

REPORT OF RESEARCH AND PROPOSAL FOR FUTURE RESEARCH

Presented to Glen Canyon National Recreation Area

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REPORT OF RESEARCH

SUMMARY

This is a report of research conducted by Douglas L. Jeffries under the supervision of Dr. Jeffrey M. Klopatek from June 1984 until Jan 1987. Five sites dominated by blackbrush (Coleogyne ramosissima Torr.) were studied in the Kaiparowits Basin of southern Utah and northern Arizona. Three sites had a variety of grazing pressures from light to very heavy, one site has had ten years of recovery from heavy grazing, and one site is a relict, ungrazed blackbrush ecosystem. Soils were composed of 87 to 99% sand with pH's between 8.1 and 8.9. The relict site had significantly more herbaceous vegetation cover (composed primarily of perennial grasses) and total cover than all other sites. The relict site also had significantly more shrub and cryptogamic cover than the moderately grazed, heavily grazed and recovering sites. The recovering site showed no significant differences than the heavily grazed site for any of the measured parameters.

INTRODUCTION

Blackbrush (Coleogyne ramosissima Torr.), the dominant species of the blackbrush association, occurs in the southern part of the Great Basin Desert shrub biome from southwestern Colorado, southeastern Utah, and northern Arizona to the northern Mohave Desert region of southern Nevada and California (Turner 1982). Blackbrush is generally considered an ecotonal community between the Mojave and Great Basin Deserts (Beatley 1974, 1975, Cronquist et al. 1972, Wallace and Romney 1972), or the vegetation typified by those areas (Benson and Darrow 1944, Sampson and Jespersen 1963, Rickard and Beatley 1965). However Shreve (1942) and Billings (1949) mention it solely in reference to the Great Basin Desert. Provenza and Urness (1981) comment that the species blackbrush occurs in nearly monospecific stands throughout its range in the southwestern United States (also, Benson and Darrow 1944, Kearney and Peebles 1951, Humphrey 1953, Bowns 1973, Beatley 1975). The blackbrush community is particularly well developed in the southeastern Great Basin Desert (Turner 1982) along the Colorado River drainage system (Cronquist et al. 1972). The blackbrush association encompasses several million hectares in the southwest and yet is probably the least studied major vegetation type in the U. S. (Bowns and West 1976, Turner 1982).

The most important economic use of blackbrush dominated areas is for winter forage by domestic livestock, especially sheep; and large ungulate wildlife, primarily mule deer and

desert bighorn sheep (USDA Forest Service 1937, Humprey 1953, Leach 1956, Sampson and Jespersen 1963, Bradley 1965, Bowns and West 1976).

The shrubs of the blackbrush association are widely spaced with large areas of bare interspace (Rickard and Beatley 1965) and act as "islands of fertility" for nutrients and moisture (Bowns 1973). Herbaceous plants, mainly annual and perennial grasses, occur in the interspace, but their overall cover may be low (Humphrey 1953, 1955, Rickard and Beatley 1965, Bowns 1973). A community of non-vascular cryptogamic plants may also be found in the interspace, sometimes forming a recognizable crust. This cryptogamic crust has been reported to be important in reducing erosion (Booth 1941, Fletcher and Martin 1948, Loope and Gifford 1972), and the portions of the crust with blue-green algae or lichens with a blue-green algal phycobiont maybe important sources of nitrogen for desert ecosystems (Snyder and Wullstein 1973, Rychert and Skujins 1974, West and Skujins 1977).

SITE DESCRIPTIONS

Five sites were studied in the Kaiparowits Basin of southern Utah and northern Arizona. Four sites are within the Glen Canyon National Recreation Area, and one is on the Navajo Indian Reservation. The Navajo Indian Reservation site (NR) (1420 m elev.) is 11 km east of the Glen Canyon Dam and 14 km south of Romana Mesa. This site has experienced yearlong, prolonged, heavy grazing, by cattle, horses, sheep and goats since the

1880's. The Wahweap site (WH) (1245 m elev.) is located 4.6 km northwest of the Glen Canyon Dam and 16 km west of Romana Mesa. This site was received moderate to heavy grazing for several decades. The Ahlstrom Point site (AP) (1415 m elev.) is 17 km northeast of the Glen Canyon Dam and 2.5 km northwest of Romana Mesa. This site had experienced little or no domestic ungulate grazing due to its lack of available water until 1981 when a stock tank was constructed 2 km to the north. Since 1981 it has had light to moderate winter grazing by cattle. Gunsight Bench (GB) (1200 m elev.) is 9 km northeast of the Glen Canyon Dam and 1 km south and directly below Romana Mesa. It was heavily grazed by cattle until 1974 when it was isolated from grazing by the formation of Lake Powell. Romana Mesa (RM) (1450 m elev.) is a completely isolated relic area atop a mesa 16 km northeast of the Glen Canyon Dam. It is a pristine ecosystem that has probably never been grazed or browsed by any ungulate.

