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A COMPARISON OF A NEAR-RELICT SITE AND A GRAZED SITE IN A PINYON-JUNIPER COMMUNITY IN THE GRAND STAIRCASE–ESCALANTE NATIONAL MONUMENT, UTAH

Debra Guenther, Thomas J. Stohlgren, and Paul Evangelista

Few areas in the American West have been left ungrazed or undisturbed by cattle, sheep, or goats. However, isolated mesa tops in the Colorado Plateau area offer a rare glimpse of what ecosystems might be like without the influence of domestic livestock; these areas are extremely valuable for research (Van Pelt and Tuhy 1991). Despite their value as control sites, difficulties remain in using these areas for comparative studies. Such sites are often extremely rocky and contain little vegetation. It is also challenging to find paired grazed sites with similar geology, slope, aspect, and vegetation type. Truly pristine sites may be difficult to find, but sites grazed in the distant past can still provide insight into grazing effects and subsequent recovery.

Several studies have examined the effects of grazing by comparing an isolated area to a nearby "mainland" area that has been grazed (Schmutz et al. 1967; Kleiner 1983; Madany and West 1983, 1984; Jeffries and Klopatek 1987; Beymer and Klopatek 1992). Mandany and West (1984) studied mixed conifer, ponderosa pine (*Pinus ponderosa*), and Gambel oak (*Quercus gambelii*) woodlands on two relict mesas in Zion National Park, and concluded that perennial herbaceous species were much more common on the relict mesas than on a nearby grazed plateau. In addition, livestock grazing was considered to be the primary cause for the increased growth in woody species on the grazed plateau due to decreased competition with grass species (Mandany and West 1983). In Grand Canyon National Park, Boysag Point had been grazed by sheep between 1920 and 1943 but has since been ungrazed. Despite the earlier grazing disturbance, perennial grasses had 36 percent cover on the Point compared to the mainland with 6 percent cover, and juniper (*Juniperus monosperma*) trees were significantly more dominant on the mainland (Schmutz et al. 1967).

Grazing comparison studies have also examined cryptobiotic crust cover. Fragile crusts contribute to the Colorado Plateau ecosystem by increasing soil stability, fixing atmospheric nitrogen in the soil, and increasing infiltration (Anderson et al. 1982a; Belnap and Gillette 1998). Jeffries and Klopatek (1987) have studied blackbrush community types in southern Utah and northern Arizona. They found slow recovery of cryptobiotic crusts even after light grazing when compared to a relict mesa. Cryptobiotic crusts in pinyon-juniper communities in Grand Canyon National Park, which also suffer from grazing, were reduced by 80 percent on a grazed site (5.2%) compared to a relict site (23.3%; Beymer and Klopatek 1992).

Other studies have focused on the vegetation or soils of a particular relict or near-relict mesa. Thatcher and Hart (1974) studied vegetation differences based on soil types on Spy Mesa in northern Arizona. Fishtail Mesa in Grand Canyon National Park was studied by Jameson and his colleagues in 1957 (Jameson et al. 1962), and the sampling was repeated 38 years later (Rowlands and Brian 2001). No Man's Mesa in southern Utah was surveyed in the mid-1960s by Mason et al. (1967). On all of these sites, perennial grasses were the dominant species in the herbaceous ground layer on most soil types.

These are all valuable studies; however, some were primarily descriptive studies without a comparison site, and most were conducted using small plot sizes (0.125 to 50 sq m). Our objectives were to examine native and non-native species cover and richness, cryptobiotic crust cover, and soil factors on a grazed and near-relict area using large (1000 sq m) multi-scale plots.

METHODS

One site that we found adequate for a grazing comparison study was No Man's Mesa in the Grand Staircase–Escalante National Monument in Utah (Figure 1), 40 km northeast of Kanab. There is no sign that deer or elk have grazed this mesa, but rabbit droppings were present. Cattle have never grazed the mesa, but it is not a true relict. Goats (and possibly sheep) grazed there in 1927 and 1928 (Mason et al. 1967); however, since then it has remained undisturbed by domestic livestock, with 73 years of recovery at the time of sampling. The mesa is 7 km long and 2 km wide and covers an area of 715 ha. Navajo Sandstone cliffs rise 200–400 m above the base of the mesa, and the elevation on the mesa top ranges from 2072 to 2200 m. The mesa is capped with the Carmel Formation, an erosion-resistant rock (Doelling and Davis 1989). The dominant plant community is pinyon-juniper (*Pinus edulis* and *Juniperus osteosperma*). Other dominant plant species include big sage (*Artemisia tridentata*), gray horsebrush (*Tetradymia canescens*), muttongrass (*Poa fendleriana*), and needle-and-thread grass (*Stipa comata*). Mason and his colleagues (1967), who were interested in assessing range characteristics on the mesa in the mid-1960s, identified two soil types: a sandy upland (479 ha) and sandy shallow breaks (236 ha). We sampled only on the sandy upland soil, which is a well-drained, Preston-like, loamy sand (Mason et al. 1967). Access to the mesa is an old trail on the north side, named the Jepson Trail.

