

FINAL REPORT

CHARACTERIZATION OF RELICT COMMUNITIES
FOR MONITORING PARK ECOSYSTEMS IN
GLEN CANYON NATIONAL RECREATION AREA

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ABSTRACT

A study was conducted in 1990 and 1991 to evaluate the effects of grazing by domestic livestock on selected Indian ricegrass/galleta grass (Oryzopsis hymenoides/Hilaria jamesii) and pinyon-juniper (Pinus edulus - Juniperus osteosperma) communities of Glen Canyon National Recreation Area (NRA). The specific objectives were to: (1) identify and characterize the vegetation, avian, and rodent components of relict-nongrazed communities, (2) identify and characterize the vegetation, avian, and rodent components of selected communities that best represented the end product of light, moderate, and heavy grazing by domestic livestock, and (3) identify and evaluate community characteristics that may serve as indicators in a comprehensive system which can be used to monitor the ecological condition and trend, using the selected relict-nongrazed communities as reference points.

A distinct shift in the composition and abundance of the major herbaceous species along the selected grazing gradient was observed in the Indian ricegrass/galleta grass communities of Grand Bench. The density and basal area of Indian ricegrass decreased in response to grazing, with density decreasing by as much as 80% on the grazed sites during both 1990 and 1991. The density and basal area of galleta grass and broom snakeweed (Gutierrezia sarothrae) tended to increase on grazed sites. The little pocket mouse (Perognathus longimembris) was the most abundant rodent species trapped on all sampled sites and demonstrated a 50% decrease in abundance at the heavily grazed

site. The deer mouse (Peromyscus maniculatus) was the second most abundant rodent species recorded and tended to increase with increasing grazing intensity. Total bird density and bird species diversity exhibited a significant decrease with increasing grazing intensity. The black-throated sparrow (Amphispiza bilineata) was the most abundant avian species recorded and suffered a 50% decrease in density at the grazed sites. The house finch (Carpodacus mexicanus), observed only at the relict site, appeared to demonstrate the greatest relict site specificity.

Several of the selected Indian ricegrass/galleta grass community components examined may serve as useful ecological indicators of community change in response to grazing by domestic livestock. It should not, however, be concluded that grazing will have parallel effects in other habitat types. It is also likely that some of the observed changes in plant and animal species composition and density along the grazing continuum can be attributed to the effects of disturbances placed on these communities by the activities of grazing livestock.

INTRODUCTION

Grazing by domestic livestock is authorized in Glen Canyon National Recreation Area (NRA) and continues on approximately 80 percent of the park. Concern over competing land uses has generated considerable interest in the direct and indirect effects of grazing on natural communities. Livestock grazing on rangelands exerts a controlling influence on plant community composition and structure, primarily as a result of selective defoliation of forage species (Stoddart et al. 1975). Similarly, it can be assumed that grazing induced alterations in the habitat could be reflected by changes in the distribution of resident animal species. An understanding of the differential and direct effects of domestic animals on plant communities is, therefore, of value in interpreting the indirect effects of livestock on native animal communities (Hanley and Page 1981).

The effects of domestic livestock grazing on vegetation composition and distribution, and the concomitant influence on large, native ungulates is well represented in the literature. However, the influence that shifts in vegetation composition as a result of grazing may have on the composition and distribution of small, non-game animals, although largely recognized, is rarely documented. While correlations do not necessarily indicate a cause-effect relationship, the results of many studies (Rosenweig and Winakur 1969; Tomoff, 1974; McCloskey, 1975; Hafner, 1977; Feldhamer, 1979; Hanley and Page, 1981; Parmenter and MacMahon, 1983; Bock et al., 1984; Bock and Webb, 1984; Knopf et al., 1990)

imply that birds and rodents can integrate certain vegetational attributes in their selection of habitat. It is generally assumed that certain habitat characteristics have a profound influence on the distribution of animal species and that habitat information is essential to interpreting community patterns (Wiens and Rotenberry, 1981).

In this study, the changes in different components of selected Indian ricegrass (Oryzopsis hymenoides)/galleta grass (Hilaria jamesii) communities along a successional continuum were studied by characterizing sites at different levels of succession. The driving force delineating the successional sequence was differential frequency and intensity of disturbance to the communities in the form of grazing by domestic livestock. The potential climax community was inferred based on the nature and occurrence of relict Indian ricegrass/galleta grass communities. In ecological usage, a relict is a community or group of plants which has survived some important change, being left behind by the disappearance or modification of an earlier vegetation, usually a climax (Weaver and Clements 1938). The specific objectives of this investigation were to: (1) identify and characterize the vegetation, avian, and rodent components of relict-nongrazed communities, (2) identify and characterize the vegetation, avian, and rodent components of selected communities that best represented the end product of light, moderate, and heavy grazing by domestic livestock, and (3) identify and evaluate community characteristics that may serve as indicators

in a comprehensive system which can be used to monitor the ecological condition and trend, using the selected relict-nongrazed communities as reference points.

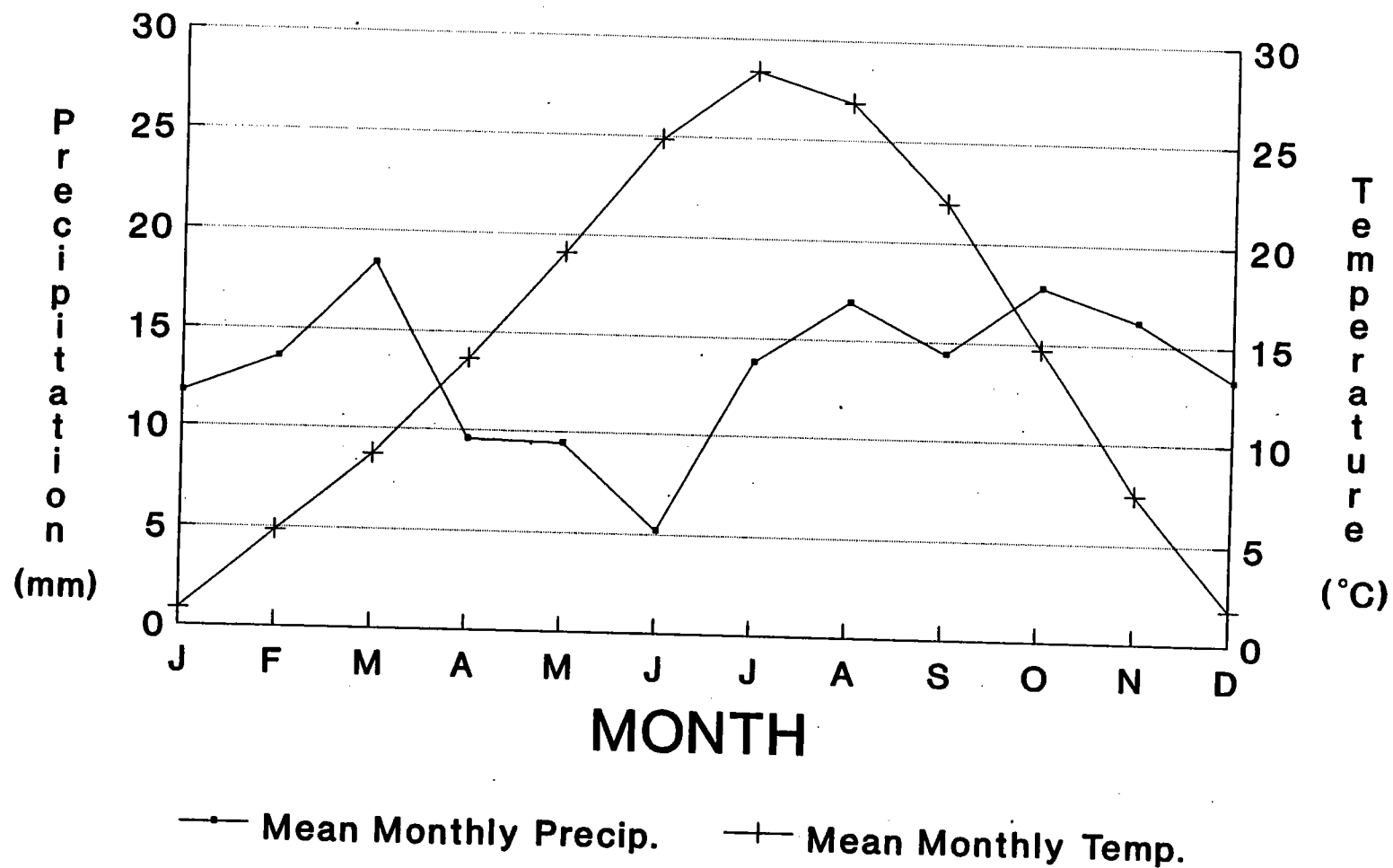


Figure 2. Long-term mean monthly precipitation (mm) and mean monthly day-time temperatures (°C) recorded from 1963-1990 at the Wahweap ranger station near Glen Canyon Dam on the Arizona-Utah border. Wahweap is located approximately 27 km southwest of the Grand Bench study area within the NRA (Jeffries 1989).