Precipitation has been measured at Page, Arizona (elev. 1320 m), located 4 km southwest of the Glen Canyon Dam, since 1957, and at Wahweap (elev. 1170 m), located 7 km north of the Glen Canyon Dam, since 1963. Personal calculations from the Climatological Data reports (NOAA 1957-1985) of the mean annual rainfall through 1985 was 162 mm for Page and 165 mm for Wahweap. [The National Oceanic and Atmospheric Administration does not compute average annual rainfall for reporting sites with less than 30 years of data.]

FIRST RESEARCH OBJECTIVE

The first objective of this study was to investigate the vegetation and edaphic features on sites with a range of grazing pressures and on a site where grazing pressure had been removed. Then, this data was compared to that of the natural potential demonstrated by a relict ecosystem to assess the effects of grazing on this rangeland. This portion of the study has essentially been completed, and the data is given below.

METHODS - First Objective

Five, 100 m random line transects were generated within each site radiating out from a central point. Twenty soil samples, consisting of 3 composites each, were collected from each site for analysis. Two depths (0-5 and 10-15 cm) were sampled from under the shrub canopy and in the interspace on each transect. Particles > 2 mm were removed by sieving and weighed, then soil texture of 100 g of sample was analyzed by the Bouyoucos hydrometer method (Bouyoucos 1928). Soil pH was determined using a 1:1 slurry and glass-rod pH meter, and converted to hydrogen ion concentrations for statistical analysis.

The shrub species were measured every 10 m along the transects by the point-quarter method (Cottam et al. 1953). Measurements included height, crown diameter (widest point), width (perpendicular at widest point), and distance. Ten 0.5 m² rectangular plots located randomly along each transect were used to determine the cover of herbaceous species. Four 0.005 m²

plots were placed at the corners of the 0.5 m² plots to sample the cryptogamic vegetation.

Four of the sites (RM, AP, GB and NR) were surveyed during the summer of 1984. The Wahweap site was surveyed in July of 1985. Plant specimens were collected at AP in May of 1985, and it was noted that the occurrence of annual herbaceous vegetation was very sparse. Nomenclature follows Lehr (1978).

Statistical analysis was performed using the ANOVA procedure and the Tukey studentized range test of the Statistical Analysis System (SAS Institute Inc., 1985) on the IBM 3081 computer of Arizona State University.

RESULTS

The mean percent sand ranged from 93 to 96.5%, silt from 2.1 to 5.1%, and clay from 1.4 to 2.3% (Table 1). Only two samples (n = 100) had percent sand less than 90%. There were some significant statistical differences in sand/silt/clay fractions between sites ($P < 0.05$), but it is unknown whether these differences would be ecologically significant. There was no significant difference in soil texture within each site. The mean pH was not significantly different within sites ($P < 0.05$), but Romana Mesa had a significantly lower pH than any of the other sites (Table 1). Again, it is not known if this difference is large enough to be ecologically significant.

The relict site (RM) had significantly more shrub cover than any other site except AP (Table 2). AP had significantly more shrub cover than GB or NR. The dominant shrub on all sites was

blackbrush, comprising 82.5 to 94.5% of the shrub cover.

RM had significantly more herbaceous vegetation than all the other sites (Table 2), which were not significantly different from one another. The reduced cover of Oryzopsis hymenoides (R. & S.) Ricker, a very palatable grass, was the primary reason for this difference. The cover of Hilaria jamesii (Torr.) Benth., a grass tolerant to grazing, was not significantly different on any of the sites, but as the total herbaceous vegetation cover decreased, the relative percent cover of this species increased.

RM and AP had significantly more cryptogamic cover than the other sites (Table 2). The decrease in cryptogams was mainly due to a loss of crust in the interspace, with the remaining cryptogams being mosses and lichens located under the blackbrush canopy.

RM had significantly more total cover than all other sites, and AP had significantly more than GB and NR (Table 2).

DISCUSSION

The data indicate that even light grazing reduces the cryptogamic cover in this system, and heavier grazing almost completely eliminates it. This agrees with the findings of Kleiner and Harper (1977), West and Skujins (1977), Johansen et al. (1981), Anderson et al. (1982), and Rychert et al. (1982). Highly disturbed areas that were protected from grazing were reported to be recovered by a cryptogamic crust in 14 to 18 years (Anderson et al. 1982), but Callison et al. (1985) found that the

cryptogamic crust in a blackbrush community that was removed by fire had no recovery in 19 years. GB has had virtually no recovery of cryptogams in 10 years.