Deer Spring Point is approximately 2 km southwest of No Man's Mesa (Figure 1). It has similar geology, slope, aspect, and vegetation to No Man's Mesa and was chosen for

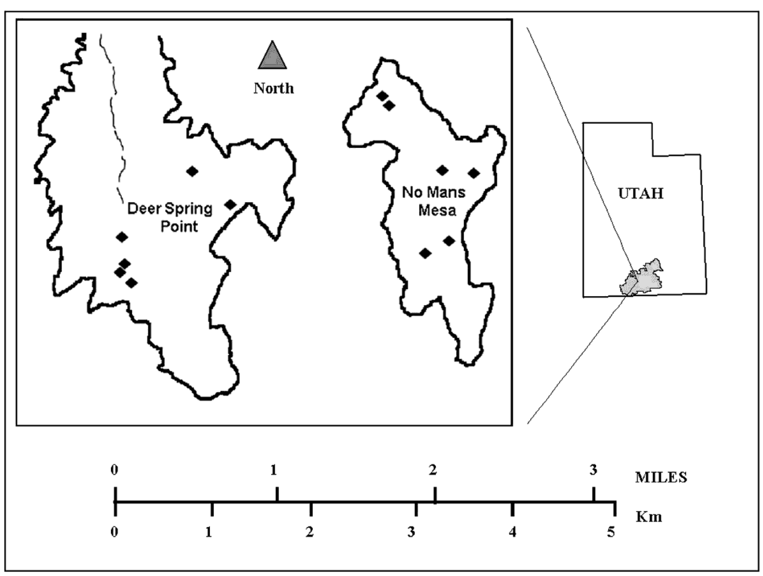

Figure 1. Locations of modified-Whittaker plots (indicated by diamonds) on No Man's Mesa and Deer Spring Point in the Grand Staircase–Escalante National Monument, Utah. The dotted line on Deer Spring Point represents the access road.

the mainland comparison area (Table 1). Its elevation ranges from 2011 to 2228 m. Deer Spring Point has been summer-grazed by domestic livestock since the late 1800s. Dominant plant species include big sage, bitterbrush (*Purshia tridentata*), and manzanita (*Arctostaphylos patula*). The soil is also a loamy sand, very similar to the soil on No Man's Mesa (Table 1). Access is by a dirt road.

We placed six multi-scale modified-Whittaker plots (Stohlgren et al. 1995) in each treatment type (grazed and near-relict) during late June of 2001. An entire plot is 1000 sq m (50 x 20 m) with a 100 sq m subplot in the center, two 10 sq m subplots in the opposite corners, and ten 1 sq m subplots arranged along the borders of the 100 sq m subplot and 1000 sq m plot. The large modified-Whittaker plot size is preferable for maximum capture of species diversity, and the nested design allows comparison at several scales (Stohlgren et al. 1998). At the 1 sq m scale, we measured cover of bare ground, litter, standing duff, woody debris, and foliar canopy cover and average height of vegetation by plant species. We also measured cryptobiotic crust cover according to a development stage gradient from 1 to 20 (U.S. Department of the Interior 1995). Younger crusts (development stages 1–4) are relatively flat and light colored, whereas older well-developed crusts (development stages 6–20) are considerably darker and bumpier, and have associated mosses and lichens. At the 10, 100, and 1000 sq m scales, we recorded the presence of plant species and cryptobiotic crust development stages. The number of cow pats in a 1 ha area including and surrounding the modified-Whittaker plot was used as an index of recent cattle usage. Any dung over 5 cm in diameter constituted a pat, and all pats were counted regardless of age.