INDIAN RICEGRASS/GALLETA GRASS COMMUNITY

Study Sites

The Indian ricegrass/galleta grass study site was located on a portion of Glen Canyon NRA known as Grand Bench (1450 m elev.). Grand Bench is a 13 km long, isolated peninsula encompassing approximately 80 km², located 30 km northeast of Page, Arizona (Figure 1). Portions of Grand Bench have been grazed by domestic livestock both presently and historically. The extent to which livestock grazing occurs is currently limited by the availability of water. Presently, the only permanent source of water is a well located at the north end of Grand Bench, limiting the heaviest grazing pressure to the northern portions of the Bench. Thus, grazing occurs naturally along a continuum of decreasing intensity with increasing distance away from the water source.

Precipitation has been measured at Page, Arizona (1320 m elev.), located approximately 30 km southwest of Grand Bench, since 1957; and at the Wahweap Ranger Station, Wahweap, Arizona (1170 m elev.), since 1963. Wahweap is located approximately 28 km west-southwest of Grand Bench and approximately 9 km northwest of the town of Page (Figure 1). A mean annual precipitation of 162 mm and 165 mm has been recorded for Page and Wahweap, respectively, during this time period (Jeffries 1989). Mean daily temperatures demonstrate a sharp peak during the mid-summer months with a mean daily temperature of approximately 28°C for July and a mean daily temperature of approximately 1°C for December and January (Figure 2). Monthly precipitation for the

years 1989, 1990, and 1991 were highly variable, fluctuating considerably around the long term monthly means (Figure 3).

The soils on Grand Bench are predominantly classified as Moenkopie fine sandy loam and Needle loamy fine sand, which are derived primarily from alluvium and eolian sandstone deposits on mesas and structural benches. These shallow soils are well drained and very low in organic matter content, with an effective rooting depth ranging between 25 and 50 cm. Infiltration to the bedrock is moderately rapid and runoff is slow (Soil Conservation Service, in press).

The dominant vegetation type on Grand Bench is the Indian ricegrass/galleta grass community type as described by Tuhy and MacMahon (1988). This community, which is composed of open stands of blackbrush with grassy interspaces, is common on much of the NRA at lower and middle elevations. Blackbrush stands occur on sites where the effective rooting depth of soil is relatively shallow (25-50 cm). Native perennial grasses such as Indian ricegrass, galleta grass, and sand dropseed (Sporobolus cryptandra) increase in abundance on sites with deeper soils (Tuhy and MacMahon 1988).

Four vegetation, avian, and rodent sampling sites were systematically located along a grazing regime of decreasing intensity, being located increasingly farther from the only permanent source of water on Grand Bench (heavy=4 km, moderate=7 km, light=9 km, relict-nongrazed=13 km) (Figure 4). The distance from permanent sources of water for domestic livestock to grazed

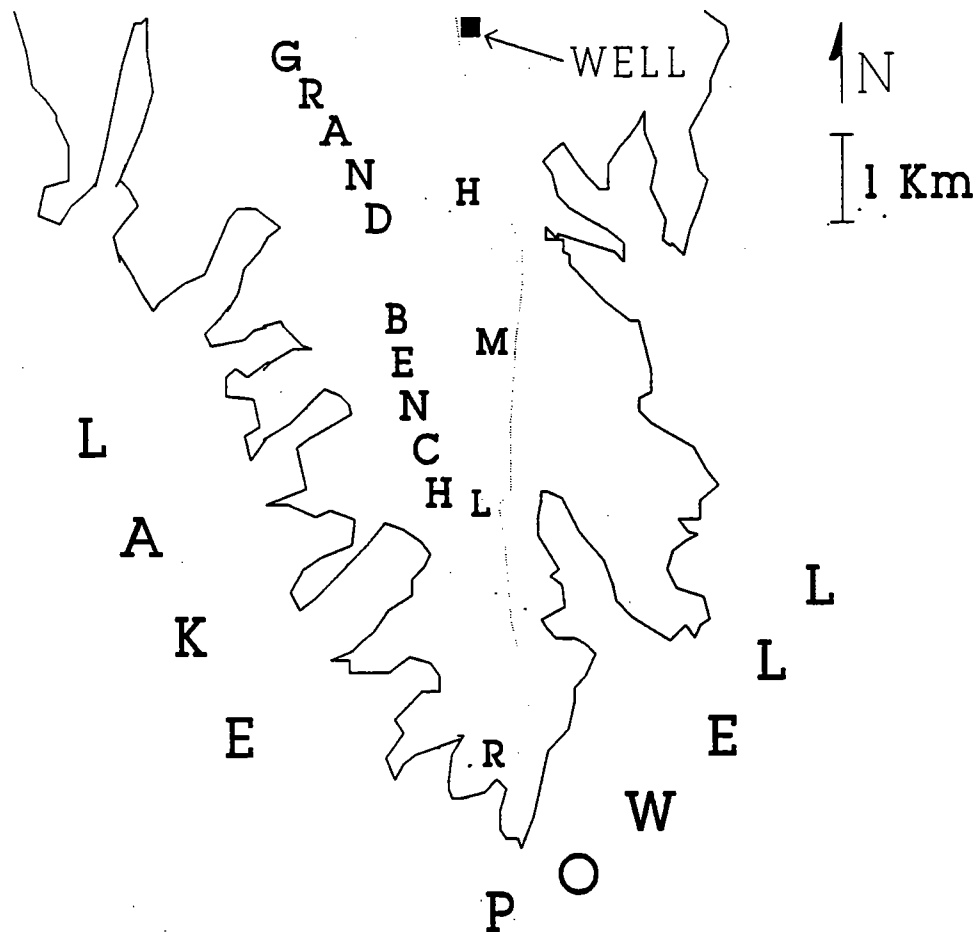


Figure 4. Location of four vegetation, avian, and rodent sampling sites on selected Indian ricegrass/galleta grass communities. The study sites, situated along a grazing regime of decreasing intensity (H=heavily grazed, M=moderately grazed, L=lightly grazed, R=relict-nongrazed), were located progressively farther from the only permanent source of water for domestic livestock on a portion of Glen Canyon NRA known as Grand Bench.

range sites is considered a primary factor governing the amount of grazing pressure that grazed sites receive (Holechek et al. 1989). The extent of physical evidence of livestock (degree of soil disturbance, number and extent of trails, presence of feces) was also used to aid in the location of sampling sites. Sites chosen for sampling exhibited similar abiotic components (soil type, soil depth, slope, and aspect), as well as uniform habitat. It was assumed that grazed areas that had similar physical characteristics had the potential to produce a similar plant community, even though current botanical composition and productivity may have been modified by grazing (Shiflett 1973).

Methods

Due to logistical problems and lack of suitable sampling sites, the effects of grazing intensity on different community attributes were examined at single sampling sights subjected to each grazing intensity (heavy, moderate, light, relict-nongrazed). Because of this lack of treatment replication, pseudoreplicates were used to detect variability in the data. Pseudoreplications of variability were years (1990 and 1991) and transects within sampling sites for vegetation data, years (1990 and 1991) for rodent abundance data, and days for avian density data.

Vegetation

The herbaceous vegetation was evaluated from four parallel

50 m transects spaced 15 m apart within each of the four sites (heavy, moderate, light, relict-nongrazed) selected for detailed study. Twenty-five, 50 X 100 cm quadrats were placed contiguously along each permanent transect beginning 10 m from one end of the transect and ending 22.5 m from the other end. Consequently, a buffer zone was used to reduce the chance that the sampled areas would be disturbed by large herbivores (and humans) attracted by the steel stakes marking the transects. Density of herbaceous species was estimated by counting the number of individuals rooting within each quadrat. Basal area of grass species and canopy cover of forb species was estimated for each site by placing each individual plant occurring within each quadrat into one of seven size classes: 1 = 0-0.5 cm² (primarily small, single-stemmed individuals), 2 = 0.6-5 cm², 3 = 6-15 cm², 4 = 16-50 cm², 5 = 51-150 cm², 6 = 151-300 cm², 7 = ≥ 300 cm². Using the above size classes rather than individually estimating percent basal cover reduced subjectivity in the sampling procedure. Canopy cover for the shrub strata (individuals > 30 cm in height) was estimated by line intercept (Mueller-Dombois and Ellenberg 1974). Shrub density was estimated by counting the number of individuals rooting within each 2 X 50 m belt transect.

