Western North American Naturalist 62(4), ©2002, pp. 414–422

VEGETATION RESPONSE TO PRESCRIBED FIRE IN DINOSAUR NATIONAL MONUMENT

Barry L. Perryman[1], Richard A. Olson[2], Stephen Petersburg[3], and Tamara Naumann[3]

ABSTRACT.—Much of western North America is dominated by dense, monotypic, late seral stands of big sagebrush (*Artemisia tridentata* Nutt.). These stands often have depauperate understories with limited species richness, diversity, and herbaceous cover. The National Park Service at Dinosaur National Monument, Colorado, is using both strategic and natural prescribed fire in Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle and Young) communities to foster intra-community (α-scale) and landscape diversity. This study analyzed an accumulated foliar cover data set between paired burn and control areas on 6 different sites during the last 20 years. Across the monitoring period, mean total vegetation cover of all combined sites was 44% control and 42% burn. Total vegetation cover in burn areas was higher than or equal to paired control areas within 2–3 years post-burn. Shrubs were essentially eliminated in burn areas, but perennial grass cover was 10–35% higher. Mean number of species on all sites and years combined was 17 control and 18 burn. Species richness was different on only 1 site-year, Dry Woman 1995 ($P = 0.001$, 15 control, 9 burn). Species similarity by site and between treatments ranged from 44% to 75%. Differences in Shannon-Weiner diversity index values between paired sites occurred in 6 of 20 years ($P < 0.05$). Index value differences on these 6 sites were due to a large annual grass component in burn areas. Prescribed burning successfully shifted late successional sagebrush-dominated communities to earlier herbaceous-dominated successional stages without lowering total vegetation cover, while maintaining α-scale diversity and species richness.

Key words: prescribed fire, vegetation cover, community diversity, species richness.

More than 54 million ha in western North America are dominated by big sagebrush (*Artemisia tridentata* Nutt.; Whitson and Alley 1984). Late seral or climax sagebrush stands are often dense and monotypic with limited species richness, diversity, and herbaceous cover in the understory (Johnson et al. 1996, West 1999), a condition due in large part to fire suppression activities and/or poor grazing management. In either case decadent, late seral sagebrush communities are left in a stable ecological state that requires energy input to shift the stand from a shrub- to a grass-dominated domain (Archer 1989, Laycock 1991). Brush control measures in decadent sagebrush stands foster intra-community (α-scale) species richness and diversity (Olson et al. 1994, Johnson et al. 1996) as well as landscape patch richness and diversity.

Anecdotal accounts by early residents of the Dinosaur National Monument, Colorado, area suggest large areas of the monument were dominated at that time by native perennial grasslands. Domestic livestock began grazing the monument area in the late 1800s, increased beginning in the 1920s, reached a peak authorized level of 35–40,000 AUMs on 56,000 ha in the 1940s, and, based on rangeland surveys, reduced to 5000 AUMs by 1973. Resource managers believe that intensive grazing pressure during those 2 decades, in coincidence with the drought of the 1930s and the initiation of effective fire suppression activities circa 1940, all contributed to a shift from grassland to big sagebrush–dominated communities. Under a 1916 Congressional mandate to conserve and protect the natural resources of National Park Service lands, resource managers initiated a complex fire management program in the early 1980s. The program includes both strategic prescription burns and prescribed natural fires. Prescribed natural fires are defined as natural ignitions allowed to burn within strict constraints of location, proximity to monument boundaries, and threats to life and property. Both ignition sources reintroduced fire into stable, decadent Wyoming sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle and Young) stands. The goal is to shift community composition from brush to perennial grassland dominance and foster

[1]School of Veterinary Medicine, College of Agriculture, Biotechnology, and Natural Resources, University of Nevada–Reno, MS 202, Reno, NV 89557.
[2]Department of Renewable Resources, College of Agriculture, University of Wyoming, PO Box 3354, Laramie, WY 82071.
[3]USDI, National Park Service, Dinosaur National Monument, 4545 East Hwy 40, Dinosaur, CO 81610.

α-scale and landscape diversity in these plant communities. A post-fire monitoring program was implemented in 1984 after the 1st prescribed burn with follow-up sampling in succeeding years. In 1998 the National Park Service decided to analyze the post-fire monitoring data collection.

