.40	0.00	03.0	09.0	00.0	04.0
TOTAL	3.46	4.56	3.39	100.0	100.0	100.0	100.0

Average absolute number of rodents caught = 36.7

Table VI-2.--continued

RAMPART CAVE MOHAVE DESERT SCRUB
IMPACT

<u>Species</u>	Number per 100 Trap-nights			Relative Abundance (percent)			
	<u>May</u>	<u>July</u>	<u>Sept.</u>	<u>May</u>	<u>July</u>	<u>Sept.</u>	<u>X</u>
<u>Ammospermophilus leucurus</u>	0.00	0.10	0.00	00.0	01.0	00.0	00.3
<u>Perognathus formosus</u>	2.44	2.83	2.68	54.0	41.0	23.0	39.0
<u>Dipodomys merriami</u>	0.11	1.17	0.62	02.0	17.0	05.0	08.0
<u>Peromyscus crinitus</u>	0.66	2.24	5.86	15.0	32.0	51.0	32.7
<u>Peromyscus eremicus</u>	0.00	0.00	0.72	00.0	00.0	06.0	02.0
<u>Peromyscus spp.*</u>	0.11	0.00	0.51	02.0	00.0	05.0	02.3
<u>Neotoma lepida</u>	1.22	0.58	1.03	27.0	08.0	09.0	14.7
TOTAL	4.54	6.92	11.42	100.0	99.0	99.0	99.3

Average absolute number of rodents caught = 74.3

CONTROL

<u>Perognathus intermedius</u>	7.78	6.54	2.98	79.0	77.0	62.0	73.0
<u>Peromyscus crinitus</u>	1.44	1.09	1.44	15.0	13.0	30.0	19.0
<u>Neotoma albigula</u>	0.11	0.00	0.00	01.0	00.0	00.0	00.3
<u>Neotoma lepida</u>	0.44	0.82	0.42	05.0	10.0	08.0	08.0
TOTAL	9.77	8.45	4.84	100.0	100.0	100.0	100.0

Average absolute number of rodents caught = 76.0

*Subadults mutilated beyond identification by ants

Table VI-3.--Familial composition of the mammalofauna occurring on two pairs of study sites. Sample sizes in parentheses.

TONTO PLATFORM

<u>Family</u>	<u>Control Site (N=110)</u>	<u>Impact Site (N=260)</u>
Sciuridae	00.7%	00.3%
Heteromyidae	30.7%	15.7%
Cricetidae	68.6%	84.0%

$$x^2 = 6.25; p < .02$$

RAMPART CAVE

<u>Family</u>	<u>Control Site (N=223)</u>	<u>Impact Site (N=228)</u>
Sciuridae	00.0%	00.3%
Heteromyidae	73.0%	47.0%
Cricetidae	27.3%	51.7%

$$x^2 = 14.19; p < .001$$

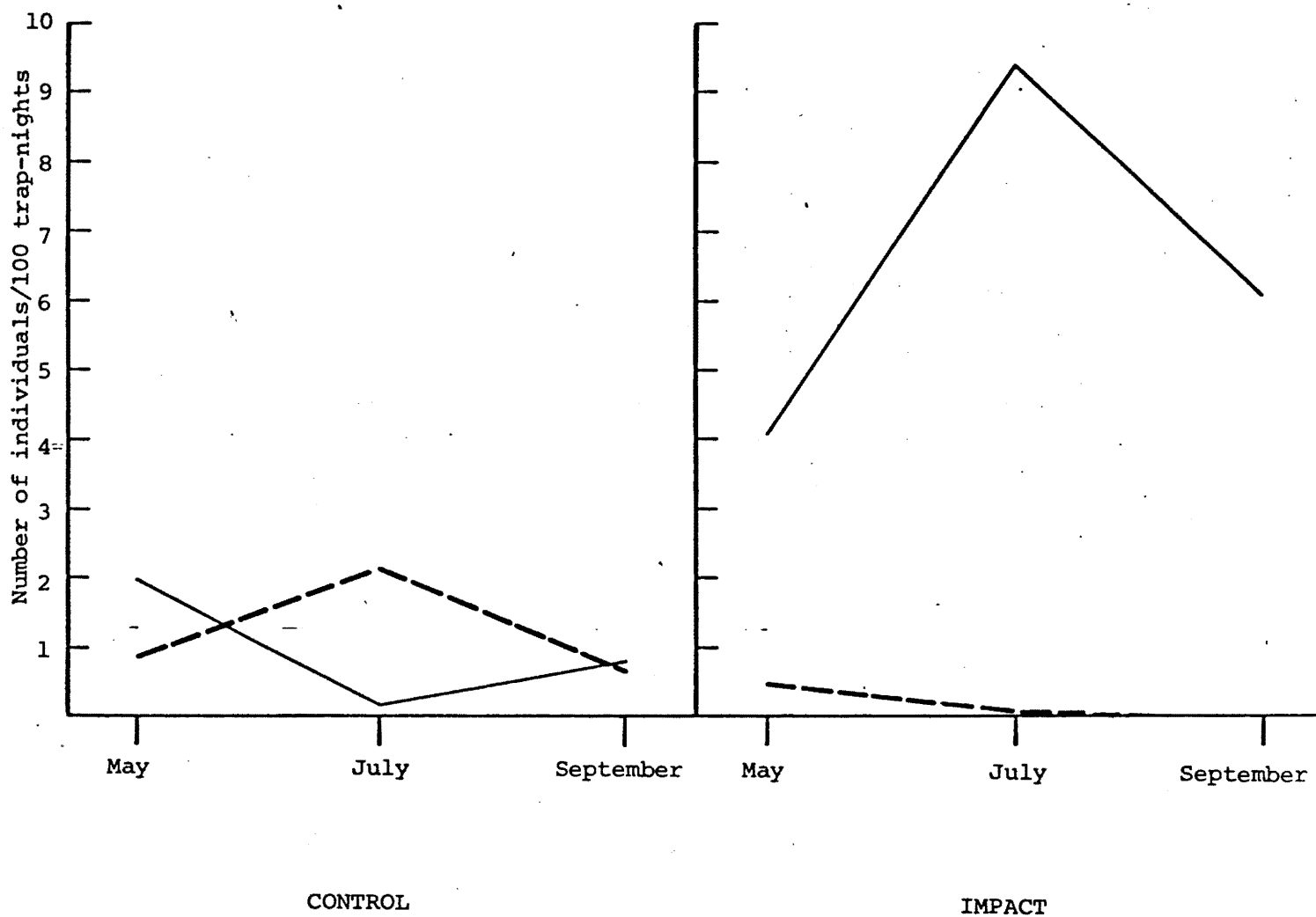


Figure VI-1.--Numbers of *Peromyscus eremicus* (—) and *Peromyscus crinitus* (---) collected per 100 trap-nights on the Tonto Platform.