The midpoints of each size class were used to calculate the average basal area (cm²) of each grass species and the average canopy cover (cm²) of each forb species. The effects of grazing intensity, year, and their interaction on the density of major herbaceous species, the basal area of major grass species, and

the canopy cover of major forb species were examined using nested two-way analysis of variance models (PROC GLM, SAS Institute, 1988; Table 1). Transects were treated as independent samples nested within each grazing regime, while the quadrats served as subsamples within each transect. Major vegetation species were those species that demonstrated distinct trends in population density along the grazing regime (Gutierrezia sarothrae, Hilaria jamesii, and Oryzopsis hymenoides). When significant differences were identified, means were separated using Bonferroni t-tests (SAS Institute 1988) to control for inflation of experimental error rate.

Diversity values for the herbaceous vegetation at each of the four sites were generated using Shannon's Diversity Index (Shannon and Weaver 1949). The effect of grazing on vegetation diversity was examined with a Kruskal-Wallis test (PROC NPAR1WAY, SAS Institute 1988), using the diversity values from the two years (1990 and 1991) as replicates. Annual differences in overall herbaceous vegetation diversity on Grand Bench in 1990 and 1991 were compared with a Wilcoxon two sample test (PROC NPAR1WAY, SAS Institute 1988).

The effects of grazing on shrub density and shrub percent canopy cover were estimated using one-way analyses of variance (PROC GLM, SAS Institute 1988). When significant differences were identified, means were separated using Bonferroni t-tests (SAS Institute 1988). Unless otherwise noted, effects were considered significant for these and all other analyses if the

probability for the statistical test was less than 0.05 ($\alpha = 0.05$).

Avian

During the 1990 field season, the avian community on Grand Bench was censused by walking a prescribed 1,000 m route surrounding each study site. No attempt was made to estimate actual densities during this survey, but the census did provide information on species composition.

In 1991, bird population densities were estimated between 15 May and 1 June, using the variable-strip transect method developed by Emlen (Emlen 1971, 1977). The variable-strip transect method is a widely used censusing technique that provides a rapid, relatively easy way to sample large areas during any season of the year (Franzreb 1981). Because the detectability of species under varying habitat conditions is accounted for in the variable-strip transect method, it is adaptable to a wide variety of habitat types (Edwards et al. 1981). Thus, this technique is well suited for use in the Indian ricegrass/galleta grass community type.

A one kilometer linear transect was located at each sampling site (heavy, moderate, light, and relict-nongrazed), extending through what appeared to be homogeneous vegetation. An area was considered homogeneous if it displayed similar plant growth forms and densities along the entire transect length. Transects were delineated using a tape measure and compass, and clearly marked

at 50 m intervals with plastic flagging. Each transect was walked by a single observer once each day for a period of four consecutive days. The sampling period began approximately one hour after sunrise and was completed within two hours. The observer moved along the transect at a uniform pace (1 km/hr) and recorded the lateral distance from the transect line to the point where each bird was first detected. Distances were recorded as precisely as possible (nearest meter) with the aid of a range finder (Ranging Inc., East Bloomfield, New York, Model 620).

Transect data were analyzed by grouping the number of individuals observed for each species into 5 m bands extending out from the transect line. Data for each species were then plotted on a graph with the distance on the x-axis and the number of observations per band on the y-axis. The density value for each species was then determined by counting the number of individuals identified in the strips on either side of the transect line proximal to the point of inflection on the distribution curve. In this way, the inflection point designated the lateral boundaries of the census strip for each species. These lateral boundary lines and the ends of the transect route defined the areal base for the density estimate function (Emlen 1977). Identification of inflection points on the species specific distribution curves yielded lateral transect boundaries for the four most common bird species observed.

The effect of grazing intensity on specific population densities, overall bird densities, and bird species diversity as

measured by Shannon's Diversity Index (Shannon and Weaver 1949) were examined with a Kruskal-Wallis test (PROC NPAR1WAY, SAS Institute 1988) since the data did not meet the ANOVA model assumptions of normality (Shapiro-Wilks statistic, SAS Institute 1988) and homoscedasticity (Levene's test, Milliken and Johnson 1984). Effects were considered significant if the resulting probability for the χ^2 -value was less than 0.10 ($\alpha = .10$). When the Kruskal-Wallis tests indicated significant differences, means were compared using Dunn's test (Hollander and Wolfe 1973).

odents

A 100 X 100 m grid of 100 Sherman live traps (8 cm X 8 cm X 25 cm) was established at the heavy, light, and relict sampling sites between 15 May and 6 June in 1990 and 1991. Limited time and logistical problems prevented the establishment of a trapping grid on the moderately grazed site. Preliminary trapping indicated that four consecutive trap-nights were required to adequately sample the resident rodent populations. Traps were opened and baited approximately one hour before dark, and were checked and closed within two hours of daylight. Upon initial capture, each individual was toe-clipped for unique identification, and the following information recorded: toe-clip number, species, sex, age class (based on pelage), length of tail, length of hindfoot, length of ear, reproductive condition, and general condition. When all data were recorded, each individual was released at the point of capture and observed

until lost from sight.

Rather than determining densities, relative abundance indices (total number captured / 400 trap nights) were used to estimate rodent populations. However, densities and abundance indices are generally highly correlated (Hansson 1967, Hanley and Page 1981). Shannon's Diversity Index was used to measure rodent community diversity (Shannon and Weaver 1949). The effects of grazing intensity on total rodent abundance and abundance of major rodent species (Perognathus longimembris and Peromyscus maniculatus) were estimated using one-way analyses of variance (PROC GLM, SAS Institute 1988) with the two years (1990 and 1991) as replicates. When significant differences were identified, means were compared using the Bonferroni t-test (SAS Institute 1988). Rodent diversity data did not meet parametric model assumptions, therefore a Kruskal-Wallis test (PROC NPAR1WAY, SAS Institute 1988) was used to identify differences among grazing intensities.

Results

Vegetation

Mean density and basal area for all herbaceous species observed during the 1990 and 1991 field seasons are found in tables 1-2 in the appendix. A total of six grass species and seven forb species were recorded at the study sites during the 1990 field season. Species richness increased in 1991, as seven grass species and 19 forb species were recorded on Grand Bench. Overall herbaceous vegetation diversity was significantly higher in 1991 than in 1990 ($Z=2.17$, $P<0.05$). However, herbaceous vegetation diversity did not differ significantly across the four sampling sites ($\chi^2=0.667$, $df=3$, N.S.).

Generally, herbaceous vegetation densities were low and species were sporadically distributed, often being recorded at only one or two of the four sampling sites. However, three species, Indian ricegrass, galleta grass, and broom snakeweed, did demonstrate distinct trends in population density along the grazing regime for both 1990 and 1991 (Tables 1 & 2). Density of Indian ricegrass was not significantly affected by a grazing intensity*year interaction (Table 1). Indian ricegrass decreased in abundance with increasing grazing intensity in both 1990 and 1991, with significant differences in density occurring between all sites except the heavily and moderately grazed sites (Table 2). Changes in basal area of Indian ricegrass in response to grazing varied with sampling year (Table 1). Although mean basal area decreased with increasing grazing pressure during both

Table 1. Results of the nested analyses of variance for plant density and basal area of the major species within each *Oryzopsis hymenoides*/*Hilaria jamesii* grass community sampled during 1990 and 1991 in relation to livestock use in Glen Canyon Recreation Area.

		<u>G. sarothrae</u>		<u>H. jamesii</u>		<u>O. hymenoides</u>	
Source	d.f.	MS	F	MS	F	MS	F
Dependent Variable: Density							
Grazing Regime	3	148.4	11.1*	1552.8	1.9	97.3	14.3*
Transect (Grazing Regime)	12	13.3		841.3		6.8	
Year	1	36.5	29.5*	24.1	1.1	32.0	9.3*
Grazing Regime*Year	3	34.4	27.8*	38.8	1.8	3.2	0.9
Transect*Year (Grazing Regime)	12	1.2		21.5		3.5	
Error	768	1165.6		24489.2		1453.2	
Dependent Variable: Basal Area							
Grazing Regime	3	2094265.3	6.4*	27031.4	1.9	865891.0	98.3*
Transect (Grazing Regime)	12	326101.6		13553.4		8809.8	
Year	1	2345247.4	10.2*	604.3	0.9	586525.7	23.9*
Grazing Regime*Year	3	1070851.9	4.6*	2019.0	3.2	111242.3	4.5*
Transect*Year (Grazing Regime)	12	230793.3		626.5		24510.2	
Error	768	30935044.8		595832.4		12359855.5	

*=significant $P < 0.05$

Table 2. Mean density (individuals/.5m²) and mean basal area (cm²) of the major grass species and mean density and mean canopy cover (cm²) for the major forb species recorded on selected heavily grazed, moderately grazed, lightly grazed, and nongrazed blackbrush/Indian ricegrass communities within Glen Canyon National Recreation Area during 1990 and 1991. Single values represent no significant year*grazing interaction and are two year means.