Five soil samples collected across the modified-Whittaker plot to a depth of 15 cm were pooled into one plastic bag. Samples were air dried for 48 hours, sieved with a standard #10 (2 mm pore size) sieve, and analyzed for particle size based on the standard hydrometer method (Gee and Bauder 1986). Soil samples were also ground in a standard ball mill grinder and analyzed for total percentage of nitrogen and carbon using a LECO-1000 CHN analyzer (Saint Joseph, Missouri). A volumetric method (Wagner et al. 1998) was used to determine inorganic carbon from carbonates, and organic carbon was calculated by the difference between total and inorganic carbon. Soil phosphorous was measured colorimetrically from a sodium-bicarbonate extraction (Kou 1996).

We used systematic random sampling for plot placement. No Man's Mesa was divided into three sections: north, central, and south, and two plots were placed randomly in each section (however the sandy shallow breaks soil type in the west-central portion of the mesa was avoided). Sites on Deer Spring Point were chosen that corresponded to similar geology type, soil type, vegetation type, slope, and aspect. The exact plot location was then chosen randomly within the analogous area. Cover analysis was based on a sample size of sixty 1 sq m subplots per treatment. Data was analyzed using SYSTAT (version 10.0, SPSS, Inc.) with two sample t tests and an alpha value of 0.05. Strongly skewed data were transformed using a $\log_{10}$ transformation prior to analysis. When calculating percent difference in native species richness between sites we used the following formula: percent difference = [(site 1 species richness – site 2 species richness) / site 1 species richness] x 100.

RESULTS

Our data revealed that the soils on No Man's Mesa and Deer Spring Point were very similar. Sand, silt, and clay percentages on No Man's Mesa (83.2%, 5.3%, and 11.5% respectively) and on Deer Spring Point (83.6%, 6.3%, and 10.1% respectively) were nearly identical. There were also no significant differences in the nitrogen, phosphorous, or organic carbon values between the two sites (Table 1). More litter, bare ground, and woody debris cover occurred on Deer Spring Point than on No Man's Mesa (Table 2). Cover of young cryptobiotic crusts was 27 percent less on Deer Spring Point com-

Table 1. Comparison of No Man's Mesa and Deer Spring Point site characteristics. T tests for soil comparisons had p values of 0.60, 0.81, and 0.58 for carbon, nitrogen, and phosphorous, respectively.

Characteristic	No Man's Mesa	Deer Spring Point
Geological substrate	Navajo Sandstone capped by Carmel Fm	Navajo Sandstone capped by Carmel Fm
Elevation range	2072–2200 m	2011–2228 m
Slope range	0–5 %	0–5 %
Aspect range	north-northwest	north-northwest
Plant community type	pinyon-juniper	pinyon-juniper
Soil texture	loamy sand	loamy sand
Soil organic C (%)	0.543	0.657
Soil N (%)	0.047	0.051
Soil P (mg/kg)	2.88	2.45
Sampling period	20–27 June 2001	23–29 June 2001
Average pat count	0	294 (143 MSE)

Table 2. Mean, standard error values, and p values for two sample t tests for cover of abiotic variables, vegetation, cryptobiotic crusts, annual and perennial plants, plant life form, and plant species origin (n = sixty 1 sq m plots per site) on No Man's Mesa and Deer Spring Point.

Variable	No Man's Mesa	Deer Spring Point	P value
Bare ground	7.1 (1.4)	13.9 (2.2)	0.010
Litter	30.0 (4.2)	45.8 (4.8)	0.053
Standing duff	2.7 (0.4)	0.25 (0.1)	0.001
Woody debris	3.8 (1.0)	6.2 (1.2)	0.004
Total cryptobiotic crust	46.3 (4.2)	30.1 (4.0)	0.020
Young crypto	36.4 (3.7)	26.6 (3.5)	0.056
Well-developed crypto	9.8 (2.2)	3.5 (1.1)	0.012
Total vegetation	30.9 (4.0)	44.4 (4.7)	0.081
Annual plants	0.6 (0.1)	1.4 (0.1)	0.001
Perennial plants	30.3 (4.0)	43.0 (4.7)	0.140
Forb	2.9 (0.3)	2.4 (0.2)	0.200
Grass	3.5 (0.5)	2.6 (0.4)	0.142
Subshrub	3.1 (0.5)	1.8 (0.4)	0.033
Shrub	3.8 (0.9)	18.9 (3.6)	0.001
Tree	17.6 (4.0)	18.6 (4.1)	0.730
Non-native plants	0 (0)	0.02 (0.01)	none
Native plants	30.1 (3.9)	43.6 (4.6)	0.085

pared to No Man's Mesa. Cover of older well-developed cryptobiotic crusts was 60 percent less on Deer Spring Point compared to No Man's Mesa.