Herbaceous vegetation cover was greatly reduced on the grazed sites as compared to the relict site. There was also a change in the dominant grass, with Oryzopsis hymenoides being dominant on the relict site, and Hilaria jamesii on the others. Since the relict site cannot be grazed or browsed by wild ungulates, it is hard to assess how much of the difference between sites can be attributed to wild vs. domestic ungulates. The absence of O. hymenoides on the recovering site (GB) is probably due to the very slow recovery of this system (see Westoby 1980), the continued grazing by the rabbit population, or a combination of both factors.

The shrub cover was less on the grazed compared to the relict site, and less on the heavily grazed versus light to moderately grazed sites. Again, it is hard to assess the difference that may be attributed to wild or domestic ungulates.

If we assume that the wild ungulates contribute little to the differences seen in the data, we can make the following conclusions. Cryptogamic cover is reduced by any grazing, with severe damage being done by even moderate grazing usage. It is possible that the development of cryptogamic crusts in sandy or gravelly soils that are characteristic of the blackbrush ecosystem is different than that of heavier textured soils, and recovery is a much more prolonged process. Cover of herbaceous

vegetation is reduced by grazing, primarily due to the removal of the perennial grasses that are not grazing tolerant. Grasses that are grazing tolerant are able to maintain their presence in the system, but do not necessarily benefit from the reduction in cover of the other species. The shrub cover is reduced by light and moderate grazing and reduced even further by heavy grazing. The species blackbrush is able to tolerate heavy grazing, and survive, but at much reduced cover. Recovery of all parameters is very slow in this system, perhaps due to edaphic factors related to the sandy soil, compounded by grazing of large and small wild animals.

The occurrence of blackbrush on Romana Mesa, an isolated area untouched by man or domestic livestock in its entire geologic history, supports one of the theories of West (1969) that it is a climax species. The data from Romana Mesa also support the observations that Blackbrush naturally occurs in nearly monotypic stands.

PROPOSALS FOR FUTURE RESEARCH

The second objective will be to determine the nutrient dynamics of the cryptogamic crust, with special emphasis on the nitrogen cycle, particularly nitrogen fixation. This information will be used to answer the following questions: 1) what is the importance of the cryptogamic crust to the nitrogen input of this arid ecosystem, 2) are significant amounts of fixed nitrogen actually retained within the ecosystem to be potentially utilized

by other components of the system, and 3) what are the potential consequences of loss of the crust by disturbance?

METHODS - Second Objective

Nitrogen fixation will be analyzed using the Acetylene Reduction Assay (ARA) (Shields 1982). Although ARA is an indirect method, it has been extensively used in both laboratory and field studies, including those of soil crusts (Turner and Gibson 1980). The advantages of ARA are; 1) high sensitivity, 2) low equipment and resource costs, 3) simplicity and 4) rapidity of use (Turner and Gibson 1980). Possible side-effects of ARA due to the absence of ATP- and nitrogenase-dependent H_2 evolution in the presence of C_2H_2 are 1) an overestimation of N_2 fixation, 2) increased sensitivity to O_2 in some microaerophilic N_2 -fixing bacteria and 3) the absence of H_2 accumulation in the C_2H_2 reduction assay which could otherwise occur under N_2 with eventual inhibition of nitrogenase by H_2 (Knowles 1980). In addition, since C_2H_2 is not a physiological substrate for nitrogenase, in nitrogen-deficient environments the presence of C_2H_2 leads to the imposition of nitrogen limitations such that growth of N_2 fixers is prevented (Knowles 1980). These disadvantages will be eliminated by utilizing ARA for short durations (< 4 hours) (Stewart 1980). C_2H_2 and C_2H_4 will be measured with a gas chromatograph using a Flame Ionization Detector, a Porapak R (100-120 mesh) 1m x 2mm i.d. glass column,

and N_2 as the carrier gas giving retention times of 1.8 and 1.3 minutes respectively for C_2H_2 and C_2H_4 (Turner and Gibson 1980). It is often assumed that 3 moles acetylene reduced will equal one mole nitrogen fixed (Stewart et al. 1967), although a wide variation of ratio's have been reported. Therefore the C_2H_2 to N_2 ratio will be calibrated by measuring N_2 -fixation directly with N-15 according to (Mague 1978), and analyses by Isotope Services Inc. Environmental parameters such as light, temperature, and moisture will be varied in order to determine optimum conditions for nitrogen fixation of crusts in this ecosystem. In situ measurements of N_2 -fixation will also be made using ARA according to Turner and Gibson (1980).