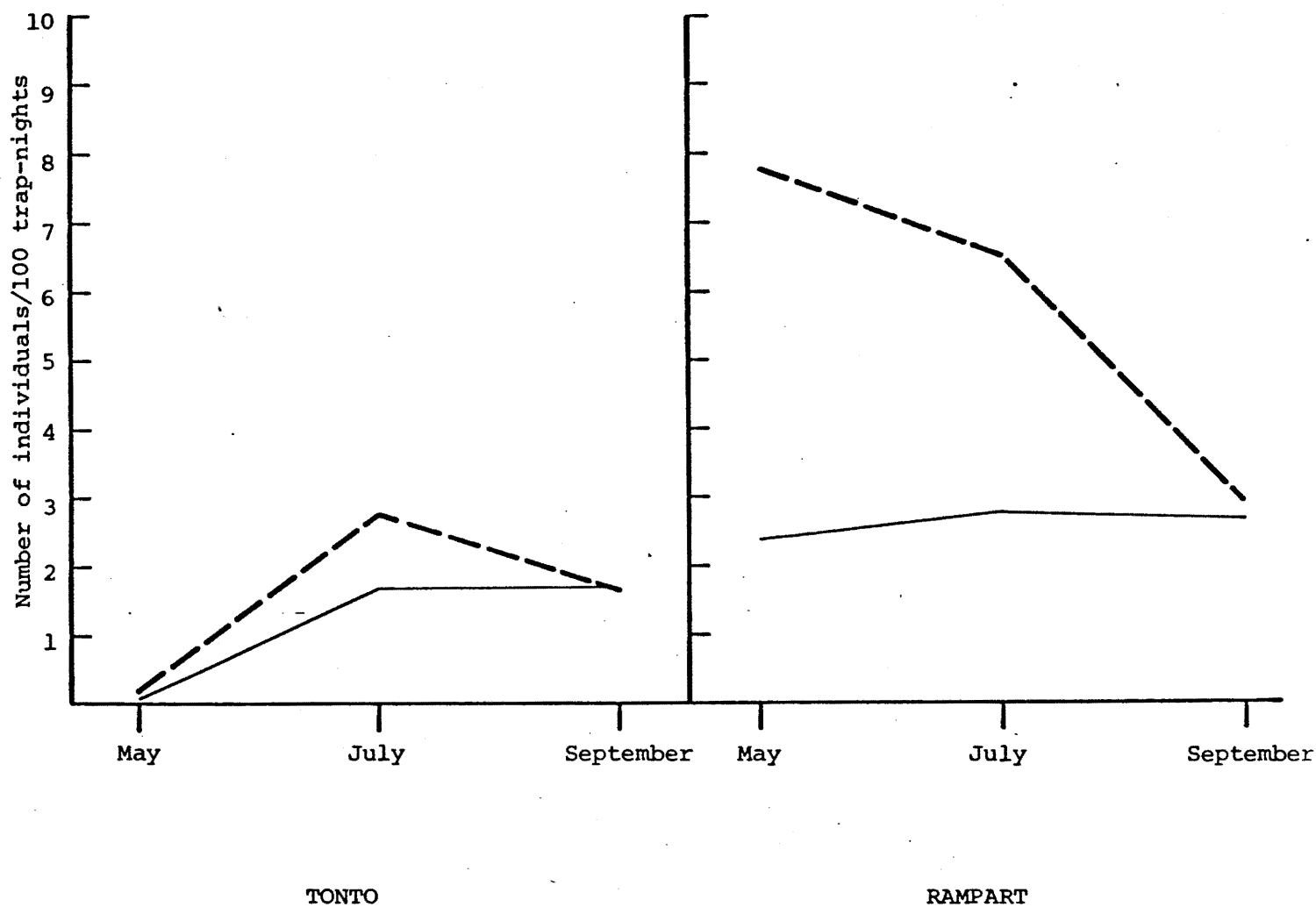


Figure VI-2.--Numbers of pocket mice collected per 100 trap-nights on the Tonto Platform and Rampart Cave study sites. On the Tonto area, Perognathus formosus (————) occurred on the control site and Perognathus intermedius (— — —) on the impact site. At Rampart Cave sites, the reverse situation was true.

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CHAPTER VII

DATA SYNTHESIS AND CONCLUSIONS

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During the course of this investigation we have shown that the feral burro is changing certain aspects of the natural ecology of Grand Canyon National Park. These changes are the cumulative result of the foraging and trampling activities of the burro. The nature and magnitude of these ecological alterations in the Park environments are primarily related to habitat type and burro densities within the specific habitats. Some areas occupied by burros display marked and easily discernible impacts, while in other areas the habitat damage is not as severe.

By comparing several environmental parameters in areas occupied by burros with similar habitats where feral burros are not found, we have quantified certain aspects of the ecological modifications inflicted by burros in the Grand Canyon. The quantification of this damage was predicated on the results of soil, vegetational and rodent population analyses in three habitat types.

Vegetation

The results of the vegetation transects analyzed during this study serve to demonstrate that the presence of burros is correlated with a variety of plant community modifications. The foraging and trampling activities of the burros result in reduction in ground cover (particularly Tortula), local elimination of palatable perennials (especially grasses), and an increase in density of unpalatable and resilient perennial shrubs. Recovery rates of plant communities

after removal of burros was too slow to be measured during the course of this study. Seed data from the study sites further suggested that densities of perennials, especially grasses, were influenced by feral burros.

Soils

Soil compaction and trail deflation were influenced by the presence of feral burros. In all but the pinyon-juniper habitat type, soil compaction was always found to be greater on the impact areas than on the control. It is believed that the amount of burro activity in the Pinyon-Juniper areas is not sufficient to cause significant changes in soil compaction. Moreover, trail deflation and relatively high rates of soil erosion were found on the areas occupied by feral burros.

Small Mammals

The effects of burros on small mammal abundances and community composition are directly proportional to the effects of these equines upon the habitat. Small mammal abundance at sites which are used irregularly by feral burros (i.e., Pinyon-Juniper and Rampart Cave Impact sites) showed little response to burro-induced habitat modifications. In both instances, total numbers of small mammals were similar on the impact and control sites. Under moderate grazing pressure in an area consistently used by feral burros (ie., Tonto Platform Impact), the small mammal abundance was greater on the impact than on the matched control site. However, when cactus mice were excluded from the analysis, small mammal abundance was greater on the Tonto Control. Clearly this species responded favorably to the habitat alterations induced by feral burros on the Tonto Platform. The cactus mouse has been shown to be a generalist, adapted to a wide variety of habitats in the Grand Canyon.

Data from areas heavily impacted by feral burros indicated that small mammal abundance was greatly reduced. These trends are exactly the same as reported by other authors studying the interactions of domestic livestock and small mammals. Moreover, the foraging and trampling activities of feral burros adversely affected small mammal community composition on the Tonto Platform and Rampart Cave impact sites. As the proportion of heteromyid rodents decreased, there was a corresponding increase in the proportion of cricetid rodents.

Burros - a View from the Pleistocene

The arguments purporting to support ecological equivalence of equine impact in the Grand Canyon, in the late Pleistocene and at present, hinge upon two assertions: that the native Pleistocene Equus was the ecological equivalent of the modern burro in terms of diet, morphology, and effect on the habitat, and that the plant communities at the time of Pleistocene

Equus extinction were similar to those of today in burro impacted areas of the Grand Canyon.

Modern plant communities in the Grand Canyon are distinctly zoned from river to rim and consist of three distinct associations of differing biogeographic origin and species composition. The Inner Gorge contains a hot Mohave desertscrub community with a center of distribution at low elevations in southern Nevada and California. The most complete development of this community in the Grand Canyon is at the extreme western end, in the Rampart Cave area (Phillips 1975). Upstream in the Inner Gorge, the narrow ribbon of Mohave Desert plants gradually decreases in species diversity and community development. The Tonto Platform supports a high desert blackbrush community, intermediate between Mohave Desert communities to the west and cold Great Basin Desert communities to the north and east. While there are some species in common between the Tonto Platform and the Inner Gorge, the two communities are basically different in dominant species, general aspect, and environment. The pinyon-juniper woodland at still higher elevations contains very few species in common with the other two. The three communities are basically distinct and recognizable, separated by environmental and elevational gradients.