No Man's Mesa and Deer Spring Point are both dominated by perennial species (Table 2). Few annual species were found at either site, but significantly more annual cover was found on Deer Spring Point (1.4% ± 0.1% MSE) than on No Man's Mesa (0.6% ± 0.1% MSE). No significant differences were found between forb or tree cover on Deer Spring Point versus No Man's Mesa (Table 2). Less grass cover occurred on Deer Spring Point (2.6% ± 0.4% MSE) than on No Man's Mesa (3.5% ± 0.5% MSE), but the difference was not significant ($p = 0.142$). Significantly more subshrub cover occurred on No Man's Mesa (3.1% ± 0.5% MSE) than Deer Spring Point (1.8% ± 0.4% MSE). *Opuntia* spp. combined represented 1.2 percent of the average cover on No Man's Mesa and only 0.2 percent of the average cover on Deer Spring Point (Table 3). A major site difference occurred in shrub cover, with significantly more cover on Deer Spring Point (18.9% ± 3.6% MSE) than on No Man's Mesa (3.8% ± 0.9% MSE). The average cover of the dominant shrubs on Deer Spring Point included 7.3 percent bitterbrush, 4.4 percent manzanita, and 3.7 percent big sage (Table 3).

Consistently greater total vegetation cover and greater native vegetation cover was found on Deer Spring Point (Table 2). No exotic species were detected in our plots on No Man's Mesa, although a few cheatgrass individuals were encountered off the plot. Four non-native species found in the plots on Deer Spring Point were flixweed (*Descurainia sophia*), cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum*), and lambsquarter (*Chenopodium album*). Endemic species found on No Man's Mesa included southwestern beardtongue (*Penstemon laevis*), a regional (Colorado Plateau) endemic, and Paria breadroot (*Pediomellum pariense*), a local endemic (primarily Kane and Garfield Counties). In addition to these two species, Newberry's twinpod (*Physaria newberryi*), a regional endemic, occurred on Deer Spring Point.

Mean native species richness at the 1 sq m and 1000 sq m plot scale was 7.1 ± 0.45, 42.2 ± 8.0 MSE for Deer Spring Point and 6.5 ± 0.3, 44.2 ± 5.0 MSE for No Man's Mesa, respectively. There was no significant difference in mean native plant species richness at the 1 sq m scale (n = 60 subplots per site, p = 0.30), and no significant difference at the 1000 sq m scale (n = 6 plots per site, p = 0.61). However, cumulative native species richness for all six 1000 sq m plots combined was higher on No Man's Mesa (84 species) than on Deer Spring Point (71 species; Figure 2). Species accumulation curves, when extrapolated to 1 ha in size (n = 10 modified-Whittaker plots per treatment), predicted No Man's Mesa to have 98 species and Deer Springs Point to have 82 species.

DISCUSSION

Cattle trampling is the most probable explanation for increased bare ground and less cryptobiotic crust cover on Deer Spring Point. Older, well-developed crusts were the most negatively affected, probably due to little recovery time between grazing episodes (Anderson et al. 1982b; Beymer and Klopatek 1992). Not only does trampling increase soil erosion and reduce the nitrogen-fixing benefits of the crusts (Belnap 1996), but the microsite disturbance can also create open sites for non-native species, which often cannot germinate in or compete with intact, well-developed cryptobiotic crust (Stohlgren et al. 2001).

There was no significant difference in grass cover between Deer Spring Point and No Man's Mesa, but there was a difference in composition. Muttongrass (*Poa fendleriana*) and needle-and-thread grass have approximately twice as much cover on No Man's Mesa as on Deer Spring Point. Similar to other studies, muttongrass is the most dominant grass species on No Man's Mesa (Jameson et al. 1962; Rowlands and Brian 2001; Beymer and Klopatek 1992). During the study in the 1960s, Mason et al. (1967) also recorded muttongrass and *Poa nevadensis* as dominant grass species along with Indian ricegrass (*Stipa hymenoides*), needle-and-thread grass, and prairie junegrass (*Koeleria macrantha*).