The specific objectives of this project were to (1) assess plant cover trends in paired burn and control areas, (2) assess intra-community (α-scale) plant species richness and diversity between paired burn and control areas, and (3) assess species richness similarity between burned and control species suites.

STUDY AREA

Study sites are within the boundary of Dinosaur National Monument, Colorado/Utah, on the east end of the Uinta Mountains in the northwest corner of Colorado with a small portion in northeastern Utah. The monument is centered on the confluence of the Green and Yampa rivers and best described as bench and canyon topography. Elevations range from 1700 to 2740 m. Annual precipitation ranges from 20 to 38 cm.

Predominant vegetation type varies by elevation. At lower elevations near springs and water courses, riparian tree and shrub communities are represented by willows (*Salix* sp.), boxelder (*Acer negundo* L.), narrowleaf cottonwood (*Populus angustifolia* James), water birch (*Betula occidentalis* Hook.), and Wood's rose (*Rosa woodsii* Lindl.). On drier sites predominant plant species are basin big sagebrush, Wyoming big sagebrush, rubber rabbitbrush (*Chrysothamnus nauseosus* [Pallus ex Pursh] Britt.), serviceberry (*Amelanchier alnifolia* Nutt.), black greasewood (*Sarcobatus vermiculatus* [Hook.] Torrey), plains prickly pear (*Opuntia polyacantha* Haw.), winterfat (*Ceratoides lanata* Pursh), sand verbena (*Verbena stricta* Vent.), and buckwheat (*Eriogonum* sp.). Rocky canyon slopes are characterized as a pinyon pine (*Pinus edulis* Engelm.) / juniper (*Juniperus osteosperma* [Torrey] Little) woodland with mountain mahogany (*Cercocarpus montanus* Raf.) and Mormon tea (*Ephedra viridis* Coville). High-elevation areas are typically dominated by ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), with scattered pockets of aspen (*Populus tremuloides* Michx.).

Six sites (East Cactus, West Cactus I, West Cactus II, Success, Iron Springs Bench, and Dry Woman) having similar elevation, annual precipitation amounts, soils, and vegetation were selected for study. Elevation at these sites is approximately 1950 m with mean annual precipitation of 20–25 cm. Soils are primarily Mollisols, formed under grasslands, with a dominant Wyoming big sagebrush and mixed-grass community. Forward rates of fire spread on all 6 sites ranged between 60 and 100 chains hour^{-1}, with residence time over perennial grass root crowns less than 20–30 seconds and surface temperatures less than 120°C. All burns were initiated during the late growing season when fine fuel loads were at annual maximum.

METHODS

Accumulated monitoring data sets from the 6 prescribed/natural burn sites in Dinosaur National Monument were analyzed to determine fire effects on plant foliar cover and diversity. Sites and sample years included in the analysis are listed in Table 1. Percent cover categories include total vegetation, herbaceous (combined grass and forb cover), shrub, grass, forb, litter, and bare ground. For each site paired burn and control sites were compared using a paired *t* test. Cover data were collected during the peak of the growing season by the National Park Service and generated from both Daubenmire quadrat (Daubenmire 1959) prior to 1992 and optical projection point measurements beginning in 1992 (Winkworth and Goodall 1962; single or 1st hits were recorded with the optical device). Percent values were conditioned for analyses using the arcsine transformation procedure to achieve normal distribution (Zar 1999). Arcsine values were used in all statistical analyses, but cover is reported as percent values. Differences were determined at $P \leq 0.1$ on all cover analyses.

Species richness (number of species) was analyzed with paired *t* tests and by determining percent of similarity ([number of shared species/total species] × 100) between paired areas on each site by year and all years combined. Diversity (species richness and evenness) assessments were performed using cover data for each identified species in each set of paired plots by year. A Shannon-Weiner index value (Shannon and Weaver 1949) was calculated for each site pair by year and a modified

TABLE 1. List of sites, years, sample size (n), mean cover (%), P-values and standard errors of vegetation cover classes by treatment.