N-15 will be used to measure nitrogen fixation directly as reported in Mague (1978), and the ratio of acetylene:nitrogen will be determined from the results. Nitrogen will be flushed from shell vials fitted with sleeve-type serum stoppers using Ar:O₂:CO₂ (80:20:.03%). 30% of the gas will be withdrawn and replaced with N-15 giving a pN-15 of 0.3 atm. Samples will be incubated for 30 to 120 min. and then inactivated with 0.5 ml of 5N H₂SO₄. Samples will be analyzed by Isotope Services Inc., Los Alamos, NM.

Either Hilaria jamesii (Torr.) Benth. [Galleta Grass] or Oryzopsis hymeniodies (R. & S.) Ricker [Indian Ricegrass] will be planted and grown for 60 to 120 days in a plexiglass chamber enriched with N-15 and containing a cryptogamic crust to determine if nitrogen fixed by the crust is utilized by

coexisting species. Leaf, stem and root parts will be excised and along with crust core samples will be prepared according to Bergersen (1980) for determination of total $^{15}\text{-N}$ nitrogen . Oven-dried and ground samples will be digested in potassium sulphate and selenium dissolved in sulphuric acid by heating at 250-300 C for 3-4 h. A blank digestion will be included to test for background $^{15}\text{-N}$ and contamination by ammonia in laboratory air. The samples will be distilled in standard Kjeldahl distillation stills (Bergersen 1980). Distillates will be analyzed by Mass Spectrometry at Isotope Services Inc., Los Alamos, NM for presence of N-^{15} .

TIMETABLE

- 1) Collect cryptogamic crust samples from Ahlstrom Point (Feb 1987) and test for presence and abundance of Nitrogen fixation using Acetylene Reduction Assay standardized with N-^{15} in the laboratory. (Mar - Aug 1987)
- 2) Construct plexiglass chamber and collect cryptogamic crust samples (Feb 1987) for determination of use of fixed Nitrogen (N-^{15}) from the crusts by other plants. (Feb - Aug 1987)
- 3) Measure soil depth at all sites (Mar 1987)
- 4) [possible additional experiment] Test blackbrush root nodules for Nitrogen fixation in the field using ARA. (Mar 1987)

The following proposals are suggested to facilitate future research:

a) VIP status is requested for Doug Jeffries to facilitate use of the park 4-wheel drive truck to collect field samples and conduct field experiments in Feb to June 1987. Boat transportation to Gunsight Bench is also requested.

b) Three 10 x 10 m exclosures be placed at each of two sties; Ahlstrom Point and Gunsight Bench, to evaluate the affects of excluding cattle, and/or rabbit grazing.

c) Helicopter time is requested to do a complete floristic survey of Romana Mesa (relict site) in April 1987, and to finish soil measurements.

d) It is further suggested that Ahlstrom Point and Romana Mesa be designated as Wilderness Research Areas.

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Table 1: SOIL AND SITE DATA

GUNSIGHT BENCH (GB) Site #1

Elev: 1196 m

Loc: R5E T43S sec. 33, NE,SE

SOIL					pH	%Carbon	Total Nitrogen	Total Phos
Soil Texture (%)				(mg kg ⁻¹)				
	Sand	Silt	Clay	Gravel				

Transect One								
CT	90.5	1.9	0.9	6.67	8.3	0.2082	36	43
CB	88.4	4.8	1.9	4.95	8.3	0.2839	50	73
IT	85.1	1.8	1.8	11.39	8.3	0.2359	75	110
IB	90.5	3.9	1.9	3.68	8.3	0.3028	127	73
Transect Two								
CT	97.4	1.0	1.0	0.63	8.3	0.2241	64	73
CB	94.1	2.4	1.5	2.03	8.6	0.4732	141	63
IT	87.2	1.3	1.3	10.12	8.4	0.1136	43	82
IB	92.0	1.9	1.9	4.20	8.3	0.3218	134	82
Transect Three								
CT	98.1	1.0	0.1	0.89	8.4	0.2271	57	43
CB	92.9	1.9	1.9	3.20	8.6	0.2460	64	73
IT	89.8	1.2	0.9	7.47	8.5	0.2477	100	110
IB	95.7	1.0	1.0	2.39	8.5	0.2271	57	63
Transect Four								
CT	94.5	3.0	1.0	1.58	8.4	0.4482	45	65
CB	95.6	1.5	1.0	1.97	8.6	0.2359	69	54
IT	82.2	3.5	0.9	13.50	8.4	0.2359	71	82
IB	85.7	3.7	2.8	7.80	8.5	0.2005	57	98
Transect Five								
CT	95.0	1.0	1.0	3.06	8.3	0.4364	124	65
CB	84.6	5.6	2.8	7.05	8.2	0.3500	99	92
IT	93.6	1.0	1.0	4.50	8.5	0.1325	64	73
IB	88.9	5.8	1.9	3.38	8.6	0.4353	155	82