One very apparent difference between the two sites was shrub cover. There was considerably less shrub cover on No Man's Mesa but increased diversity, including six species of shrubs found on No Man's Mesa but not present on Deer Spring Point. Mason et al. (1967) also reported a wide diversity of shrubs on No Man's Mesa dominated by big

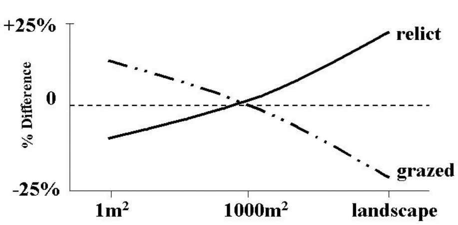

Figure 2. Percent difference in mean native species richness for No Man's Mesa and Deer Spring Point at sixty 1 sq m subplots per treatment, six 1000 sq m plots per treatment, and the sum of six plots in each treatment (landscape).

Table 3. Species contributions to average cover (%) and frequency (%) for No Man's Mesa and Deer Spring Point in the Grand Staircase–Escalante National Monument, Utah. Plant species with only frequency values did not occur in the 1 sq m subplots where cover was recorded but did occur in the larger plots where strictly presence was recorded. Non-native species are in bold.

	No Man's Mesa		Deer Spring Point	
Species	n = 60 cover	n = 6 frequency	n = 60 cover	n = 6 frequency
Trees				
Juniperus osteosperma	8.73	100.0	8.25	100.0
Pinus edulis	5.31	100.0	10.20	100.0
Quercus gambelii	3.59	50.0	0.17	83.3
Shrubs				
Artemisia tridentata	1.42	83.3	3.65	83.3
Tetradymia canescens	0.94	50.0	–	50.0
Artemisia campestris	0.37	50.0	–	–
Symphoricarpos oreophilus	0.34	33.3	–	–
Purshia tridentata	0.32	100.0	7.27	100.0
Chrysothamnus nauseosus	0.23	16.7	0.47	33.3
Chrysothamnus vaseyi	0.23	16.7	–	–
Arctostaphylos patula	0.15	16.7	4.43	33.3
Chrysothamnus linifolius	0.08	50.0	0.02	16.7
Ephedra viridis	0.06	66.7	0.63	33.3
Amelanchier utahensis	–	50.0	1.17	66.7
Cercocarpus montanus	–	33.3	0.13	33.3
Chrysothamnus viscidiflorus	–	16.7	–	–
Eriogonum corymbosum	–	33.3	–	–
Eriogonum microthecum	–	16.7	–	–
Peraphyllum ramosissimum	–	–	–	33.3
Subshrubs				
Eriogonum umbellatum	0.79	100.0	0.78	100.0
Opuntia spp.	0.76	66.7	0.13	16.7
Leptodactylon pungens	0.52	66.7	0.4283.3	–
Phlox austromontana	0.38	66.7	0.2666.7	–
Opuntia erinacea	0.35	33.3	0.0666.7	–
Gutierrezia sarothrae	0.25	66.7	0.2266.7	–
Opuntia polyacantha	0.05	16.7	–	–
Yucca angustissima	–	33.3	0.02	33.3
Yucca spp.	–	50.0	–	–
Graminoids				
Poa fendleriana	1.20	66.7	0.55	66.7
Stipa comata	1.04	100.0	0.64	66.7
Perennial grass	0.73	66.7	0.70	66.7
Stipa hymenoides	0.15	100.0	0.18	83.3
Vulpia octoflora	0.13	50.0	0.33	83.3
Koeleria macrantha	0.12	33.3	–	33.3
Muhlenbergia spp.	0.08	16.7	–	–
Carex rossii	0.07	16.7	–	–
Elymus elymoides	0.01	16.7	0.02	50.0
Carex spp.	–	16.7	0.03	33.3
Hilaria jamesii	–	16.7	0.02	16.7
Muhlenbergia pungens	–	16.7		
Sporobolus cryptandrus	–	16.7	–	–
Distichlis spicata	–	–	0.16	16.7
Agropyron cristatum	–	–	–	**16.7**
Bromus tectorum	–	–	–	**50.0**

Table 3 (continued)