			Total vegetation			Shrub			Herbaceous		
Site	Year	n	Control	Burn	P-value	Control	Burn	P-value	Control	Burn	P-value
East Cactus	1988	2	47(±6)	14(±3)	0.187	25(±5)	0(±0)	0.10	22(±2)	14(±3)	0.338
	1989	2	34(±1)	26(±1)	0.129	14(±1)	0(±0)	0.022	20(±1)	26(±1)	0.189
	1991	2	34(±0)	16(±0)	0.013	22(±1)	0(±0)	0.016	12(±1)	16(±1)	0.030
	1992	3	47(±3)	60(±3)	0.008	16(±2)	1(±0)	0.014	30(±2)	57(±3)	0.002
	1994	3	49(±3)	42(±2)	0.262	28(±3)	0(±0)	0.011	19(±2)	42(±3)	0.033
West Cactus I	1987	2	79(±4)	56(±4)	0.212	41(±1)	0(±0)	0.001	37(±4)	56(±4)	0.248
	1988	2	51(±3)	35(±3)	0.250	32(±3)	0(±0)	0.05	18(±1)	35(±3)	0.21
	1990	2	53(±5)	51(±1)	0.748	30(±1)	0(±0)	0.009	23(±4)	51(±1)	0.124
	1993	5	47(±2)	47(±1)	0.987	25(±1)	0(±0)	0.001	21(±3)	47(±1)	0.001
West Cactus II	1989	2	31(±5)	27(±2)	0.373	3(±0)	0(±0)	0.058	28(±5)	27(±2)	0.642
	1990	2	41(±1)	36(±1)	0.172	6(±1)	0(±0)	0.079	36(±1)	36(±1)	0.844
	1995	5	60(±2)	61(±3)	0.908	20(±2)	3(±1)	0.001	37(±2)	57(±3)	0.002
Success	1988	2	24(±9)	34(±18)	0.427	12(±2)	0(±0)	0.5	13(±2)	34(±18)	0.469
	1993	4	29(±2)	43(±2)	0.01	16(±2)	0(±0)	0.002	13(±1)	42(±3)	0.005
Iron Springs Bench	1996	4	45(±2)	33(±3)	0.021	34(±3)	0(±0)	0.001	10(±1)	33(±3)	0.005
	1997	4	71(±2)	83(±7)	0.145	36(±2)	0(±0)	0.001	34(±1)	82(±6)	0.005
Dry Woman	1984	1	48	31		10	0		37	31	
	1987	1	46	66		11	1		36	66	
	1990	1	36	44		5	2		30	43	
	1995	5	58(±1)	66(±4)	0.079	23(±1)	0(±0)	0.001	33(±2)	62(±4)	0.002

TABLE 1. Continued.

Grass			Forb			Litter			Bare ground		
Control	Burn	*P*-value	Control	Burn	*P*-value	Control	Burn	*P*-value	Control	Burn	*P*-value
17(±3)	12(±3)	0.572	5(±1)	2(±0)	0.175	38(±5)	14(±1)	0.140	41(±7)	84(±1)	0.09
12(±1)	23(±1)	0.133	7(±0)	4(±0)	0.033	22(±1)	12(±1)	0.125	46(±1)	52(±4)	0.38
8(±1)	11(±1)	0.129	5(±1)	4(±0)	0.451	28(±8)	11(±2)	0.301	57(±3)	74(±1)	0.29
16(±3)	42(±6)	0.022	10(±5)	17(±4)	0.031	20(±3)	21(±1)	0.872	28(±1)	23(±1)	0.124
12(±2)	34(±1)	0.021	7(±1)	8(±3)	0.774	23(±3)	42(±4)	0.011	31(±5)	16(±4)	0.128
26(±1)	41(±4)	0.161	12±(4)	15(±1)	0.571	32(±2)	23(±4)	0.078	38(±2)	50(±8)	0.291
11(±1)	27(±2)	0.042	7(±2)	8(±1)	0.795	41(±1)	15(±7)	0.154	45(±4)	54(±6)	0.523
12(±1)	41(±1)	0.026	12(±4)	10(±0)	0.781	22(±1)	28(±2)	0.112	42(±0)	40(±5)	0.775
11(±2)	37(±4)	0.007	9(±1)	11(±3)	0.584	32(±1)	36(±2)	0.182	22(±2)	17(±3)	0.358
18(±2)	19(±3)	0.716	10(±3)	8(±1)	0.663	28(±4)	19(±1)	0.283	33(±4)	50(±4)	0.272
22(±2)	23(±2)	0.806	14(±2)	13(±1)	0.795	25(±4)	9(±1)	0.167	42(±4)	53(±7)	0.503
24(±1)	40(±2)	0.005	13(±1)	18(±3)	0.141	23(±2)	30(±2)	0.042	18(±1)	14(±1)	0.079
10(±1)	31(±18)	0.469	2(±1)	4(±1)	0.479	20(±3)	36(±14)	0.529	45(±9)	39(±5)	0.777
8(±1)	37(±2)	0.001	5(±1)	5(±1)	0.883	16(±1)	43(±2)	0.001	49(±1)	15(±1)	0.001
9(±1)	25(±3)	0.018	2(±1)	7(±2)	0.067	35(±1)	3(±0)	0.001	18(±3)	63(±2)	0.001
23(±1)	60(±4)	0.004	11(±1)	23(±2)	0.019	18(±1)	13(±3)	0.131	11(±2)	18(±1)	0.039
23	15		15	16		40	18		53	68	
20	50		16	16		36	39		30	29	
15	28		16	16		28	19		45	44	
20(±1)	38(±3)	0.008	13(±2)	24(±2)	0.008	25(±1)	23(±1)	0.372	18(±1)	23(±1)	0.64