- = species not recorded

T = species with a density < .1 individuals/.5m²

Species	Heavy		Moderate		Light		Relict	
	1990	1991	1990	1991	1990	1991	1990	1991
<u>Oryzopsis hymenoides</u>								
Density	0.4 ^c		0.6 ^c		1.1 ^b		2.0 ^a	
Basal Area	1.9 ^d	3.2 ^B	39.8 ^c	8.0 ^B	116.0 ^b	29.5 ^B	200.6 ^a	101.0 ^A
<u>Hilaria jamesii</u>								
Density	4.6		6.8		6.6		0.8	
Basal Area	16.7		30.0		27.5		4.3	
<u>Gutierrezia sarothrae</u>								
Density	0.9 ^b	2.6 ^B	1.2 ^b	1.2 ^A	T ^a	-	T	T
Canopy Cover	225.4 ^c	125.2 ^B	347.0 ^b	19.8 ^A	7.2 ^a	-	T	T

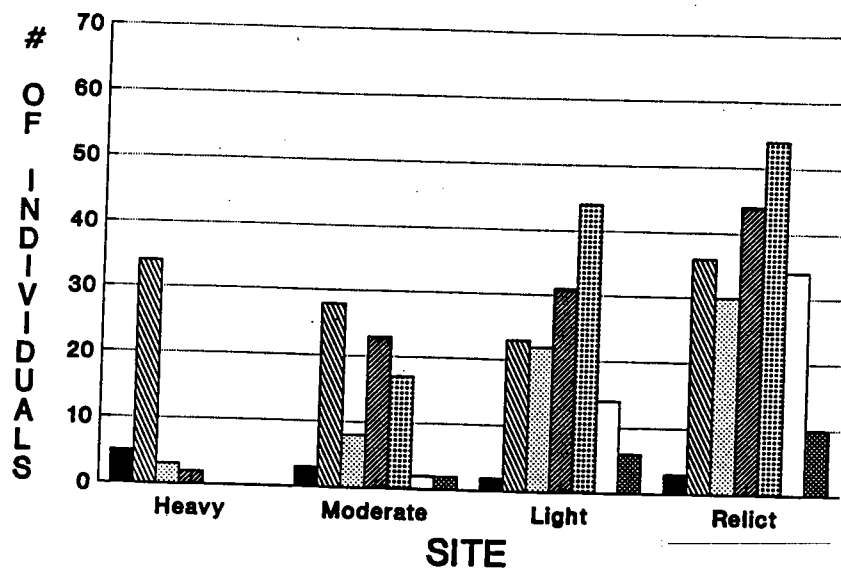
Values labeled with different letters are significantly different $\alpha = 0.05$ (Bonferroni t-test)
Capital and lower case letters distinguish differences between years.

years, values recorded during 1991 on the moderately grazed, lightly grazed, and nongrazed sites were substantially lower compared to 1990.

The number of plants in size class one (small, single-stemmed individuals) was substantially higher at all sites during 1991 compared to 1990 (Figure 5). Seventy-seven percent of the Indian ricegrass plants sampled at the heavily grazed site during the 1990 field season were in size class two. In contrast, Indian ricegrass plants were distributed in relatively equal numbers across size classes one and two during 1991. A similar trend was identified at the moderate and lightly grazed sites. Sixty-seven percent of the Indian ricegrass plants sampled during the 1990 field season at the lightly grazed and relict sites had basal areas greater than 15.0 cm^2 (size class three or greater). However, during the 1991 sampling period, only 38% of the plants had basal areas greater than 15.0 cm^2 at the same two sites.

Plant density and basal area for galleta grass was highly variable for both sampling periods (Table 1). Galleta grass plants were, however, generally less abundant on the relict and the heavily grazed sites (Table 2). Basal area of galleta grass was not significantly affected by a grazing intensity*year interaction. The two-year means for basal area of galleta grass were significantly higher at the moderately and lightly grazed sites compared to the heavily grazed and relict-nongrazed sites. Basal area was significantly lower at the relict site compared to all other sites, while the heavily grazed site had an

1990



1991

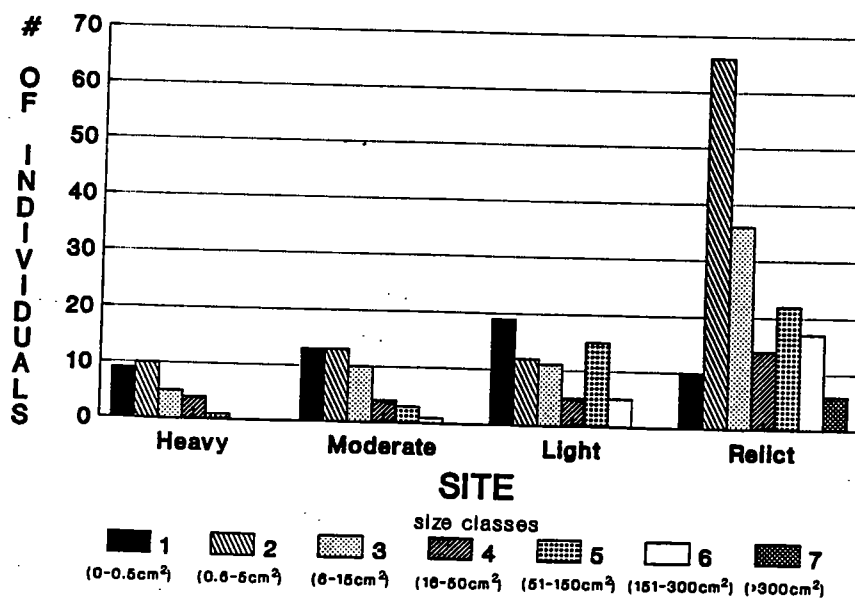


Figure 5. Size class distribution (based on basal area) of individual Indian ricegrass plants recorded on selected heavily grazed, moderately grazed, lightly grazed, and relict-nongrazed Indian ricegrass/galleta grass communities within the NRA during 1990 and 1991.

intermediate value which was significantly different from all other sites.

The density and canopy cover of broom snakeweed was significantly influenced by the interaction of grazing intensity and year (Table 1). Broom snakeweed increased in abundance with increasing grazing intensity in both the 1990 and 1991 field seasons (Table 2). Mean densities were significantly higher at the heavily grazed and moderately grazed sites compared to the lightly grazed and nongrazed sites during both years. However, in 1991 broom snakeweed density at the heavily grazed site was substantially higher than the previous year. Mean canopy cover of broom snakeweed increased with increasing grazing intensity during both 1990 and 1991. However, mean canopy cover values for broom snakeweed at the heavily grazed and moderately grazed sites were substantially higher in 1990 compared to 1991.

A total of six shrub species was recorded on the study sites on Grand Bench (Tables 3 & 4). Although significant differences in density and canopy cover were identified for some species at the different sites along the grazing gradient, shrub populations were highly variable and trends were difficult to identify. However, broom snakeweed shrubs demonstrated a response to grazing similar to the trends identified in the herbaceous layer, increasing at the grazed sites. Mormon tea (Ephedra viridis) and yucca (Yucca sp.) both decreased substantially on the grazed sites, however, these trends may simply be an artifact of site location rather than a result of grazing pressure.

Table 3. Mean density (individuals / ha.) $\pm$ standard error (n=4) for shrub species (individuals $\geq$ 30cm in height) recorded on selected heavily grazed, moderately grazed, lightly grazed, and relict-nongrazed blackbrush/Indian ricegrass communities within Glen Canyon NRA during 1990.

Species	Density (individuals / ha.)			
	Heavy	Moderate	Light	Relict
<u>Atriplex confertifolia</u>	25 $\pm$ 25 _b	150 $\pm$ 29 _a	0 _b	50 $\pm$ 29 _b
<u>Chrysothamnus viscidiflorus</u>	400 $\pm$ 204 _a	25 $\pm$ 25 _b	50 $\pm$ 29 _{ab}	0 _b
<u>Coleogyne ramosissima</u>	200 $\pm$ 0 _{ab}	100 $\pm$ 71 _{ab}	0 _a	275 $\pm$ 170 _b
<u>Ephedra viridis</u>	500 $\pm$ 254 _a	725 $\pm$ 268 _a	1850 $\pm$ 1008 _a	5050 $\pm$ 1588 _b
<u>Gutierrezia sarothrae</u>	875 $\pm$ 160 _a	1675 $\pm$ 131 _b	25 $\pm$ 25 _c	0 _c
<u>Yucca</u> sp.	25 $\pm$ 25 _a	0 _a	500 $\pm$ 261 _b	900 $\pm$ 481 _b
TOTAL	2025 $\pm$ 111 _a	2850 $\pm$ 239 _a	2425 $\pm$ 945 _a	6775 $\pm$ 2001 _b

Means with different letters within rows are significantly different at the $\alpha_e = 0.05$ level (Bonferroni t-test).