	91.1	2.5	1.4	5.02	8.4	0.2793	82	75

GUNSIGHT BENCH (GB) Site #1

	Calcium	Exchangeable: Magnesium	(mg Kg ⁻¹) Potassium	Sodium

Transect One				
CT	1500	698.5	172.24	40.58
CB	2000	813.7	89.66	39.86
IT	1900	813.7	78.57	24.64
IB	4050	1456.3	121.71	23.92
Transect Two				
CT	650	740.4	105.68	55.07
CB	4500	1267.7	118.01	42.03
IT	2100	967.4	115.54	23.19
IB	8250	1466.81	109.38	29.71
Transect Three				
CT	1500	897.5	57.62	28.26
CB	2250	1054.7	79.81	19.57
IT	1850	796.3	52.69	40.58
IB	2500	908.0	68.71	26.09
Transect Four				
CT	2850	1047.7	63.78	26.09
CB	3200	949.9	73.64	27.54
IT	7300	1473.8	79.80	60.15
IB	13050	1844.0	84.73	63.77
Transect Five				
CT	2100	1026.8	81.03	36.96
CB	29950	5937.1	140.19	131.88
IT	2950	1128.0	63.78	23.19
IB	15500	3771.8	85.96	52.17
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	5547.5	1453.0	92.13	40.76

AHLSTROM POINT (AP) Site #2

Elev: 1415 m

Loc: R5E T43S sec. 16, SW,S

SOIL

	Soil Texture (%)				pH	%Carbon	Total Nitrogen	Total Phos
	Sand	Silt	Clay	Gravel			(mg kg ⁻¹)	

Transect One								
CT	88.9	7.8	1.0	2.35	9.0	0.9085	304	168
CB	91.1	4.9	2.0	2.07	8.5	0.4732	163	123
IT	88.9	6.8	2.0	2.35	8.4	0.5000	172	225
IB	90.6	4.9	1.9	2.63	8.6	0.2650	97	123
Transect Two								
CT	92.1	5.0	2.0	1.00	8.4	0.5544	162	122
CB	84.1	5.5	2.8	7.59	8.5	0.5072	113	131
IT	83.8	5.0	1.8	9.43	8.3	0.3657	196	180
IB	77.3	6.9	1.7	14.09	8.3	0.5190	264	154
Transect Three								
CT	91.1	5.9	2.0	1.00	8.3	0.6724	322	141
CB	94.1	3.5	1.5	1.00	8.5	0.4921	52	111
IT	86.5	5.6	1.9	6.00	8.3	0.1893	134	111
IB	84.9	5.5	1.8	7.75	8.5	0.3028	181	123
Transect Four								
CT	93.1	5.0	1.0	1.00	8.4	0.4732	106	134
CB	93.5	3.0	2.0	1.59	8.6	0.3218	116	111
IT	93.1	4.0	2.0	1.00	8.3	0.4600	124	154
IB	93.9	2.5	2.0	1.65	8.5	0.2650	163	100
Transect Five								
CT	92.1	5.0	2.0	1.00	8.3	1.2150	203	121
CB	93.7	3.0	2.0	1.36	8.6	0.5489	228	111
IT	88.3	4.3	1.9	5.53	8.4	0.4246	45	177
IB	92.5	3.0	2.0	2.63	8.5	0.6246	276	134

	89.7	4.8	1.9	3.65	8.4	0.5041	171	138

AHLSTROM POINT (AP) Site #2

	Calcium	Exchangeable: Magnesium	(mg Kg ⁻¹) Potassium	Sodium

Transect One				
CT	5600	1536.7	140.19	52.90
CB	8250	1508.7	118.01	38.41
IT	7750	1436.3	108.15	52.90
IB	10400	1631.0	87.20	40.58
Transect Two				
CT	7000	1351.6	114.31	49.28
CB	22750	2270.1	157.45	64.49
IT	11750	1498.2	93.36	36.96
IB	36500	2500.6	119.24	64.49
Transect Three				
CT	6800	1362.0	126.64	43.48
CB	6950	1327.1	120.47	60.14
IT	6750	1239.8	89.66	31.16
IB	8700	1274.7	82.27	30.43
Transect Four				
CT	6500	1190.9	108.15	45.65
CB	7250	1211.9	98.29	26.09
IT	4600	859.1	63.78	28.99
IB	6000	988.3	66.24	22.46
Transect Five				
CT	5850	1285.2	110.61	34.06
CB	8900	1292.2	105.68	25.36
IT	8450	1327.1	87.20	35.51
IB	15250	1697.3	90.89	44.93
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	10100	1440.8	104.39	41.41