Species	No Man's Mesa		Deer Spring Point	
	n = 60 cover	n = 6 frequency	n = 60 cover	n = 6 frequency
Forbs				
Lesquerella ludoviciana	0.38	100.0	0.15	83.3
Arenaria fendleri	0.32	83.3	0.21	50.0
Cryptantha cinerea	0.19	50.0	0.12	66.7
Cordylanthus parviflorus	0.18	100.0	0.09	66.7
Phoradendron juniperinum	0.15	100.0	0.03	33.3
Hymenopappus filifolius	0.13	83.3	0.09	66.7
Penstemon comarrhenus	0.12	83.3	0.02	66.7
Astragalus spp.	0.10	66.7	0.11	83.3
Eriogonum racemosum	0.08	50.0	–	33.3
Penstemon pachyphyllus	0.08	16.7	–	–
Gayophytum ramosissimum	0.08	33.3	0.02	16.7
Pedicularis centranthera	0.07	33.3	0.03	33.3
Penstemon leiophyllus	0.07	16.7	–	–
Gilia spp.	0.07	33.3	0.08	16.7
Phlox hoodii	0.05	16.7	–	–
Chaetopappa ericoides	0.03	16.7	–	–
Penstemon laevis	0.03	33.3	0.02	66.7
Erigeron pumilus	0.03	33.3	0.11	83.3
Annual forb	0.03	50.0	0.06	50.0
Arabis perennans	0.03	16.7	0.03	16.7
Astragalus bisulcatus	0.03	16.7	–	–
Erigeron eatonii	0.03	83.3	0.05	50.0
Polygonum douglasii	0.03	16.7	0.07	16.7
Gayophytum spp.	0.03	16.7	0.24	83.3
Comandra umbellata	0.02	83.3	0.08	50.0
Lupinus sericeus	0.02	16.7	–	–
Gilia inconspicua	0.02	16.7	–	–
Phacelia demissa	0.02	16.7	0.17	66.7
Trifolium spp.	0.02	33.3	0.01	16.7
Calochortus nuttallii	0.01	83.3	0.03	66.7
Delphinium andersonii	0.01	33.3	0.08	66.7
Eriogonum alatum	0.01	33.3	0.02	16.7
Eriogonum inflatum	0.01	33.3	–	–
Hymenoxys acaulis	0.01	16.7	–	–
Lappula occidentalis	0.01	16.7	0.03	16.7
Lomatium spp.	0.01	33.3	–	–
Lygodesmia grandiflora	0.01	33.3	–	–
Arabis spp.	0.01	50.0	0.03	16.7
Abronia fragrans	–	33.3	–	–
Arabis hirsuta	–	16.7	–	–
Astragalus convallarius	–	16.7	–	–
Crepis acuminata	–	16.7	0.02	33.3
Cryptantha flava	–	16.7	–	–
Crepis intermedia	–	16.7	–	–
Delphinium nuttallianum	–	16.7	–	–
Lomatium foeniculaceum	–	16.7	–	–
Machaeranthera canescens	–	50.0	–	–
Machaeranthera grindelioides	–	33.3	–	–
Orobanche fasciculate	–	16.7	33.3	
Oxytropis spp.	–	16.7	–	–
Penstemon angustifolius	–	16.7	16.7	–
P. angustifolius var. *venosus*	–	16.7	–	–

Table 3 (continued)

Species	No Man's Mesa n = 60 cover	No Man's Mesa n = 6 frequency	Deer Spring Point n = 60 cover	Deer Spring Point n = 6 frequency
Forbs (cont.)				
Penstemon spp.	–	16.7	0.02	50.0
Pediomelum pariense	–	16.7	–	33.3
Penstemon utahensis	–	33.3	–	–
Gilia leptomeria	–	–	0.08	33.3
Perennial forb	–	–	0.02	16.7
Castilleja linariifolia	–	–	0.01	16.7
Descurainia sophia	–	–	**0.02**	**33.3**
Mentzelia albicaulis	–	–	0.02	16.7
Microsteris gracilis	–	–	0.14	83.3
Phlox gracilis	–	–	0.04	33.3
Physaria newberryi	–	–	0.01	16.7
Agoseris glauca	–	–	–	16.7
Arceuthobium divaricatum	–	–	–	16.7
Chenopodium album	–	–	–	**16.7**
Ipomopsis aggregata	–	–	–	16.7
Linum lewisii	–	–	–	16.7
Streptanthus cordatus	–	–	–	16.7