Table 4. Mean canopy cover (%) $\pm$ standard error (n=4) for shrub species (individuals $\geq$ 30cm in height) recorded on selected heavily grazed, moderately grazed, lightly grazed, and relict-nongrazed blackbrush/Indian ricegrass communities within Glen Canyon NRA, during 1990.

Species	Canopy Cover (%)			
	Heavy	Moderate	Light	Relict
<u>Atriplex confertifolia</u>	0.21 $\pm$ 0.21 _{ab}	0.61 $\pm$ 0.33 _a	0 _b	0 _b
<u>Chrysothamnus viscidiflorus</u>	3.98 $\pm$ 2.74 _a	0 _b	0.17 $\pm$ 0.17 _b	0 _b
<u>Coleogyne ramosissima</u>	2.66 $\pm$ 0.44 _a	0.54 $\pm$ 0.46 _b	0 _b	2.74 $\pm$ 1.68 _a
<u>Ephedra viridis</u>	1.05 $\pm$ 0.48 _a	0.22 $\pm$ 0.14 _a	0.33 $\pm$ 0.15 _a	1.17 $\pm$ 0.43 _a
<u>Gutierrezia sarothrae</u>	0.39 $\pm$ 0.39 _a	1.95 $\pm$ 0.36 _b	0 _a	0 _a
<u>Yucca</u> sp.	0.10 $\pm$ 0.10 _a	0 _a	0.85 $\pm$ 0.44 _a	1.03 $\pm$ 0.60 _a
TOTAL	8.35 $\pm$ 3.02 _a	3.38 $\pm$ 0.78 _b	1.36 $\pm$ 0.31 _c	4.94 $\pm$ 1.34 _{ab}

Means with different letters within rows are significantly different at the $\alpha_e = 0.05$ level (Bonferroni t-test).

Avian

Fourteen bird species were observed on Grand Bench during the 1990 and 1991 field seasons (Table 5). However, only seven species of birds were detected on the study sites during 1991 using the variable-strip transect method. Avian species diversity was highest at the relict-nongrazed site with a significantly different mean Shannon's diversity value between the relict-nongrazed and heavily grazed sites ($X^2=9.622$, $df=3$, $P<.05$) (Table 6). Comparisons of mean diversity values from all other sites were non-significant.

Total bird density was highest at the relict-nongrazed site ($X^2=8.04$, $df=3$, $P<.05$), while the lowest total density was at the heavily grazed site, where only one species, the black-throated sparrow was observed (Table 6). The small sample size prevented density calculations for the rarer species; thus, density estimates were only calculated for the four most abundant species. Response to grazing across the grazing regime varied somewhat among the different species. No significant differences were found in the population density of the black-throated sparrow across the four sites ($X^2=4.843$, $df=3$, N.S.); however, density values were highest at the relict site. The house finch was sampled only at the relict site, with a mean density significantly greater than at the three grazed sites ($X^2=14.619$, $df=3$, $P<.01$). Brewer's sparrows (Spizella brewerii) and horned larks (Eremophila alpestris) failed to demonstrate any distinct trends in population density along the grazing continuum.

Table 5. Avian species recorded on selected heavily grazed, moderately grazed, lightly grazed, and relict-nongrazed blackbrush/Indian ricegrass communities within Glen Canyon NRA during the 1990 and 1991 field seasons. The 1990 census was accomplished by walking a prescribed 1,000 m route at each sampling site. The 1991 census was accomplished using the variable-strip transect method (Emlen 1971, 1977).

SPECIES

^{4,5} Black-Throated Sparrow	(<u>Amphispiza bilineata</u>)
^{4,5} Horned Lark	(<u>Eremophila alpestris</u>)
^{4,5} House Finch	(<u>Carpodacus mexicanus</u>)
^{4,5} Brewer's Sparrow	(<u>Spizella breweri</u>)
⁴ Ash-Throated Flycatcher	(<u>Myiarchus cinerascens</u>)
¹ Says's Phoebe	(<u>Sayornis saya</u>)
Pinyon Jay	(<u>Gymnorhinus cyanocephalus</u>)
¹ Rock Wren	(<u>Salpinctus obsoletus</u>)
Common Raven	(<u>Corvus corax</u>)
White-Throated Swift	(<u>Aeronautes saxatalis</u>)
Violet-Green Swallow	(<u>Tachycineta thalassina</u>)
Cliff Swallow	(<u>Hirundo pyrrhonota</u>)
^{2,3,4} Gray Vireo	(<u>Vireo vicinior</u>)
^{2,3,4} MacGillivray's Warbler	(<u>Oporornis tolmiei</u>)

¹Observed only in 1990

²Observed only in 1991

³Identification tentative

⁴Species observed in 1991 by the variable-strip transect method

⁵Species included in the population density estimates of 1991 using the variable-strip transect method

Table 6. Mean densities (individuals / 40 ha) $\pm$ standard errors for the four major bird species and total mean bird density recorded at selected heavily grazed, moderately grazed, lightly grazed, and relict-nongrazed blackbrush/Indian ricegrass communities within Glen Canyon NRA during 1991 using the variable-strip transect method (Emlen 1971, 1977). Also shown are Shannon's diversity index values for the avian communities at each of the four sites.

SPECIES	SITE			
	Heavy	Moderate	Light	Relict
<u>Amphispiza bilineata</u>	17.5 $\pm$ 6.3	15.0 $\pm$ 6.5	15.0 $\pm$ 6.5	35.0 $\pm$ 6.5
<u>Carpodacus mexicanus</u>	0 _b	0 _b	0 _b	17.2 $\pm$ 6.2 _a
<u>Eremophila alpestris</u>	0 _b	12.9 $\pm$ 1.4 _a	8.6 $\pm$ 2.9 _{ab}	0 _b
<u>Spizella breweri</u>	0 _b	7.1 $\pm$ 7.1 _{ab}	0 _b	14.3 $\pm$ 4.9 _a
TOTAL BIRD DENSITY	17.5 $\pm$ 6.3 _b	35.0 $\pm$ 12.0 _{ab}	23.6 $\pm$ 4.6 _{ab}	66.4 $\pm$ 8.3 _a
SHANNON'S DIVERSITY INDEX	0 _b	0.59 $\pm$.21 _{ab}	0.34 $\pm$.19 _{ab}	0.92 $\pm$.04 _a

Means with different letters within rows are significantly different at the $\alpha_e = .10$ level (Dunn's Test).

However, Brewer's sparrows had a significantly higher density at the relict site compared with the heavy and light grazed sites where they were not represented ($X^2=10.161$, $df=3$, $P<.01$). A small population of Brewer's sparrows was also identified at the moderately grazed site, but the density estimate was not significantly different from any of the other sites. Horned larks were observed only at the moderately and lightly grazed sites. However, the density estimate for horned larks at the moderately grazed site was significantly higher than all other sites ($X^2=12.064$, $df=3$, $P<.01$).

Rodents

A total of 182 rodents representing seven species was captured during both years at the three trapping sites (Table 7). Ninety-seven individuals were captured in 1990 while 85 individuals were captured in 1991. The total number of rodents captured did not differ significantly among the three grazing intensities ($F_{2,3}=2.69$, N.S.). Shannon's diversity values also did not differ significantly among the grazing treatments ($X^2=0.286$, $df=2$, N.S.).

The abundance of two rodent species varied along the grazing regime (Table 7). The little pocket mouse was the most commonly captured species at each of the three sites for both 1990 and 1991. This species was significantly less abundant at the heavily grazed site ($F_{2,3}=9.63$, $P<0.05$) compared with the lightly grazed and relict sites which did not differ from each

Table 7. Total number of rodents captured during 400 trap-nights and Shannon's diversity indices of rodent communities on selected heavily grazed, lightly grazed, and relict-nongrazed blackbrush/Indian ricegrass communities within Glen Canyon NRA during 1990 and 1991.