NAVAJO INDIAN RESERVATION (NR) Site #4

Elev: 1415 m

Loc: 36 52 N, 111 20 W

SOIL

	Soil Texture (%)				pH	%Carbon	Total Nitrogen	Total Phos
	Sand	Silt	Clay	Gravel			(mg kg ⁻¹)	

Transect One								
CT	95.5	0.5	3.0	1.03	8.6	0.5780	130	110
CB	89.9	6.4	2.0	1.72	8.5	0.8138	247	123
IT	88.1	7.7	1.0	3.18	8.6	0.6246	87	111
IB	86.1	6.9	4.9	2.12	8.5	0.3333	276	179
Transect Two								
CT	93.1	3.0	3.0	1.00	8.5	0.4364	126	87
CB	96.0	1.0	2.0	1.06	8.6	0.3184	94	76
IT	95.0	1.0	3.0	1.00	8.6	0.5544	106	110
IB	94.1	4.0	1.0	1.00	8.5	0.2477	100	87
Transect Three								
CT	91.2	6.9	1.0	0.85	8.4	0.2167	31	100
CB	96.6	1.0	2.0	0.40	8.6	0.2000	50	100
IT	97.5	0.5	1.5	0.50	8.2	0.2477	69	54
IB	96.3	1.5	2.0	0.25	8.5	0.1333	87	87
Transect Four								
CT	95.4	3.0	1.0	0.65	8.4	0.2500	172	87
CB	93.3	5.0	1.0	0.75	8.7	0.3500	163	77
IT	95.2	1.0	2.0	1.81	8.6	0.3184	27	121
IB	95.3	2.0	2.0	0.70	8.5	0.3167	87	77
Transect Five								
CT	95.0	1.0	3.0	1.00	8.6	0.4667	148	118
CB	88.4	4.8	1.9	4.95	8.6	0.3667	21	123
IT	89.7	2.4	2.4	5.55	8.6	0.2500	49	134
IB	84.4	4.1	3.2	8.29	8.6	0.2500	97	123

	92.8	3.2	2.1	1.89	8.5	0.3636	108	104

NAVAJO INDIAN RESERVATION (NR) Site #4

	Calcium	Exchangeable: Magnesium	(mg Kg ⁻¹) Potassium	Sodium

Transect One				
CT	1000	1103.6	100.75	58.70
CB	12650	2619.3	159.91	97.10
IT	2650	1250.3	104.45	61.59
IB	17350	2846.3	130.33	77.54
Transect Two				
CT	750	1187.4	87.20	56.52
CB	2350	1421.4	120.47	65.22
IT	750	1114.1	67.48	40.58
IB	6550	2078.0	132.80	66.38
Transect Three				
CT	300	981.4	77.34	41.30
CB	600	949.9	78.57	50.72
IT	350	908.0	57.62	35.51
IB	550	894.1	58.85	21.74
Transect Four				
CT	700	1138.5	93.36	55.07
CB	2400	1397.0	124.17	60.14
IT	3400	1512.2	109.38	63.04
IB	4700	1690.3	126.64	57.25
Transect Five				
CT	1500	1690.3	113.08	67.39
CB	8200	1823.0	147.59	82.61
IT	2150	998.8	81.03	62.32
IB	13350	1941.8	108.15	52.90
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	4112.5	1448.3	103.96	57.68

ROMANA MESA (RM) Site #5

Elev: 1450 m

Loc: R5E T43S sec. 28, SE,SW

SOIL

	Soil Texture (%)				pH	%Carbon	Total Nitrogen	Total Phos
	Sand	Silt	Clay	Gravel			(mg kg ⁻¹)	

Transect One								
CT	95.0	2.5	2.0	0.57	8.1	0.5690	148	132
CB	94.6	2.0	2.0	1.44	8.4	0.2831	188	170
IT	90.7	2.9	1.9	4.50	8.2	0.3184	112	233
IB	93.3	2.4	2.0	2.28	8.2	0.3067	82	210
Transect Two								
CT	94.6	2.0	2.0	1.50	8.4	0.5308	197	177
CB	93.6	3.0	2.0	1.48	8.1	0.4333	71	190
IT	91.7	3.9	2.0	2.46	8.3	0.2167	144	151
IB	92.5	3.9	2.0	1.60	8.4	0.2333	138	111
Transect Three								
CT	93.9	2.0	2.0	2.16	8.4	0.3667	175	131
CB	94.6	2.5	2.0	0.92	8.3	0.2500	111	101
IT	88.5	3.3	1.9	6.33	8.4	0.2167	138	357
IB	93.1	2.9	2.0	1.97	8.3	0.1500	106	121
Transect Four								
CT	93.7	4.0	2.0	0.28	8.1	0.5667	270	210
CB	82.1	4.0	2.2	11.74	8.2	0.5667	251	210
IT	85.4	3.7	2.3	8.69	8.1	0.4600	315	268
IB	65.4	6.8	3.0	24.82	8.2	0.4333	295	387
Transect Five								
CT	94.8	2.0	2.0	1.24	8.1	0.5544	155	177
CB	88.9	5.4	3.4	2.30	8.2	0.4500	226	121
IT	86.3	5.7	2.4	5.69	8.1	0.3067	287	190
IB	88.2	6.8	2.4	2.54	8.2	0.3833	213	141