The Pleistocene equine and its extinct compatriots were living in an environment different from that which exists in the Grand Canyon today, one for which there is no modern analogue (Phillips and Van Devender 1974, Phillips 1977). Recently an intensive study has been made of the vegetation

occurring in the Grand Canyon surrounding the critical time of extinction (Phillips 1977). Using ancient packrat middens preserving identifiable fragments of plants, it has been possible to reconstruct in detail the vegetation occurring in the Grand Canyon from 8,000 to 30,000 years ago. In the Rampart Cave area, Pleistocene communities were dominated by juniper, Fraxinus anomala (single-leaf ash), and at least ten other species which occurred as low as 440 m in elevation until about 8,500 years ago. Today, these species are not found below the rim. The vegetation change occurring 8,000 to 8,500 years ago was not a simple replacement of woodland by desert, but rather a gradual loss of woodland species. Most of the desert species important in the area today were already there, and had been there at least since the end of the Full Glacial 14,000 years ago. The plant community of the Inner Gorge at the time of Equus extinction was a mixture of desert and woodland species which are today separated by 1000 m of elevation and corresponding environmental parameters (Phillips 1977). Van Devender and Mead (1976) have shown that similar Pleistocene vegetation existed in the Peach Springs Wash and Shinumo Creek areas. The change to modern plant communities did not occur until 3,000 years after the Pleistocene Equus was extinct. Even if the assumption of similarity between modern and Pleistocene equines is accepted, modification of the Recent Inner Gorge plant community cannot be compared to that of the Pleistocene because the vegetation was different.

The degree of ecological equivalence of the Pleistocene Equus and the modern African Equus asinus is difficult to assess. Despite some morphological similarities, there are no data regarding the diet, habitat interactions, or population levels of Pleistocene equines. That their impact is similar to that of the modern feral burro is pure speculation. The fact exists that introductions of exotic animals are almost always proven to be ecologically disastrous, either for the beast or for the environment. Nutria (Myocastor coypus) in Florida and hares (Lepus europaeus) in Australia are among the more obvious examples. When herbivores are introduced into an environment with which they have not coevolved, there is really no reason to expect that an equilibrium will be reached simply. The concept of "niche" is so complex that an empty niche can probably never be filled by introduction of anything short of the same beast, genetically and behaviorally, as the one which evolved there. Therefore it is unreasonable to assume that the modern African equine would occupy precisely the same niche as the one vacated by the Pleistocene Equus.

Management Considerations

We have reviewed records of previous Park Service efforts to control feral burros at Grand Canyon (CHAPTER I) in conjunction with our studies on distribution and density of these animals (CHAPTER II) and recruitment rates of two populations of feral burros in Grand Canyon (APPENDIX III). These data are crucial to the development of management plans for feral burros at Grand Canyon.

Johnston and Pontrelli (1969) and Ohmart (1975) have noted the necessity of developing management plans and controlling numbers of

feral equines on the public domain. Currently, direct reduction by shooting has been demonstrated to be the only effective method of controlling feral burros within Grand Canyon (CHAPTER I). The question arises as to whether Park Service management plans should be aimed at limited reductions or complete removal.

Carothers et al. (1976) summarized the early Park Service efforts to reduce feral burros at Grand Canyon. Based on that review and the information presented here (CHAPTERS I and II, APPENDIX III), it is clear that limited reduction of feral burros is inappropriate. For example, Ruffner and Carothers (APPENDIX III) have documented that previously reduced populations of feral burros have higher recruitment rates. Therefore, programs of partial reduction may actually stimulate population growth. Under these conditions, if management programs aimed only at partial reduction are adopted, it is likely that cropping of feral burros would have to occur several times in each decade. At the present rate of growth, the burro population could potentially increase from 300 to 1200 individuals in 10 years. To maintain the present population size, it would be necessary to annually remove approximately 43 burros from the total Canyon population.

The complete removal of feral burros from Grand Canyon is another alternative. De Vos and Petrides (1967) have discussed the problems involved in completely removing a well established exotic species. Warwick (1934) reported the only successful case of complete removal of a widely distributed, well established mammal. Although complete reduction seems unlikely, it is the only alternative that conforms completely to current National Park Service administrative policies.

The fates of exotic and feral animals in the entire National Park system are tied to the fate of feral burros at Grand Canyon and elsewhere. The fact that feral goats (Capra hircus) in Hawaii and feral boars (Sus scrofa) in Tennessee have been removed from National Park Service lands can no longer be ignored when formulating a management program for feral burros at Grand Canyon. Finally, if the purpose of the National Park system is to preserve the land in a natural state, "unimpaired by the hand of man", then habitat modifications by feral burros must be confronted with this in mind. These are the relevant points that need to be addressed by the National Park Service and the American public.

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APPENDIX I

Rodents on Burro-Impacted and Control Areas in the Vicinity of
Indian Canyon.

PX821071444

Carothers et al. (1976) showed a decrease in numbers and diversity of rodents on a burro-impacted area in the desertscrub of the Inner Gorge. In 1600 trap-nights (400 traps for two nights per impact or control site) at each of two habitat types during October 1977 we obtained similar results (Table 1).

Table 1.--Numbers of rodents taken in 3200 trap-nights on burro-impacted and control (burros absent) areas in two habitat types in the vicinity of Indian Canyon.

Species	Impact (River Mile 207.5 R)		Control (River Mile 208L)	
	<u>Night 1</u>	<u>Night 2</u>	<u>Night 1</u>	<u>Night 2</u>
<u>Perognathus intermedius</u>	-	-	13	7
<u>Perognathus formosus</u>	1	2	-	-
<u>Peromyscus crinitus</u>	3	2	0	0
<u>Peromyscus eremicus</u>	15	2	50	5
<u>Neotoma lepida</u>	-	-	2	0
<u>Neotoma albigula</u>	-	-	0	1
Total	18	6	65	13
<u>Perognathus intermedius</u>	-	-	14	3
<u>Peromyscus crinitus</u>	10	1	-	-
<u>Peromyscus eremicus</u>	-	-	10	3
<u>Neotoma lepida</u>	4	1	3	1
Total	14	2	27	7

APPENDIX II

Diets of a Feral Burro Population During August and September
From the Area Between Parashant Canyon (River Mile 198) and Fall Canyon
(River Mile 210.5), Grand Canyon National Park, Arizona.

Table 1.--Relative density (percent) of plant fragments in the August and September diets of feral burros from the area between Parshant Canyon (River Mile 198) and Fall Canyon (River Mile 210.5), Grand Canyon National Park, Arizona.

PLANT SPECIES	RELATIVE DENSITY
Grasses	
<u>Aristida adscensionis</u>	2.2
<u>Bouteloua barbata</u>	15.9
<u>Bromus rubens</u>	0.5
<u>Hilaria rigida</u>	5.5
<u>Oryzopsis hymenoides</u>	0.8
<u>Sporobolus cryptandrus</u>	0.8
<u>Sporobolus flexuosus</u>	0.5
<u>Tridens pulchellus</u>	2.6
Subtotal	28.8
Forbs	
<u>Allionia incarnata</u>	7.5
<u>Cassia covesii</u>	trace
<u>Cryptantha pterocarya</u>	0.7
<u>Eriogonum spp.</u>	0.4
<u>Euphorbia fendleri</u>	0.2
<u>Lathyrus graminifolius</u>	trace
<u>Melilotus alba</u>	1.4
<u>Mirabilis multiflora</u>	trace
<u>Pectis papposa</u>	0.4
<u>Plantago spp.</u>	1.9
<u>Oenothera multijuga</u>	trace
<u>Perophyllum gracile</u>	trace
<u>Stanleya pinnata</u>	0.1
<u>Sarcostema cynanchoides</u>	trace
Subtotal	12.6
Browse	
<u>Acacia greggii</u>	11.7
<u>Agave utahensis</u>	0.8
<u>Alhagi camelerum</u>	2.8
<u>Atriplex canescens</u>	0.1
<u>Bebbia juncea</u>	0.1
<u>Brickellia californica</u>	0.2
<u>Encelia farinosa</u>	0.1
<u>Ephedra spp.</u>	1.4