Species	Individuals Captured / 400 Trap-Nights		
	<u>heavy</u> 1990 / 1991	<u>light</u> 1990 / 1991	<u>relict</u> 1990 / 1991
<u>Ammospermophilus leucurus</u>	- / -	3 / 1	1 / 1
<u>Dipodomys ordii</u>	2 / -	1 / 2	1 / 1
<u>Neotoma lepida</u>	2 / -	3 / 1	- / 1
<u>Perognathus intermedius</u>	1 / -	- / -	- / -
<u>Perognathus longimembris</u>	16 / 10 _b	29 / 23 _a	26 / 27 _a
<u>Peromyscus crinitus</u>	- / -	1 / 1	1 / 4
<u>Peromyscus maniculatus</u>	7 / 8 _a	1 / 2 _b	2 / 3 _b
TOTAL RODENT ABUNDANCE	28 / 18	38 / 30	31 / 37
SHANNON DIVERSITY INDEX	1.16 / 0.69	0.89 / 0.91	0.66 / 0.98

Number of captures for 1990 and 1991 were used as replicates in one-way analyses of variance testing for differences in total captures and captures of specific rodent species between the three grazing treatments. Number of captures with different letters within rows are significantly different at the $\alpha = .05$ level (Bonferroni t-test).

other. The deer mouse was significantly more abundant at the heavily grazed site ($F_{2,3}=41.3$, $P<0.01$) compared with the lightly grazed and relict sites which did not differ significantly.

Discussion

Vegetation

The response of the vegetation community to grazing was most evident in changes in density and cover of the three major herbaceous species: Indian ricegrass, galleta grass, and broom snakeweed. Mean density and basal area of Indian ricegrass, probably the most palatable forage species within these communities, decreased with increasing grazing intensity; while the mean density and basal area of galleta grass, a species tolerant to grazing, increased with increasing grazing intensity. A similar response of Indian ricegrass and galleta grass to various levels of grazing pressure was also identified by Jeffries and Klopatek (1987) in Indian ricegrass/galleta grass communities of Glen Canyon NRA and the surrounding area.

Desert plants, when defoliated at levels which even moderately reduce vigor, require a significant period of nonuse for complete recovery (Cook and Child 1971). This is especially true for species which do not have appropriate physiological or morphological adaptations necessary to cope with intense grazing pressure (Briske 1986). On Grand Bench, year-round grazing by domestic livestock allows little time for individual Indian ricegrass plants to recover following grazing. This is especially true for sites located near permanent sources of water for livestock, where grazing continues at high intensities. Although Indian ricegrass may withstand moderate grazing by implementing rapid regrowth following defoliation (Cook and Child

1971, Trlica and Orodho 1989), frequent heavy grazing could eventually deplete the carbohydrate reserves necessary for individual plants to recover to previous states of vigor (Orodho and Trlica 1990). In this way, continued heavy grazing at the community level eventually reduces the cover and density of Indian ricegrass, causing shifts in vegetative composition.

As expected, species tolerant to grazing such as galleta grass, whose growth form renders it less susceptible to grazing, did exhibit a concomitant increase in density and basal area under moderate levels of grazing pressure. However, there is a significant decline in both mean density and mean basal area of galleta grass at the heavily grazed site, which may represent a shift in consumer diet selection from Indian ricegrass to galleta grass. This is a characteristic response of a typical increaser species. The decrease in basal area and density of many increaser species under heavy grazing pressure can be explained by shifts in livestock foraging behavior and mechanical disruption of individual plant growth.

A significant interaction effect between year and grazing intensity on the mean basal area of Indian ricegrass was identified along the grazing continuum. Mean basal areas were substantially higher in 1990 compared to 1991 at the moderate, light, and relict-nongrazed sites. The substantial increase in the number of individuals recorded in size class 1 (small, single-stemmed individuals) during 1991 may be attributable to increased success of Indian ricegrass seed germination over

levels of recruitment for 1990. This could be due to favorable germination microclimates during the spring of 1991 for Indian ricegrass seeds, which are highly variable in germination success and length of dormancy (Robertson 1976, Griffith and Booth 1988).

The apparent decline in the number of larger Indian ricegrass individuals (size classes 3-7) recorded at all sites was especially evident at the lightly grazed and relict-nongrazed sites. Such a trend may be the result of increased fragmentation and/or senescence by larger/older Indian ricegrass bunchgrass plants. The process may have been accelerated by 1) grazing during the winter months between the 1990 and 1991 growing seasons, 2) water stress during the spring drought of 1991, or 3) a combination of these two factors. An increase in senesced Indian ricegrass mean density at the relict site and mean basal area at the lightly grazed and relict sites between the 1990 and 1991 growing seasons tends to support this hypothesis.

Broom snakeweed, an unpalatable perennial half-shrub, demonstrated a response to grazing which is typical for an invader species, being absent in the climax and increasing in abundance at the disturbed sites. It is generally recognized that broom snakeweed increases in abundance following heavy grazing, aggressively invading disturbed sites (Jameson 1970, Ueckert 1979). Consequently, broom snakeweed is often considered a valuable indicator of overgrazing on rangelands of Western North America (Jameson 1970).

A significant interaction effect between year and grazing

intensity on both the mean density and mean canopy cover of broom snakeweed was observed along the grazing continuum. Broom snakeweed seems to respond differentially to annual fluctuations in available precipitation along the grazing continuum. It is also possible that the populations are simply undergoing natural oscillations (Jameson 1970). In either case, broom snakeweed could be expected to be more prolific at the heavily grazed sites, which are highly disturbed and have an abundance of available propagules from broom snakeweed plants that already exist in the area.

Avian and Rodent

Avian diversity and total avian density significantly decreased with decreasing distance from the water source. Populations of the black-throated sparrow, house finch, deer mouse, and little pocket mouse responded differentially to the direct or indirect effects of grazing by domestic livestock. Although these preliminary results indicate that avian and rodent populations may be influenced by grazing, several years of data are needed before any valid inferences concerning changes in avian and rodent populations can be made. Trends in animal species distribution must be monitored carefully to determine if the cause is due to current management practices or due to circumstances out of the control of the investigator (precipitation, disease, migration, casualties, etc.). However, it is probable that some of the changes in avian and rodent

density can be attributed to grazing.

Livestock use commonly reduces the abundance of perennial herbs, particularly bunchgrasses which are not grazing tolerant, in a wide variety of habitat types. Within Indian ricegrass communities of Glen Canyon NRA, grazing caused substantial shifts in plant species composition. A decrease in abundance of Indian ricegrass alone, which could be considered a "keystone" resource in these communities, may limit the density of granivorous and omnivorous species inhabiting the community.

The diversity and abundance of animals is strongly dependent upon habitat quality, with different species preferring to reside in areas that have all the necessary habitat requirements for survival and reproduction. Vegetation density, as well as vertical and horizontal patterning of the habitat figure prominently in determining species abundance, distribution, and diversity among North American birds (MacArthur and MacArthur 1961, MacArthur 1964, Wilson 1974, Balda 1975, Cody 1981), and rodents (M'Closkey 1975, Rosenzweig and Winakur 1969, Meserve 1976, Hafner 1977, Price 1978, Holbrook 1979, Parmenter and MacMahon 1983, Brown 1989) in a wide variety of habitat types. Generally, the ability of animals to exploit resources is increased in structurally complex communities compared to structurally simple communities in a wide range of habitat types. Increased plant diversity and productivity probably increase the diversity of seed size and microhabitat as well as other factors, such as seed type and resource predictability (Hanley and Page

supply itself (Cody 1981).

House finches consume virtually no insects and feed nestlings almost entirely on seeds (Ehrlich et al. 1988). This diet preference was evident at the relict community, as house finches were frequently observed foraging on the seed crop of Indian ricegrass and curly dock (Rumex hymenosepalus) (personal observation). The observed pattern in house finch distribution may be partly explained by their dependence on plant material as a food source.

Black-throated sparrows and Brewer's sparrows, both omnivores that feed on a variety of insects and plant products (Smyth and Bartholomew 1966, Petersen et. al. 1986), may not be as highly dependent on plants as food sources, a characteristic which might allow these species to dwell in more heavily grazed communities where plant food resources are less abundant.

No significant trends in total rodent abundance existed along the grazing continuum. However, several rodent species responded differentially to grazing activities of domestic livestock. Abundance of the little pocket mouse was lowest at the heavily grazed site, while deer mouse abundance was highest at the heavily grazed site. These results indicate that the little pocket mouse acts as a "decreaser" under grazing pressure and the deer mouse acts as an "increaser" under grazing pressure within the Indian ricegrass/galleta grass communities studied in this investigation. Similar patterns of differential response to grazing by rodent species have been identified by Hanley and Page

(1981) within Great Basin communities, and by Bock et al. (1984) within a semidesert grassland of southeastern Arizona. These trends may be partially explained by the ecology of each species.