	90.0	3.6	2.2	4.32	8.2	0.3799	181	189

ROMANA MESA (RM) Site #5

	Calcium	Exchangeable: Magnesium	(mg Kg ⁻¹) Potassium	Sodium

Transect One				
CT	2400	883.6	101.99	21.74
CB	2300	768.3	90.89	24.64
IT	2350	754.4	69.94	21.01
IB	3000	862.6	74.87	15.22
Transect Two				
CT	1900	792.8	76.10	23.29
CB	4000	1051.2	90.89	19.57
IT	2800	967.4	82.27	15.22
IB	4400	897.5	68.71	18.12
Transect Three				
CT	2500	866.1	74.87	22.46
CB	3250	942.9	74.87	14.49
IT	2150	726.4	62.55	10.87
IB	2850	711.9	58.85	13.77
Transect Four				
CT	2500	722.9	88.43	41.30
CB	5350	1295.7	118.01	34.78
IT	2400	754.4	76.10	21.74
IB	9700	1442.4	141.42	32.91
Transect Five				
CT	3400	1100.1	104.45	18.84
CB	6500	1327.1	119.24	34.06
IT	4900	1211.9	99.52	25.36
IB	9000	1215.4	97.06	49.28
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	3882.5	965.3	88.55	23.48

WAHWEAP (WH) Site #6

Elev: 1256m

Loc: R5E T41N sec. 10 SE,SE

SOIL

	Soil Texture (%)				pH	%Carbon	Total Nitrogen	Total Phos
	Sand	Silt	Clay	Gravel			(mg kg ⁻¹)	

Transect One								
CT	95.2	2.5	1.5	0.79	8.8	0.4833	163	62
CB	96.5	1.5	2.0	0.00	8.6	0.3167	119	42
IT	94.1	2.4	1.0	2.48	8.2	0.1887	63	54
IB	94.2	2.0	2.0	1.88	8.5	0.3000	87	62
Transect Two								
CT	95.0	2.0	2.0	1.07	8.7	0.6133	63	20
CB	95.6	1.5	1.5	1.43	8.7	0.6167	150	62
IT	90.3	1.9	1.9	5.99	8.5	0.2500	100	72
IB	94.6	1.5	1.5	2.52	8.6	0.2333	112	41
Transect Three								
CT	96.0	2.5	1.5	0.00	8.3	0.2477	98	54
CB	96.8	2.0	1.0	0.21	8.7	0.2667	81	52
IT	95.6	2.5	1.0	0.93	8.3	0.2167	68	52
IB	96.3	2.5	1.0	0.20	8.6	0.0667	62	42
Transect Four								
CT	94.7	3.5	1.0	0.88	8.6	0.3333	119	42
CB	97.2	0.5	2.0	0.26	8.7	0.3000	87	52
IT	95.7	2.5	1.5	0.33	8.2	0.2005	88	42
IB	95.8	2.5	1.5	0.25	8.4	0.1833	81	42
Transect Five								
CT	96.4	2.0	1.0	0.60	8.6	0.4333	100	54
CB	97.6	1.0	1.0	0.36	8.9	0.2713	51	65
IT	93.2	2.9	1.0	2.94	8.4	0.2241	64	43
IB	95.3	2.0	1.5	1.24	8.6	0.2241	106	98
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	95.3	2.1	1.4	1.22	8.5	0.2985	93	53

WAHWEAP (WH) Site #6

	Calcium	Exchangeable: Magnesium	(mg Kg ⁻¹) Potassium	Sodium

Transect One				
CT	6700	775.3	105.68	3.62
CB	6700	677.5	93.36	5.72
IT	2450	475.0	39.13	0.72
IB	500	656.6	66.24	0.72
Transect Two				
CT	400	576.3	81.03	12.32
CB	800	796.3	82.27	10.87
IT	550	632.1	55.15	0.72
IB	1250	702.0	63.78	10.14
Transect Three				
CT	350	698.5	79.80	2.17
CB	450	632.1	72.41	0.72
IT	400	558.8	48.99	0.72
IB	400	468.0	46.53	0.36
Transect Four				
CT	450	649.6	79.80	0.72
CB	550	646.1	76.10	0.72
IT	300	544.8	42.83	1.30
IB	450	537.8	52.69	0.72
Transect Five				
CT	450	625.1	73.64	0.72
CB	550	639.1	72.41	6.52
IT	400	565.8	50.22	0.72
IB	550	488.9	55.15	2.90
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	1232.5	617.3	66.86	3.16