t test performed for each paired set of index values (Zar 1999). When differences in paired index values occurred, a Bray-Curtis polar ordination (Gauch 1982) was performed to assess similarity/dissimilarity of the paired species assemblages. Diversity differences were determined at $P < 0.05$.

Statistical analyses were performed on all sites (and years) where data existed for more than 1 transect. Where only 1 transect was sampled, exact values were recorded and summarized.

RESULTS

Vegetation Cover

Across the monitoring period, mean total vegetation cover of all combined sites was 44% (control) and 42% (burn). Total vegetation cover in burn areas was higher than or equal to paired control areas on all sites within 2–3 years post-burn. The greatest species composition shifts occurred between shrub and perennial grass components. Shrubs were essentially eliminated in burn areas, but perennial grass cover was 10%–35% higher compared to paired control plots. Overall shrub cover was 21% in control areas and zero in burn areas, while mean grass cover was 32% in burn areas and 15% in control areas. Foliar cover results by site and year are shown in Table 1.

EAST CACTUS.—In 1988 (1st post-fire growing season), the only differences in cover by vegetation class between paired sites were bare ground and shrub. In 1989 forb and shrub cover were both greater in control than burn areas; no other class comparisons were significant. Results for 1991 indicate that total vegetation cover was higher in control than burn areas, while shrub cover was again greater in the control area. However, herbaceous cover was higher in burn areas. By 1992 total vegetation cover was higher in the burn area than control. Herbaceous, forb, and grass cover were also higher in burn areas than control. The large increase of herbaceous cover in the burn area from the previous year (16% to 60%) was a response to April 1992 precipitation (9.5 cm), 6.5 cm above normal. Shrubs were still more prevalent in control areas. Results for 1994 show continued trends from 1992. There was no difference in total vegetation cover; however, herbaceous and grass cover were higher in burn areas. Litter was also more abundant in burn areas due to increased grass production from the previous 2 years.

WEST CACTUS I.—The 1987 analysis (1st post-burn growing season) indicated that the burn was effective in reducing shrub cover and that the litter component was reduced on the burn area. There were no differences between the other classes. In 1988 shrub cover was still lower in the burn area; however, burn area grass cover increased over that in the control area. There was no difference in litter cover, unlike the previous year. The same trend was apparent in the 1990 results. Shrub cover was lower in the burn area and grass cover was higher. In 1993 shrub cover was again higher in control areas, and both grass and total herbaceous cover were higher in burn areas. The greater herbaceous cover was largely due to an increase in the grass component.

WEST CACTUS II.—In 1989 and 1990 (1st and 2nd years post-burn), the only cover differences were in the shrub class. However, by 1995 herbaceous and litter cover were higher in burn than control areas. Bare ground and shrub cover were greater in the control areas.