The little pocket mouse has a specific diet, favoring the small, dry seeds of grasses, and only occasionally forages on the shoots and stems of grasses and selected forbs (Brown and Lieberman 1973, Meserve 1976). Because of these feeding characteristics, little pocket mouse populations generally fluctuate in response to the available seed crop (Brown and Lieberman 1973). Indian ricegrass and other grasses growing within communities exposed to significant grazing pressure may experience a reduced seed crop. A significant reduction in food resource availability may, in turn, limit the number of little pocket mice which each grazed community could support on a sustained basis. Furthermore, the little pocket mouse tends to avoid foraging in open areas, instead preferring to glean seeds from the ground beneath shrubs and herbaceous vegetation (Thompson 1982). Again, it can be assumed that the reduction in herbaceous vegetation by livestock grazing could reduce the availability of suitable foraging sites and limit the number of little pocket mice which the community could support (Price 1978).

The diet of the deer mouse has been studied extensively within many different habitat types (Cogshall 1928, Hamilton 1941, Jameson 1952, Williams 1959, Johnson 1961, Whitaker 1966, Drickamer 1970, Osborne and Sheppe 1971, and Meserve 1976).

These studies indicate that the deer mouse has a highly generalized diet, utilizing a wide range of food types including green vegetation, berries, fruits, and seeds of all types of plants, arthropods, and various other items when available. Therefore, the deer mouse may not be as dependent on the seed crop of Indian ricegrass and other grasses as is the little pocket mouse. Because of its generalized diet, the deer mouse could potentially shift its diet to other food sources when seed yields are reduced. Under these conditions, populations of the little pocket mouse could be expected to decrease, thereby reducing the amount of interspecific competition for resources and allowing the population of deer mice to increase.

Heteromyid rodents are of significant abundance within Indian ricegrass/galleta grass communities of the NRA, and they may be important in the dispersal and establishment of Indian ricegrass. The seeds of Indian ricegrass characteristically have low germinability under artificial conditions (McAdoo et al. 1983). Consequently, a long history of research on the germination of Indian ricegrass has attempted to identify how seeds of this species germinate in nature. McAdoo et al. (1983) report that heteromyid rodents selectively harvested "full" Indian ricegrass seeds and rejected empty seeds and polymorphic forms with reduced germination in the Carson Desert of Nevada. Furthermore, rodents cache some of these highly germeable seeds, and in the process remove the lemma and palea, and place the seeds in a favorable microenvironment for germination. They

concluded that the emergence of seedlings from these caches was apparently the primary means of renewing stands of Indian ricegrass at this site.

The importance of Indian ricegrass on these sites may continue to decline, even with a reduction in grazing, as rodent populations could monopolize the limited seed crop and severely inhibit the reestablishment of Indian ricegrass on heavily grazed sites. This situation could potentially develop an alternative stable state community dominated by "increaser" and "invader" species, if the seed production of Indian ricegrass is insufficient to support both resident animals and seedling recruitment. Alternatively, if the little pocket mouse exhibits only a numerical response and not a functional response to decreased seed availability such that they continue the caching behavior, these rodents may be critical to recovery of Indian ricegrass on heavily disturbed sites (McAdoo et al., 1983).

PINYON-JUNIPER COMMUNITY

Study Sites

The pinyon (*Pinus edulis*) -juniper (*Juniperus osteosperma*) study sites are found on the Orange Cliffs and the Block which encompass an area of about 21,800 ha (Figure 6). Elevations range from 1,656 m to 2,135 m. The Orange Cliffs, located about 50 km southeast of Hanksville, Utah include most eastern Wayne and Garfield counties and are adjacent to the eastern border of Canyonlands National Park. The Cliffs have a relatively long history of grazing by sheep and cattle, and is currently grazed year-round by cattle. After reconnoitering the Orange Cliffs area in 1989 and 1990, it was determined that the pinyon-juniper communities throughout the area had been significantly influenced by the activities of domestic livestock. Several springs are scattered over the entire area and grazing appeared to be uniform throughout the Orange Cliffs. Although the heaviest grazing intensity probably occurs closest to permanent sources of water, a definite grazing continuum, similar to the one on Grand Bench, could not be established. Two grazed study sites, Site One and Site Two, were selected for detailed study in 1990 and 1991.

Two areas in western Canyons National Park were considered as potential non-grazed, relict sites in 1990, but they proved to have been either disturbed by livestock in the past or were located on a significantly different substrate. Therefore, a definite relict and/or lightly grazed site could not be located during the 1990 field season. Two relict sites on the Block were

evaluated during the 1991 field season. The Block, 20 km northeast of Hite Marina, Utah, is located south of the Orange Cliffs and is subdivided into a north and south section at an elevation of 2050 m. The Block has not been grazed since the 1930's when it was subjected to winter sheep grazing (Tuhy and MacMahon 1989).

The climate of the region is characterized as arid, temperate, and continental (West 1983). Typical of the Colorado Plateau, peaks in rainfall occur in the spring, midsummer, and fall (Shultz et al. 1987). The 30 year mean annual precipitation measured at Hanksville, Utah is 145 mm (NOAA 1992). Annual precipitation recorded during the investigation at Hanksville was 71 mm for 1989 and 107 mm for 1990. Han's Flat Ranger Station, located near Site One, recorded 158 mm in 1989 and 242 mm in 1990. No long-term information was available for this station (NOAA 1992). Mean monthly temperatures recorded at Hanksville range from -3.5 °C in January to 26.7 °C in July (NOAA 1992).

Soils at the three sites consist primarily of alluvium and eolian deposits derived from the Mellenthin-Rock outcrop-Mido complex. This unit is 30% Mellenthin gravelly fine sandy loam, 30% rock outcrop, 20% Mido loamy fine sand, 15% Begay loamy fine sand, and 5% Mellenthin soils that have a channery surface layer. The Mellenthin gravelly fine sandy loam unit has been classified as a loamy-skeletal, mixed, mesic Lithic Ustollic Calciorthids. This soil has an effective rooting depth of 250-500 mm depending on the location of the bedrock (Jefferies 1989). The Mido loamy

fine sand unit has been classified as mixed, mesic, Ustic Torripsamments with an effective rooting depth of 500 mm (USDA-SCS 1990). The Begay loamy fine sand unit has been classified as coarse-loamy, mixed, mesic, Ustollic Camborthids with an effective rooting depth of 600 mm or more (USDA-SCS 1990).

The vegetation is characterized by piñon-juniper woodland in open stands with shrub and herbaceous species occupying the interstitial spaces. Associated shrubs include, big sagebrush (Artemisia tridentata), roundleaf buffaloberry (Shepherdia rotundifolia), green ephedra (Ephedra viridis), cliff-rose (Purshia mexicana), alder-leaf mountain mahogany (Cercocarpus montanus), Utah serviceberry (Amelanchier utahensis), and Fremont mahonia (Mahonia fremontii). Herbaceous species typically include the perennial grasses; Indian ricegrass, squirreltail (Elymus elymoides), galleta grass, and muttongrass (Poa fendleriana) (USDA-SCS 1990, Tuhy and MacMahon 1988).

Methods

The herbaceous vegetation was evaluated from four parallel 50 m transects spaced 15 m apart within each of the four sites (grazed=Site One & Site Two, Relict=North Block & South Block) selected for detailed study. Twenty-five, 50 X 100 cm quadrats were placed contiguously along each permanent transect beginning 10 m from one end of the transect and ending 22.5 m from the other end. Consequently, a buffer zone was used to reduce the chance that the sampled areas would be disturbed by large

Table 8. continued.

Species	<u>Orange Cliffs, 1990</u>		<u>Orange Cliffs, 1991</u>		<u>The Block, 1991</u>	
	Heavy	Moderate	Heavy	Moderate	North	South
<u>Senecio multicapitatus</u>	-	-	-	-	0.5	T
<u>Streptanthus cordatus</u>	-	-	T	1.5	-	T
<u>Yucca</u> spp.	-	-	T	-	-	0.1
Unkown Forbs	0.9	2.6	0.3	0.3	0.5	0.1
WOODY PLANTS						
<u>Artemisia tridentata</u>	-	0.2	-	T	-	-
<u>Chrysothamnus viscidiflorus</u>	-	T	-	-	-	-
<u>Ephedra viridis</u>	T	0.2	-	-	T	T
<u>Juniperus osteosperma</u>	-	T	-	-	-	T
<u>Pinus edulis</u>	T	0.1	T	0.3	T	T
<u>Purshia mexicana</u>	-	T	-	0.6	T	T
TOTAL ¹	2.0a	2.2a	1.2a	5.5b	6.4b	2.2a

¹ Total means within a year followed by a different letter are different $P < 0.05$, Duncans Multiple Range Test (SAS Institute 1988).

Table 9. Mean plant density (individuals/ha) $\pm$ standard error in the shrub (30cm<shrub<2m) and tree (>2m) strata recorded at two grazed sites on the Orange Cliffs¹ (1990) and on a non-grazed relict site on the South Block² (1991), Glen Canyon National Recreation Area, Utah.