Table 2: VEGETATION DATA

Shrub, herbaceous, and cryptogamic vegetation cover for blackbrush communities studied in the Kaiparowits Basin.

	¹ SITES				
	RM	AP	WH	NR	GB
Shrub cover (m ² ha ⁻¹)	*3645a	2874ab	2454bc	1405c	1372c
% Blackbrush	87.0a	82.5a	84.0a	91.5a	94.5a
mean area/shrub (m ²)	0.31bc	0.28c	0.56a	0.16d	0.36b
mean distance (m):	0.94b	0.98b	1.54a	1.08b	1.56a
Herbaceous cover (m ² ha ⁻¹)					
	1047a	256b	201b	102b	127b
Orhy cover (m ² ha ⁻¹)	846a	62b	37b	2b	4b
Hija cover (m ² ha ⁻¹)	30a	36a	134a	41a	98a
% Orhy	80a	22b	21b	3b	4b
% Hija	2c	11c	61ab	32bc	76a
Cryptogamic cover (m ² ha ⁻¹)					
	2129a	1196a	100b	70b	50b
Total cover (m ² ha ⁻¹)	6821a	4326b	2755bc	1576c	1549c

¹RM = Romana Mesa (relict), AP = Ahlstrom Point (light grazing), WH = Wahweap (moderate grazing), NR = Navajo Reservation (heavy grazing), and GB = Gunsight Bench (recovering).

*Means in the same row followed by the same letter are not significantly different at the 0.05 probability level as determined by Tukey's studentized range test.

Table 3: LIST OF FLORA

Presence (X) of species on sites studied in the blackbrush association in the Kaiparowits Basin.

Taxon	Family	¹ SITES				
		RM	AP	WH	NR	GB
AGAVACEAE						
<u>Yucca angustissima</u> Engelm.		X		X	X	
CACTACEAE						
<u>Opuntia erinacea</u> Engelm. & Bigel.		X	X	X	X	X
CHENOPODIACEAE						
<u>Atriplex canescens</u> (Pursh) Nutt.		X	X			
<u>A. confertifolia</u> (Torr. & Frem.) Wats.		X				
<u>Grayia spinosa</u> (Hook.) Moq.		X				
COMPOSITAE						
<u>Artemisia filifolia</u> Torr.				X	X	
<u>A. tridentata</u> Nutt.				X		
<u>Chrysothamnus nauseosus</u> (Pall.) Britt.					X	
<u>Xanthocephalum wrightii</u> Gray		X	X	X	X	
CRUCIFERAE						
<u>Lepidium montanum</u> Nutt.		X	X	X		
EPHEDRACEAE						
<u>Ephedra torreyana</u> Wats.		X	X	X	X	X
<u>E. viridis</u> Cov.		X	X			
GRAMINEAE						
<u>Bromus rubens</u> L.		X	X	X	X	X
<u>Erioneuron pulchellum</u> (H.B.K.) Tateoka					X	
<u>Hilaria jamesii</u> (Torr.) Benth.		X	X	X	X	X
<u>Oryzopsis hymenoides</u> (R. & S.) Ricker		X	X	X	X	X
<u>Sporobolus cryptandrus</u> (Torr.) Gray					X	X
<u>Stipa</u> sp.		X	X	X	X	X
<u>Vulpia octoflora</u> (Walt.) Rydb.		X			X	
LEGUMINOSAE						
<u>Astragalus</u> sp.			X			
<u>Lupinus</u> sp.						X
MALVACEAE						
<u>Sphaeralcea grossulariaefolia</u> (H. & A.) Rydb.		X		X		X
PLANTAGINACEAE						
<u>Plantago</u> sp.					X	X

POLYGONACEAE

<u>Eriogonum inflatum</u> Torr. & Frem.	X
<u>Eriogonum</u> sp.	X

ROSACEAE

<u>Coleogyne ramosissima</u> Torr.	X	X	X	X	X
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¹RM = Romana Mesa (relict), AP = Ahlstrom Point (light grazing),
 WH = Wahweap (moderate grazing), NR = Navajo Reservation
 (heavy grazing), and GB = Gunsight Bench (recovering).