sage, prickly pear, manzanita, bitterbrush, and horsebrush, along with Mormon tea (*Ephedra viridis*), buckwheat (*Eriogonum* spp.), snowberry (*Symphoricarpos oreophilus*), and others. However, 86 percent of the shrub cover on Deer Spring Point was dominated by only three shrub species: bitterbrush, manzanita, and big sage. The greater shrub cover on Deer Spring Point can most likely explain the greater total vegetation cover and increased litter cover on the site. Other studies have shown increased woody tree and shrub cover in grazed areas due to decreased competition with perennial grasses (Mandany and West 1983; Schmutz et al. 1967). Beymer and Klopatek (1992) theorized that a decrease in cryptobiotic crusts along with the grazing of cool-season grasses can result in a time at which the herbaceous vegetation can no longer respond quickly enough, thereby allowing woody trees and shrubs to dominate.

Winterfat (*Ceratoides lanata*) is a good indicator of grazing intensity, but it is absent on both sites. It is possible that the goats ate most of it in 1927 and 1928; however, it was present on Boysag Point, which had more intensive grazing by sheep and had only 16 years of recovery before sampling began (Schmutz et al. 1967). It may not have been common enough to have been encountered in our plots, or it may simply be absent on that particular geology type.

Due to increased physical disturbance, we anticipated finding considerably more invasive non-native species on Deer Spring Point (Stohlgren et al. 2001), but that was not the case. Non-native species were not very abundant on either the grazed or relict site. Only one non-native species was detected in the 1 sq m plots (flixweed on Deer Spring Point). Three more additional non-native species were recorded in the 1000 sq m plots (lambsquarter, crested wheatgrass, and cheatgrass) on Deer Spring Point. Our use of large-scale plots aided in detecting these species. Though not abundant, more non-native species were discovered on the long-term grazed site, with the potential for future large-scale invasion.

Mean native species richness at the 1000 sq m plot scale was remarkably high on both the grazed (42.2 ± 8.0 MSE) and relict sites (44.2 ± 5.0 MSE). These values far exceed the average value for native species richness for pinyon-juniper plots on the Grand Staircase–Escalante National Monument (27.1 ± 0.73 MSE) and even exceeded values from species-rich mesic sites such as aspen stands or wet meadows, which have an average of 32.3 (3.1 MSE) and 30.2 (4.9 MSE) species respectively in the same 1000 sq m area (Stohlgren et al. 2001). Harner and Harper (1976) found an average of 52.2 plant species per hectare in pinyon-juniper communities in Utah. However, extrapolating our species accumulation curves, we could find 98 species in a hectare on No Man's Mesa and 82 species in a hectare on Deer Spring Point. Xeric mesa tops seem unlikely to support such high levels of diversity. We did encounter three endemic species in our plots that are common in drier, harsher environments such as a mesa top (Stebbins 1952); however this surely does not account for such high species richness and low number of non-native species. Perhaps the geology type or relative isolation can explain this phenomenon.

Our use of large, multi-scale plots allowed us to examine the difference in native species richness at several scales. Although it appears as though grazing microsite disturbance increases species richness at a small (1 sq m) scale, there is a homogenization of species richness at the landscape (6000 sq m and 1 ha) scale, which is the scale with which managers are most concerned. Also, although grazing does not appear to directly affect non-native species invasions at this site, it may indirectly affect future invasions. The increase in shrub and litter cover increases fuel for possible future fires. Data gathered near the Buckskin Mountain area of the monument indicate that fire disturbance greatly increases cheatgrass and other exotic species cover if a seed source is present (Evangelista, unpublished data, Colorado State University). Although not very common, cheatgrass is present on Deer Spring Point. Subsequent fires could cause non-native species to spread throughout the burned area. Once a cheatgrass fire cycle is introduced into this system, a negative feedback loop is formed wherein the cheatgrass provides fuel for future fires which in turn allows it to persist and spread further (D'Antonio and Vitousek 1992).

ACKNOWLEDGMENTS

The authors would like to thank Mark Miller, Chris Killingsworth, Amy Randell, Rod Rochambeau, Ben Chemel, Nate Alley, Trina Mitchell, Lisa Dardy, Jeanette Haddock, and Rick Shory for their assistance with logistical information, fieldwork, and data analysis. We also thank John Spence, Dave Clausnitzer, and Matthew Loeser for their helpful comments and review. This research project is supported by the Bureau of Land Management, Grand Staircase–Escalante National Monument.

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