Species	Grazed Orange Cliffs		Non-Grazed South Block
	Site One	Site Two	Relict
SHRUB STRATUM			
<u>Artemisia tridentata</u>	-	300 $\pm$ 38	300 $\pm$ 71
<u>Chrysothamnus vicidiflorus</u>	-	217 $\pm$ 39	-
<u>Ephedra viridis</u>	17 $\pm$ 7	200 $\pm$ 21	275 $\pm$ 63
<u>Juniperus osteosperma</u>	33 $\pm$ 9	67 $\pm$ 14	75 $\pm$ 24
<u>Pinus edulis</u>	150 $\pm$ 18	100 $\pm$ 18	300 $\pm$ 96
<u>Purshia mexicana</u>	-	333 $\pm$ 53	-
<u>Shepherdia rotundifolia</u>	83 $\pm$ 22	117 $\pm$ 32	-
<u>Symphoricarpos longiflorus</u>	-	67 $\pm$ 27	-
<u>Yucca</u> spp.	500 $\pm$ 59	183 $\pm$ 75	200 $\pm$ 20
TREE STRATA			
<u>Juniperus osteosperma</u>	108 $\pm$ 11	100 $\pm$ 5	138 $\pm$ 26
<u>Pinus edulis</u>	192 $\pm$ 10	100 $\pm$ 18	163 $\pm$ 6
<u>Purshia mexicana</u>	-	33 $\pm$ 10	-

¹ n=6

² n=4

decrease in response to frequent and intensive grazing. It is often the seral species that are enhanced by grazing, while climax species are often reduced. We found no consistent trends in vegetation composition among the four sites sampled in 1991 in this study. In this particular community type with its sparse understory vegetation, it may take several years of intensive study using recognized relict sites to detect any shifts in botanical composition which can be related to grazing by domestic livestock. However, evidence from the literature suggests that in desert ecosystems the effects of even light grazing occur quite rapidly while recovery from overgrazing occurs slowly. It is possible that the Block has not fully recovered from grazing conducted in the 1930's; therefore, it is not a true relict site (Tuhy and MacMahon 1988).

We also found no consistent trends in crust cover that could be directly related to grazing by domestic livestock. However, from studies conducted in and around the NRA, it appears that cryptogams may be the most sensitive index of grazing (Kleiner and Harper 1972, Anderson et al. 1982, Jefferies and Klopatek 1987). These researchers reported that even a modest amount of activity by domestic livestock will significantly reduce cryptogamic cover, and heavy use will almost completely eliminate it (Jefferies and Klopatek 1987). Cryptogamic crusts are a major factor in reducing erosion (Booth 1941, Loope and Gifford 1972) and an important source of nitrogen in desert communities (Snyder and Willstein 1973).

RECOMMENDATIONS

It is probable that the observed trends in vegetational change along the grazing continuum can be attributed to effects of grazing by domestic livestock. These changes are evident in the deterioration of range condition at the heavy and moderately grazed sites, which exhibit a distinct decrease in valuable forage grasses, namely Indian ricegrass, and a concomitant increase in the abundance of increaser and invader species. Birds and rodents generally respond to changes in vegetation structure and composition as an indirect consequence of grazing rather than to the direct presence of livestock. Therefore, changes in the habitat could be expected to be reflected in the resident animal populations. The observed changes in rodent and bird species composition and density at these selected sites suggest that animal populations within Indian ricegrass/galleta grass communities are effected by livestock grazing, with species demonstrating differential responses to the grazing pressure. Furthermore, these plant and animal species may serve as valuable indicators of the ecological condition of selected Indian ricegrass/galleta grass communities within Glen Canyon NRA.

Although grazing can always be considered a disturbance to individual plants, it may or may not be considered a disturbance at the community level, depending on the degree to which a particular community is adapted to grazing pressure (Milchunas et al. 1989). However, grazing will, no doubt, elicit a substantial disturbance on biotic communities when it occurs at levels

significantly greater than the community has been exposed to over its evolutionary history (Mack and Thompson 1982). This is likely the case within the Indian ricegrass/galleta grass communities of Glen Canyon NRA as well as other plant communities found west of the Rocky Mountains in North America, where herds of large herbivores have historically been absent (Mack and Thompson 1982). Due to these evolutionary considerations, the Indian ricegrass/galleta grass communities of Glen Canyon NRA are probably not adapted to recover from heavy grazing pressure from large herbivores.

Although the detrimental effects of grazing on vegetation communities may be mitigated by favorable growing seasons, it is doubtful that the heavily disturbed sites will ever improve without sufficient time to recover from continued grazing. Some possible solutions to this problem might be variations in the intensity, duration, and/or timing of grazing which would allow a sufficient amount of time for important forage species to recover. For example, Cook and Child (1971) observed that Indian ricegrass could tolerate light use during all seasons of the year and even moderate use during winter and early spring within desert ranges of western Utah. Furthermore, they found that late spring harvesting was significantly more harmful to Indian ricegrass plants than early spring harvesting. Data such as these suggest that grazing without range deterioration can be maintained within Indian ricegrass/galleta grass communities if management programs allow the communities time to recover or if

series of exclosures at one or, ideally, several locations along the grazing continuum on Grand Bench. This would enable investigators to identify changes that occur in the communities during the recovery process from disturbance to climax.

Exclosures would also allow investigators to manipulate the frequency, duration, and timing that grazing occurs inside the exclosure. This could provide information on the length of time which these communities require for recovery after grazing, as well as data on which times of the year are most conducive to community recovery.

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Table 2. Mean basal area (cm²) $\pm$ standard error (n=100) of major grass species and mean canopy cover (cm²) $\pm$ standard error (n=100) of major forb species recorded on selected heavily grazed, moderately grazed, lightly grazed, and relict-nongrazed Indian ricegrass/galleta grass communities within Glen Canyon National Recreation Area during 1990 and 1991. Species missing from the table were not recorded or had a sample size of < 10 individuals at all of the respective sampling sites.

Species	Heavy		Moderate		Light		Relict	
	1990	1991	1990	1991	1990	1991	1990	1991
GRASSES -----Basal Area (cm2)-----								
<i>Festuca octoflora</i>	T	1.0 $\pm$ 0.3	T	0.3 $\pm$ 0.1	0.5 $\pm$ 0.3	10.1 $\pm$ 1.2	-	12.2 $\pm$ 2.1
<i>Hilaria jamesii</i>	15.4 $\pm$ 1.7	17.9 $\pm$ 2.3	25.3 $\pm$ 3.5	34.0 $\pm$ 5.0	30.8 $\pm$ 4.2	24.1 $\pm$ 3.5	3.1 $\pm$ 0.9	5.5 $\pm$ 1.5
<i>Oryzopsis hymenoides</i>	1.9 $\pm$ 0.7	3.1 $\pm$ 1.2	39.8 $\pm$ 8.6	8.0 $\pm$ 2.9	116.0 $\pm$ 18	29.5 $\pm$ 8.4	200.6 $\pm$ 23	101.0 $\pm$ 16
<i>Sporobolus cryptandrus</i>	0.5 $\pm$ 0.4	5.6 $\pm$ 1.4	1.9 $\pm$ 1.1	3.0 $\pm$ 1.6	T	10.3 $\pm$ 2.2	-	-
FORBS AND CACTI -----Basal Area (cm2)-----								
<i>Erigeron</i> sp.	-	23.5 $\pm$ 9.5	-	T	-	-	-	-
<i>Gutierrezia sarothrae</i>	225.4 $\pm$ 32	125.2 $\pm$ 23	347.0 $\pm$ 46	19.8 $\pm$ 5.9	7.2 $\pm$ 6.1	-	T	T
<i>Hymenopappus filifolius</i>	-	361.7 $\pm$ 43	-	12.6 $\pm$ 5.0	-	163.5 $\pm$ 23	-	-
<i>Lappula occidentalis</i>	-	T	-	-	-	112.3 $\pm$ 33	-	26.3 $\pm$ 9.7
<i>Opuntia erinacea</i>	14.9 $\pm$ 4.9	15.5 $\pm$ 7.2	T	T	30.0 $\pm$ 12	29.4 $\pm$ 10	217.2 $\pm$ 35	245.7 $\pm$ 34
<i>Plantago patagonica</i>	T	T	-	T	-	-	-	73.3 $\pm$ 11
<i>Sphaeralcea parvifolia</i>	T	11.6 $\pm$ 2.3	-	10.5 $\pm$ 2.1	-	42.3 $\pm$ 8.8	10.8 $\pm$ 3.1	27.7 $\pm$ 7.3
<i>Tetradymia</i> sp.	12.0 $\pm$ 7.5	-	-	-	-	-	-	-

- = Species not recorded

T = Sample size < 10 individuals