SUCCESS.—There were no differences between cover classes in 1988 (1st year post-burn). However, variability of mean values and only 1 degree of freedom probably reduced the power of the statistical analyses. A visual comparison of paired means shows that total vegetation, herbaceous, grass, and litter cover means are substantially higher in burn areas while shrub cover is higher in the control area (Table 1). In 1993 variability was lower (4 df) and statistical analyses show differences in all classes except forbs.

IRON SPRINGS BENCH.—In the 1st post-burn year (1996), analyses indicated differences in all cover classes. Total vegetation, shrub, and litter cover were greater in the control area. All other classes were higher in the burn area. In 1997 herbaceous, grass, forb cover, and bare ground were higher in the burn area. Shrub cover was greater in the control area.

DRY WOMAN.—In 1984, 1987, and 1990, only 1 transect was sampled in each paired area, making it impossible to perform a statistical analysis since the lack of replication precluded calculating a measure of variance. Actual transect values of each paired area are listed in Table 1. The burn treatment was successful in reducing shrub cover, and trends for other cover classes were similar to the other 5 sites.

In 1995 we sampled 5 transects in each paired site, making analyses possible. Results indicated that total vegetation, herbaceous, grass, and forb cover were higher in the burn area. Shrub cover was higher in the control area.

Diversity

Mean numbers of species on combined control and burn areas were 17 and 18, respectively. Statistical comparisons (*t* tests) of species numbers (richness) are displayed in Table 2. Dry Woman 1995 was the only site where a difference in species number occurred ($P < 0.001$) between the control (15) and burn (9) area.

A summary of percent species similarity (percent of species shared) between paired areas by site and year is shown in Table 3. Actual shared species fluctuated over time at each site. East Cactus similarity ranged from a high of 67% in 1988 to a low of 43% in 1992; West Cactus I ranged from 40% in 1990 to 59% in 1987; and West Cactus II ranged from 59% similarity in 1989 to 78% in 1995. Success 1988 and 1993 were 50% and 47% similar, respectively. Iron Springs 1996 was 55% similar, while Iron Springs 1997 was 71% similar. The Dry Woman site ranged from 22% similarity in 1984 to 57% in 1990. Combining all years on each of the 6 sites, East Cactus was 62% similar; West Cactus I, 44%; West Cactus II, 72%; Success, 44%; Iron Springs, 75%; and Dry Woman, 62%.

Differences in Shannon-Weiner index values ($P < 0.05$) occurred in 6 of 20 paired analyses (Table 4: West Cactus I, 1997; Success 1993; Iron Springs 1996 and 1997; Dry Woman 1984 and 1995). A Bray-Curtis ordination of these 6 sites is displayed in Figure 1. Even though these 6 sites have different diversity index values between paired burn and control areas, they do ordinate along shrub (x)- and grass (y)-dominated axes. In all but a single instance (Dry Woman 1995), control sites ordinate to the right of each paired burn site, indicating similar community composition. Dry Woman 1995 again was the only pair exhibiting different species richness values (Table 2).

Further investigation of the raw data indicated that community differences fell into 2 general categories. In 5 instances there was a major component of annual grass species, cheatgrass (*Bromus tectorum* L.) and/or six weeks fescue (*Vulpia octoflora* [Walt.] Rydb.) measured in the burn areas at the time of sampling (Dry Woman 1984, Dry Woman 1995, West Cactus I, 1987, and Iron Springs 1996, 1997). The Dry Woman site has a continuing history of heavy spring/summer grazing by domestic animals; the Iron Springs Bench site also had a spring/summer grazing history prior to removal in 1985. These grazing histories may have been partially responsible for the initial invasion and could have exacerbated proliferation of the annual brome. The other site, Success 1993,

TABLE 2. Species richness (mean number of species) and standard errors of paired sites for all areas and sample years.