Table 1.--continued

Browse

<u>Fouquieria splendens</u>	1.1
<u>Ambrosia dumosa</u>	5.5
<u>Lycium andersonii</u>	0.7
<u>Krameria parvifolia</u>	0.2
<u>Opuntia spp.</u>	3.7
<u>Pluchea sericea</u>	0.1
<u>Prosopis juliflora</u>	24.4
<u>Sphaeralcea grossulariaefolia</u>	2.8
<u>Tamarix pentandra</u>	0.7

Subtotal	56.4
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Unknowns

2.2

Total	100.0
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Plants listed in relation to importance in diets:

1.	<u>Prosopis juliflora</u>	24.4
2.	<u>Bouteloua barbata</u>	15.9
3.	<u>Acacia greggii</u>	11.7
4.	<u>Allionia incarnata</u>	7.5
5.	<u>Franseria dumosa</u>	5.5
6.	<u>Hilaria rigida</u>	5.5
7.	<u>Opuntia spp.</u>	3.7
8.	<u>Sphaeralcea grossulariaefolia</u>	2.8
9.	<u>Alhagi camelorum</u>	2.8
10.	<u>Tridens pulchellus</u>	2.6
	Total	82.4%

APPENDIX III

Age Structure, Condition and Reproduction of Two Feral Burro

(Equus asinus) Populations From Grand Canyon National Park, Arizona.

This paper has been submitted for publication to the Journal of Mammalogy.

Data were gathered during July, August and September of 1976 under the auspices of National Park Service Contract No. CX821050007 to the Museum of Northern Arizona.

AGE STRUCTURE, CONDITION, AND REPRODUCTION
OF TWO FERAL BURRO (EQUUS ASINUS) POPULATIONS
FROM GRAND CANYON NATIONAL PARK, ARIZONA

by

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ABSTRACT

This paper presents the results of an investigation of the age structure, condition, and reproduction of two feral burro populations in Grand Canyon National Park, Arizona. Sixty-three animals from two areas were sacrificed and autopsied. The two populations were distinct in all demographic characteristics evaluated. Members of the Bedrock Canyon Herd were generally younger, in better condition, and females began reproducing at younger ages than their counterparts in the Lower Canyon Herd. Uneven sex ratios of young animals in the Bedrock Canyon Herd could not be adequately interpreted by traditional explanations. Predation appeared to have negligible influence on recruitment. Reproductive strategies of Grand Canyon burros were in contrast with those previously reported from Death Valley populations.

INTRODUCTION

The feral burro (Equus asinus), a native of northeastern Africa, was introduced into North America in the sixteenth century by Spanish explorers. It has been suggested (McKnight, 1958) that the burro did not become feral in the southwestern United States until sometime during the nineteenth century (see also Carothers et al., 1976).

Some of the land management problems (e.g., overgrazing, soil erosion) associated with feral burros in southwestern rangelands have been identified (McKnight, 1958; Woodward and Ohmart, 1976) and recently other investigators have begun to quantify the habitat destruction associated with the foraging activities of these animals. Carothers et al. (1976), in Grand Canyon National Park, studied vegetation and rodent populations on two similar study areas, one where feral burros occurred and another where feral burros were absent. On the study area where feral burros were present, plant species diversity, density, and cover were significantly reduced. In addition, native rodent populations were reduced by a factor of four on the study area frequented by feral burros.

Since feral burros are an established member of the large herbivore fauna in the southwestern United States, there are critical management implications associated with understanding the biology of this species. Little demographic information is available regarding feral burro populations. Moehlman (1974), Woodward (1976), and Norment and Douglas (1977) studied the ecology and behavior of feral burros in California. Potter and Berger (1977) found that sympatric populations of feral burros and native mule deer (Odocoileus hemionus) forage on many of the same species of plants during the winter in New Mexico. Woodward and Ohmart (1976) have studied diets and

movement of feral burros in the lower Colorado River Valley and Hansen and Martin (1973) compared the diets of bighorn sheep (Ovis canadensis), domestic cattle (Bos taurus), and feral burros in the lower Grand Canyon.

The objectives of this study are to analyze the age structure, condition, sex ratios and reproduction of two feral burro populations in differing habitats within Grand Canyon National Park, Arizona.

DESCRIPTION OF STUDY AREAS

The study was conducted on the right bank of the Colorado River within the Inner Gorge of Grand Canyon National Park, Arizona. Feral burros were removed from the vicinity of Bedrock Canyon between Colorado River Mile 125 and 130 (Township 33N, Range 2W, to Township 34N, Range 2W) and from the area between Parashont Canyon (Colorado River Mile 198) and Colorado River Mile 210.5 (Township 31N, Range 10W, to Township 29, Range 10W).

The Bedrock Canyon study area is bisected by numerous drainages. Elevation ranges from 914 meters (m) to 1524 m. Bedrock Canyon and the surrounding area are within the Mohave desert scrub vegetative community (Brown and Lowe, 1974). Burros are largely confined to this community by local topography, and only occasionally reach the Colorado River near River Mile 124. Characteristic floral components include brittlebush (Encelia farinosa), beavertail cactus (Opuntia basilaris), Indian tea (Ephedra spp.), four-wing saltbush (Atriplex canescens), globemallow (Sphaeralcea grossulariaefolia), catclaw (Acacia greggi), big galleta (Hilaria rigida), wolfberry (Lycium andersonii), poreleaf (Porophyllum gracile), red brome (Bromus rubens), and plantago (Plantago insularis).

The Lower Canyon study area is characterized by rugged terrain with elevations between 610 m and 1220 m. This area is also within the Mohave desert scrub vegetative community (Brown and Lowe, 1974) and an extensive riparian community is present along the Colorado River. In this area, the feral burros occupy both the riparian and desert scrub associations. Typical desert scrub flora of this study area includes creosote bush (Larrea tridentata), white bur-sage (Ambrosia dumosa), brittlebush, ocotillo (Fouquieria splendens), ratany (Krameria spp.), poreleaf, four-o'clock (Allionia incarnata), Indian

tea, plantago, and red brome. The riparian community is characterized by acacia, mesquite (Prosopis juliflora), tamarisk (Tamarix chinensis), willow (Salix spp.), greythorn (Condalia lycioides), wolfberry, arrow-weed (Pulchea sericea), and red brome.

The two study areas differ floristically in an important way. The desert community of the Inner Gorge is on the eastern edge of the Mohave desert scrub community which extends upstream along the Colorado River. Mohave Desert species are confined elevationally to the Inner Gorge and predominate as far upstream as Marble Canyon, over 200 river miles from the western end of the Grand Canyon. Species diversity of plants in the Inner Gorge increases downstream toward the main part of the Mohave Desert to the west of the Grand Canyon. Thus, the major difference between the Bedrock Canyon and Lower Canyon areas is the presence of several species in the Lower Canyon that are not found as far upstream as Bedrock Canyon. The most important of these are creosote bush, white bur-sage, ocotillo, and mesquite.

METHODS AND MATERIALS

Feral burros were collected with high-powered rifles and autopsied by personnel from the Museum of Northern Arizona and Grand Canyon National Park. The entire population, consisting of 18 burros, was sacrificed on 18 and 19 July 1976 in the vicinity of Bedrock Canyon. On 6 August 1976, 19 burros were collected from the area between Parashont Canyon and River Mile 210.5. This area was revisited on 11 and 12 September 1976, when an additional 26 burros were removed. No animals were wounded and lost.

Each animal was assigned a sequential number and the exact location of each collection noted. Sex, approximate age, general condition and indications of reproductive activity (e.g., lactation) were recorded for each animal. Standard measurements including total length, tail length, hind foot length, ear length, and foreleg length were recorded in centimeters (cm). Testes, ovaries and embryos were removed and preserved. Mandibles were removed from each specimen to facilitate more precise aging in the laboratory.

Tissues from each specimen were placed in 3 mil plastic bags with a 10 percent formalin solution. Each bag was closed, labeled, and placed in 18.9 liter (5 gallon) sealed plastic buckets for transportation to the laboratory. During the analysis data were statistically evaluated using the Student's *t* Test (Freese, 1967), Mann-Whitney U test, and χ^2 test (Siegel, 1956). Yate's correction for continuity was used in the χ^2 analysis where any of the expected frequencies were less than 5.

Accurate aging techniques were essential during this study. We have used the technique developed by Joubert (1972) based upon tooth eruption and wear. There are remarkable similarities in timing and patterns of tooth eruption and wear in the plains zebra (E. burchelli boehmi, Klingel and Klingel, 1966), the mountain zebra (E. zebra hartmannae, Joubert, 1972), and

the horse (E. caballus, Duerst, 1922; Butz and Bottger, 1946). We assumed that feral burros exhibit similar patterns; therefore, our age determinations were based upon eruption and wear of mandibular dentition. Mean age was calculated for the Bedrock Canyon and Lower Canyon populations using the midpoint of each age class.

The Kidney Fat Index (Riney, 1955) was modified and used to evaluate the physical condition of the burros. The revised Kidney Fat Index was computed from the weight of perirenal fat on the left kidney, divided by the total body length, and the quotient multiplied by 100. Our modifications were based on the following findings. Dauphine (1975) criticized Riney's (1955) index and suggested substituting a seasonally constant skeletal measurement (e.g., total body length) for kidney weight in the equation. During our study total length did not vary seasonally or between sexes ($t = 1.09$, $p > .20$, $n = 60$). Each kidney was removed using the technique described by Anderson et al. (1972). The fat was carefully stripped from each kidney and weighed to the nearest gram (g) on a 100 g or 300 g spring-loaded Pesola balance. We noted that the weight of perirenal fat was significantly greater on the left kidney than on the right ($t = 1.75$, $p < .04$, $n = 104$).

We adopted two techniques, previously used on fetal horses, to age 20 burro fetuses recovered during the study. Cole et al. (1931) found discernible changes with time in the ovaries of pregnant horses. They developed four periods of pregnancy, primarily based upon the presence, absence, or degree of development of corpora lutea in ovaries of pregnant females. We prepared the ovaries of each female burro by hardening them in a 10 percent formalin solution and then serially sectioning each in 1-2 mm sections. Sections were

laid out in order and corpora lutea were examined macroscopically and counted. Using these criteria we were able to estimate an age of each fetus. Jones (1974) summarized age and development of fetal horses. The 20 embryos were grouped, based on measurements of total length and foreleg length, and assigned an age based upon these measurements and major developmental events (e.g., presence of hair on the mane or around the lips, and internal differentiation of organs.). Burro embryos were aged independently by each of the two techniques and these data were combined to provide an estimate of average age in months for each fetus. These two methods, when used in conjunction, provided a consistent estimation of age in the fetuses.

After estimating the age of each fetus we calculated the month of conception and parturition for each female, assuming a gestation period of 12 months (Kenneth, 1953; Moehlman, 1974). The terms "reproductive activity" and "reproductively active" are used in the text to describe those female burros that were either pregnant or lactating.

RESULTS

Figure 1
 The age class determinations of all individuals in both herds (see Figure 1) demonstrate that the two populations have different age structure characteristics. Animals in the Bedrock Canyon herd were younger (mean age = 4.1 years) than those in the Lower Canyon herd (mean age = 5.8 years) but the differences were not significant ($t = 0.56$, $p > .10$, $n = 63$). Seventy-eight percent ($n = 18$) of the animals in the Bedrock Canyon area were between 1 month and 4 years of age, with the remaining 22 percent being between 5 and 15 years old. This contrasts with the Lower Canyon population where 49 percent ($n = 45$) of the individuals were between 1 month and 4 years, and the remaining 51 percent were in the 5 to 15 year old category ($\chi^2 = 4.35$, $p < .04$).

The ratio of kidney fat to total body length (Kidney Fat Index or KFI) indicates that there are intra- and inter-population differences in health and condition. The individuals ($n = 17$) in the Bedrock Canyon area were in better condition, having significantly greater KFI's ($U = 580.5$, $p < .01$) than the individuals ($n = 41$) in the Lower Canyon population. No significant differences in KFI's were detected between males ($n = 9$) and females ($n = 8$) in the Bedrock Canyon population ($U = 42.0$, $p > .28$). However, females ($n = 21$) had significantly higher KFI's than males ($n = 20$) in the Lower Canyon herd ($U = 332.5$, $p < .01$). Pregnant and lactating females in both populations ($n = 22$) had significantly greater KFI's than non-reproductive females, males, and young ($n = 36$) ($U = 519.5$, $p < .03$).

Figure 2
 Since KFI's were greater for the Bedrock Canyon herd than the Lower Canyon herd it is not surprising that the Bedrock Canyon population also showed the highest rates of reproduction (Figure 2). Eighty-nine percent of all females ($n = 9$) removed from the Bedrock Canyon area were either

pregnant or lactating compared to 73 percent of the females ($n = 22$) in the Lower Canyon area. In both populations the youngest reproductively active females were between 1 and 2 years old. The major difference in reproduction was exhibited by females between 1 and 4 years old. For this age class, in Bedrock Canyon all females ($n = 6$) were either pregnant or nursing foals, while in the Lower Canyon population only 54 percent ($n = 11$) were reproductively active ($\chi^2 = 5.56$, $p < .02$).

Twenty embryos were recovered from sacrificed females, six from Bedrock Canyon and 14 from the Lower Canyon. Age determinations of the embryos further indicate that 1 and 2 year old females were reproductively active in both populations. The sex ratio of embryos from the Lower Canyon was essentially even (six males, six females, and two unknown), whereas all six embryos from Bedrock Canyon were males ($\chi^2 = 5.02$, $p < .03$). These data are curious in that the sex ratio of post partum individuals in both herds approached 1:1.

Figure 3
3
Figure 3 presents the projected birth dates for the 20 aged embryos. There was no detectable difference in periods of natality between the two herds and, with one exception, foaling was limited to a 5 month period from March to July.

DISCUSSION

Odum (1971) noted that age distribution is an important factor influencing natality and mortality of populations. He suggested that expanding populations are typified by a large proportion of younger individuals, stable populations by evenly distributed age classes, and declining populations by a greater proportion of older individuals. Using Odum's model and comparing the age distribution of the populations from our two study areas, we found that the Bedrock Canyon population has a significantly higher proportion of younger individuals and therefore is expanding, whereas the Lower Canyon herd has an age distribution more closely resembling that of a stable population.

Other than our information, few data are available on age structure of feral burro populations. A sample of feral burros from the Chemehuevi Mountains of southern California suggests that this population is currently comprised of predominately young individuals and is expanding rapidly (Woodward, 1976). The Bedrock Canyon population and the population studied by Woodward are both small ($n \leq 100$ animals). Young, expanding, and relatively small populations of feral burros reflect the influence of a period of intensive cropping or predation. In both instances man has been the only major predator. At Grand Canyon, Park Service records for the period between March 1965 and June 1969 show that at least 28 feral burros were sacrificed in the vicinity of Bedrock Canyon. Only 17 percent ($n = 18$) of the entire population we removed in 1976 were old enough to be alive before June 1969.

The Lower Canyon population has not been exposed to an extensive control program, as has the Bedrock Canyon population. In Death Valley, Norment and Douglas (1977) reported an age structure of feral burros that shows some

similarity to the Lower Canyon population. They found, however, that trapping and adoption programs have altered the age distribution of Death Valley feral burro populations. Almost 80 percent of the feral burros adopted were 3 years of age or less (Norment and Douglas, 1977). Moehlman (1974) also noted that limited cropping programs were carried out prior to her study. It is apparent that the observed differences in age structure of southwestern feral burro populations result from the variety of management programs to which they have been exposed.

Working on introduced Himalayan thar (Hemitragus jemlahicus) in New Zealand, Caughley (1970) noted that Kidney Fat Indices were higher for female members of increasing populations, intermediate in stable populations, and lowest in declining populations. He suggested that this relationship could provide an indication of the potential for increase in populations. Comparing our two populations, Kidney Fat Indices were significantly greater for both females ($U = 119.0$, $p < .05$) and males ($U = 175.5$, $p < .01$) in the Bedrock Canyon population. The differences in condition between the two populations may be related to the overall productivity of their ranges and the intra-population age distributions. Preliminary investigations indicate that general range conditions are better in the Bedrock Canyon area (Ruffner et al., 1976).

The Kidney Fat Indices of reproductively active females indicate that these individuals were in significantly better condition than all males and non-reproductive females. These data contrast with previous studies of pronghorn (Antilocapra americana, Bear, 1971) and mule deer (Anderson et al., 1972). These studies of native ungulates indicate that mean Kidney Fat Indices are lower in females and males during the late spring and summer months and are probably related to the costs of gestation, parturition, and/or lactation.

In Death Valley, female burros were sexually mature at 1 1/2 years but, typically, did not have their first foal until 4 years of age or more (Moehlman, 1974). Although we found no significant difference in the total number of reproductively active females in the two populations, there were significantly more pregnant or lactating females in the 1 to 4 year old age class at Bedrock Canyon. In light of differences in age structure and reproductive activity, it is apparent that the Bedrock Canyon herd was undergoing a greater rate of population increase than was either the Lower Canyon or Death Valley population (Moehlman, 1974).

Based upon the age structure determinations of each population (see Figure 1), and assuming that males and females mature sexually by 1 year, there was a potential increase of reproductively mature individuals of 17 percent per year in the Bedrock Canyon herd compared to 11 percent per year in the Lower Canyon herd. During trips to the study areas in July, August, and September, we found very few animals less than 1 year old, even though many females were reproductively active. The low numbers of individuals less than 1 year old suggest high mortality of young. We do not believe that predation is responsible, since during numerous trips through the study areas over the last five years we have observed only a few predators or indications of their presence. The predators present include bobcats (Lynx rufus), mountain lions (Felis concolor), and coyotes (Canis latrans). In 2 1/2 years Moehlman (1974) substantiated only one instance of predation on feral burros. Thus, it appears that the seeming high mortality of young feral burros is a result of abortion, disease, and/or other factors.

Differential mortality and nutritional requirements are some of the traditional explanations for unbalanced primary and secondary sex ratios in

vertebrates (Robinette et al., 1957). Recently, Trivers and Willard (1973) postulated that sex ratios in vertebrate populations are influenced by the physical condition and age of the female. This hypothesis has been summarized by Wilson (1975) as follows:

- 1) In many vertebrates large healthy males mate more commonly than do small weak males; nearly all females mate successfully.
- 2) Females in the best physical condition produce the healthiest offspring, which tend to grow up to be large, healthy adults.
- 3) Thus, females should produce a higher proportion of males when they are healthiest, because these offspring will compete most successfully for mates with other males and produce the maximum number of offspring. As the females' conditions decline, they should shift increasingly to the production of daughters, since almost all female offspring will mate regardless of condition and thus represent the safer investment at this time.

These arguments provide a novel explanation of unbalanced sex ratios and fit previously unexplained data from several taxa of mammals (Trivers and Willard, 1973). This model would also apply to this study where the females in the Bedrock Canyon herd, which are in better condition and begin reproducing at an earlier age, produced higher proportions of male offspring than did their counterparts in the Lower Canyon.

Projected birth dates of 20 aged embryos revealed that, with one exception, births were limited to the 5 month period from March to July. In Death Valley, burro births peaked between May and July but young were born in every month of the year (Moehlman, 1974). Our data indicate, however, that births were generally limited to the spring and early summer. Nishikawa and Hafez (1968)

noted that literature pertaining to the breeding season in domestic female horses is "conflicting and inconsistent." They classified breeding mares into three categories:

- 1) those with a defined breeding season coinciding with the longest days of the year during which several estrus cycles occur and foals are born during a restricted foaling season;
- 2) those with a transitory breeding season with estrus cycles throughout the year but ovulation during the breeding season and foals born during a limited foaling season; and
- 3) those with year-round breeding, ovulation accompanying each estrus cycle and foals born throughout the year.

Burro populations in Death Valley appear to be year-round breeders (Moehlman, 1974), while Grand Canyon populations are characterized by either a defined or transitory breeding season.

It is tempting to speculate on the factor(s) that encourage different reproductive strategies exhibited by burros in Grand Canyon and Death Valley. Several authors (Beatley, 1969; Reichman and Van De Graaff, 1975; and others) have suggested that a relationship exists between precipitation, production of green plants, and reproduction of desert rodents. Marshall (1961) suggested that vertebrates in certain "special areas" such as deserts have abandoned reproductive responses to photoperiod and adopted more effective stimuli to ensure reproductive success. In southern Rhodesia, Burchell zebra foals were observed during every month except at the peak of the dry season in August and September (Dasmann and Mossman, 1962). At Grand Canyon the period of greatest birth (March - July) closely follows the peak period of spring rainfall (February - April) and slightly preceeds the peak period of summer

ne >
4. rainfall (July - September, Figure 4). The greatest production of green vegetation occurs in response to spring rains, whereas there is little or no vegetative response to summer rains in Grand Canyon (A.M. Phillips, III, pers. comm.). These observations suggest a relationship between late winter and spring rains and vegetative productivity, which may cue reproduction in burros at Grand Canyon. The peak period of births also corresponds to the increasing photoperiod. Birth corresponds, generally, to the most favorable environmental regime or season.

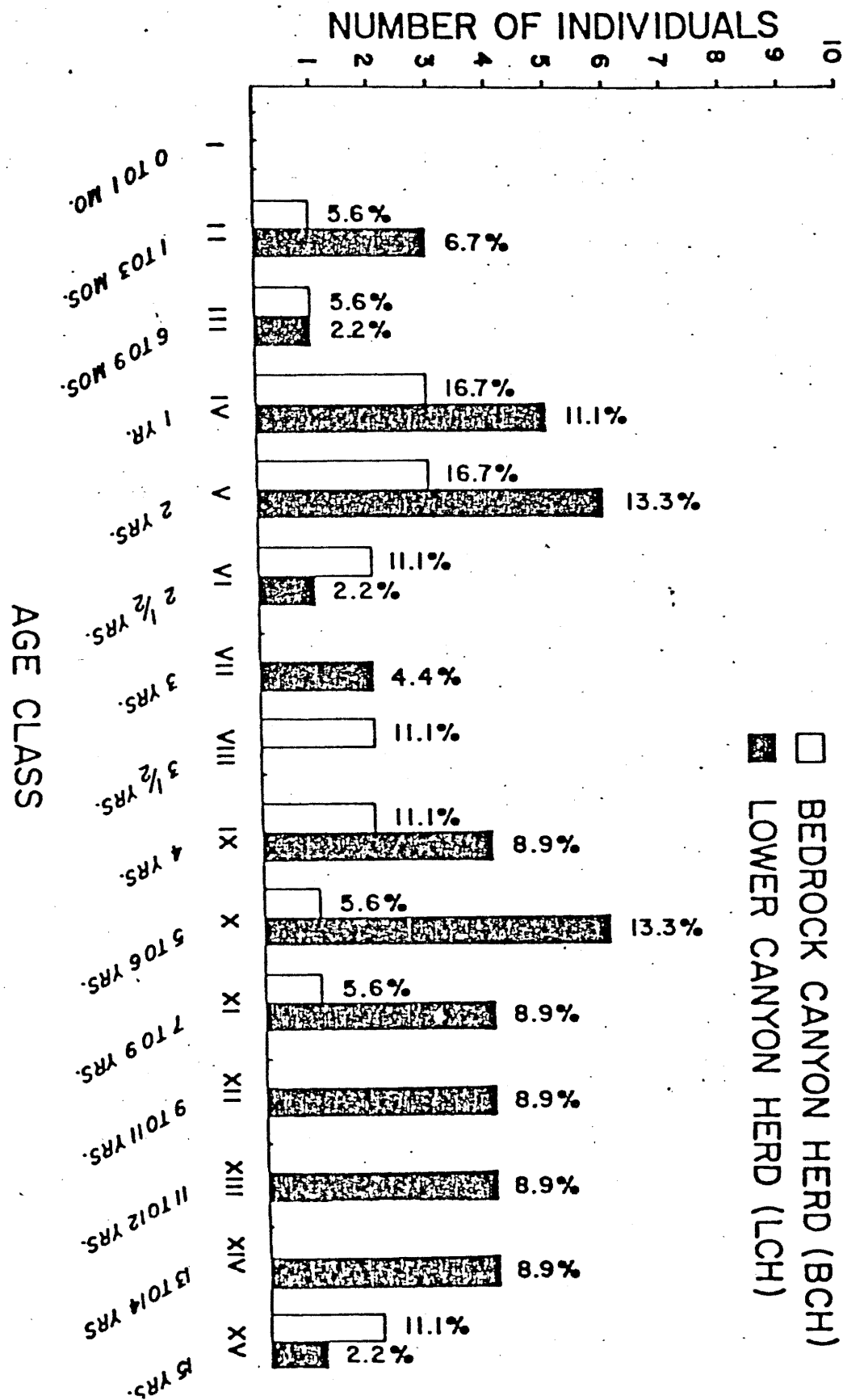
In summary, the differences in age structure between the two Grand Canyon populations may be attributed to previous reduction programs conducted by the National Park Service. The previously cropped Bedrock Canyon population was expanding in contrast to the relatively stable Lower Canyon population. Kidney Fat Indices for both populations support this conclusion. These indices also suggest that pregnant and lactating females are in better condition than all other individuals. Reproduction and recruitment rates of sexually mature individuals further support the conclusion that the Bedrock Canyon population was expanding at a greater rate than is the Lower Canyon population. Sex ratios of embryos from the Bedrock Canyon area lend support to the hypothesis that sex ratios in vertebrate populations are influenced by physical condition and age of the female. Young feral burros are generally born in the spring and early summer months at Grand Canyon, the period of greatest vegetative productivity and increasing photoperiod.

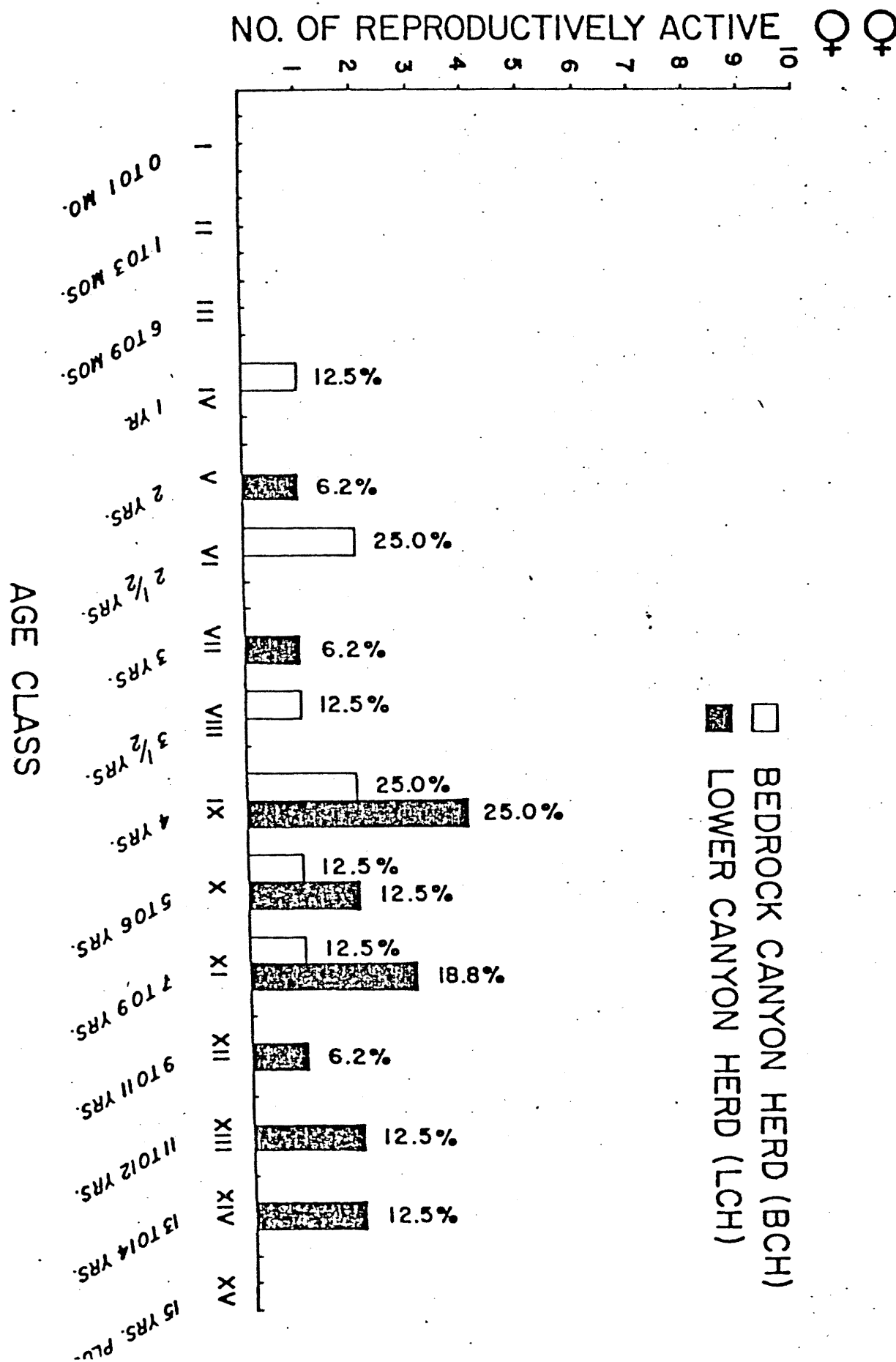
Figure 1. Age structure of two populations of feral burros, Grand Canyon National Park, Arizona.

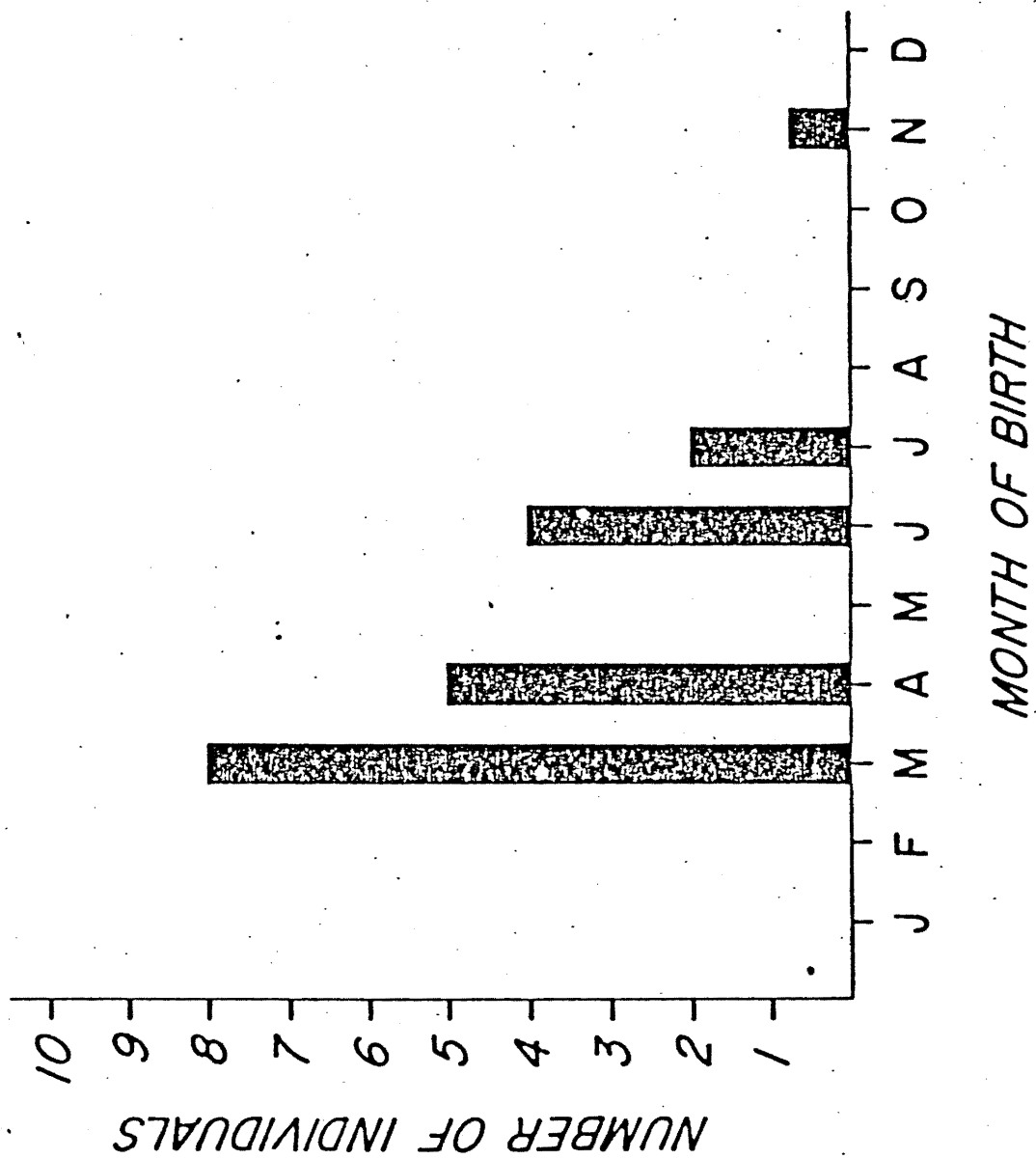
Figure 2. Age structure of reproductively active females in two populations of feral burros, Grand Canyon National Park, Arizona.

Figure 3. Projected birthdates of burro embryos, Grand Canyon National Park, Arizona.

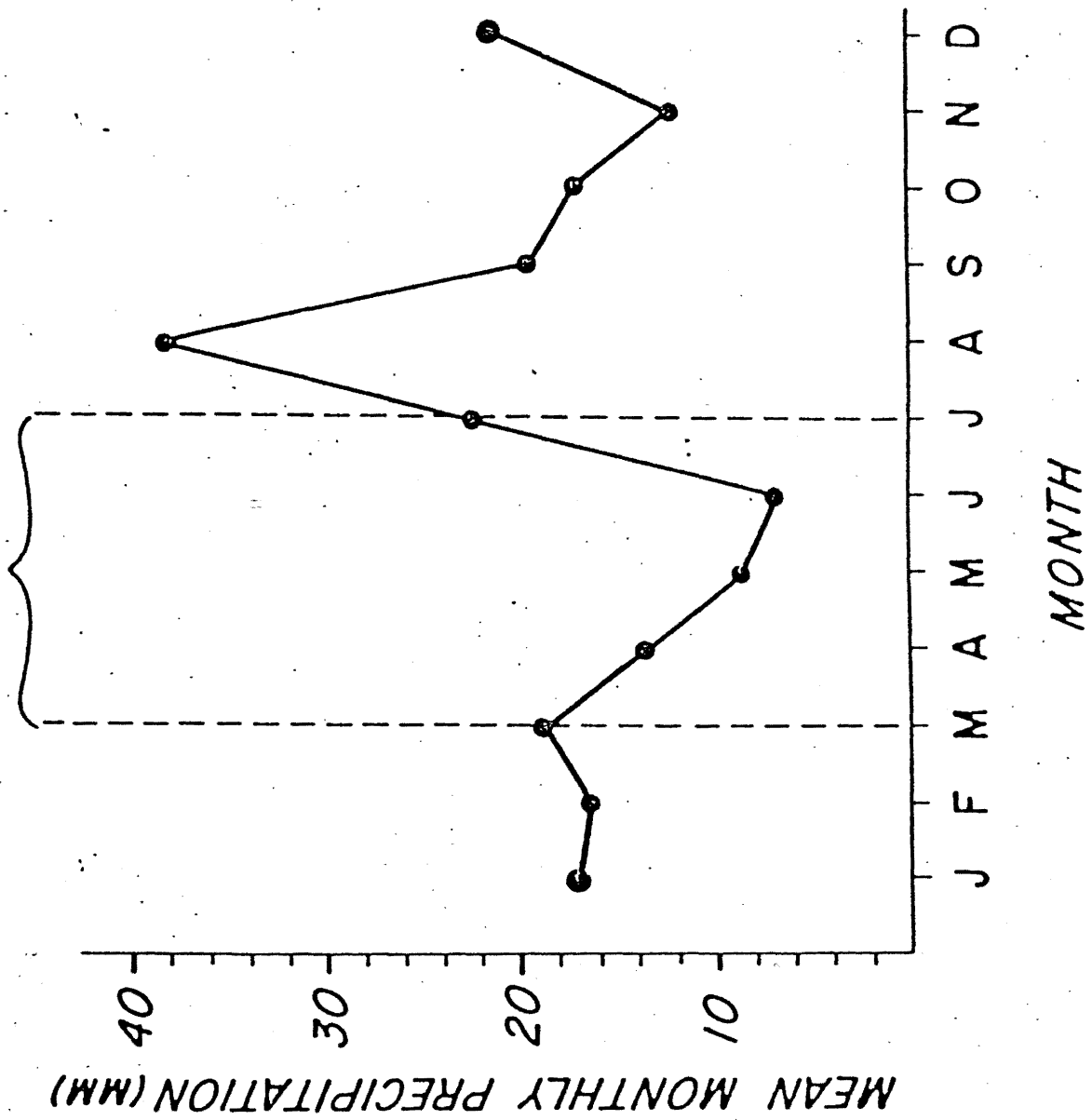
Figure 4. Mean monthly precipitation at Bright Angel Ranger Station, Grand Canyon National Park, Arizona. Data from Sellers and Hill (1974).







PERIOD OF GREATEST NATALITY



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