Site	Control	Burn	df	*P*-value
West Cactus I, 1987	12 (±1)	15 (±0)	1	0.09
West Cactus I, 1988	13 (±0)	16 (±1)	1	0.126
West Cactus I, 1990	18 (±1)	16 (±1)	1	0.295
West Cactus I, 1993	12 (±7)	8 (±0)	4	0.018
East Cactus, 1988	11 (±0)	10 (±1)	1	0.5
East Cactus, 1989	9 (±1)	8 (±1)	1	0.705
East Cactus, 1991	15 (±0)	16 (±1)	1	0.05
East Cactus, 1992	10 (±1)	13 (±1)	2	0.015
East Cactus, 1994	9 (±1)	9 (±0)	2	0.184
Iron Springs, 1996	10 (±1)	11 (±1)	3	0.297
Iron Springs, 1997	16 (±1)	15 (±1)	3	0.613
Success, 1988	8 (±1)	7 (±1)	1	0.5
Success, 1993	9 (±1)	7 (±1)	3	0.103
Dry Woman, 1984	18	12	n/a	n/a
Dry Woman, 1987	16	15	n/a	n/a
Dry Woman, 1990	24	23	n/a	n/a
Dry Woman, 1995	15 (±1)	9 (±1)	4	0.001[a]
West Cactus II, 1989	13 (±1)	12 (±0)	1	0.5
West Cactus II, 1990	23 (±2)	23 (±2)	1	0.5
West Cactus II, 1995	19 (±1)	18 (±1)	4	0.587

[a]Significant at $\alpha = 0.05$.

TABLE 3. Summary of percent plant species similarity ([# shared species / # total species] × 100) between burn and control areas by site and sample year.

Site	Total species	Species shared	Percent similarity
West Cactus I, 1987	17	10	59
West Cactus I, 1988	22	10	45
West Cactus I, 1990	25	10	40
West Cactus I, 1993	19	11	58
East Cactus, 1988	15	10	67
East Cactus, 1989	14	9	64
East Cactus, 1991	20	12	60
East Cactus, 1992	21	9	43
East Cactus, 1994	19	9	47
Iron Springs, 1996	18	10	56
Iron Springs, 1997	24	17	71
Success, 1988	16	8	50
Success, 1993	19	9	47
Dry Woman, 1984	18	4	22
Dry Woman, 1987	20	10	50
Dry Woman, 1990	23	13	57
Dry Woman, 1995	23	12	52
West Cactus II, 1989	17	10	59
West Cactus II, 1990	33	20	61
West Cactus II, 1995	36	28	78

TABLE 4. Shannon-Weiner diversity index (H′) and *t*-test summary between all paired sites and sample years.

Site	Control H′	Burn H′	df	*P*-value
West Cactus I, 1987	0.72	0.94	80	0.008[a]
West Cactus I, 1988	0.52	0.72	49	0.09
West Cactus I, 1990	0.66	0.72	54	0.579
West Cactus I, 1993	0.63	0.59	42	0.669
East Cactus, 1988	0.68	0.60	28	0.439
East Cactus, 1989	0.55	0.36	27	0.084
East Cactus, 1991	0.05	0.44	23	0.667
East Cactus, 1992	0.71	0.77	55	0.408
East Cactus, 1994	0.55	0.71	48	0.098
Iron Springs, 1996	0.41	0.85	37	<0.001[a]
Iron Springs, 1997	0.95	0.76	65	0.024[a]
Success, 1988	0.52	0.52	33	0.988
Success, 1993	0.63	0.38	40	0.033[a]
Dry Woman, 1984	0.94	0.71	45	0.01[a]
Dry Woman, 1987	0.90	0.77	70	0.06
Dry Woman, 1990	0.88	0.86	43	0.841
Dry Woman, 1995	0.81	0.58	64	0.012[a]
West Cactus II, 1989	0.55	0.39	30	0.205
West Cactus II, 1990	0.90	0.83	39	0.384
West Cactus II, 1995	0.89	0.90	48	0.899

[a]Significant at $\alpha = 0.05$.

exhibited a very large difference in the amount of cover from needle-and-thread grass (*Stipa comata* Trin. & Rupr.) in the burn area.

DISCUSSION

Prescribed burning caused a shift from late successional, sagebrush-dominated communities to earlier successional, grassland communities. This occurred without reducing total vegetation cover, while improving forage quantity for large grass-preference ungulates such as elk (*Cervus elaphus*) that occur in the monument. Intra-community (α-scale) diversity has been maintained. Overall species richness in burn and control plots was not different, and only a single instance (Dry Woman 1995) had different species richness. However, the proportionality

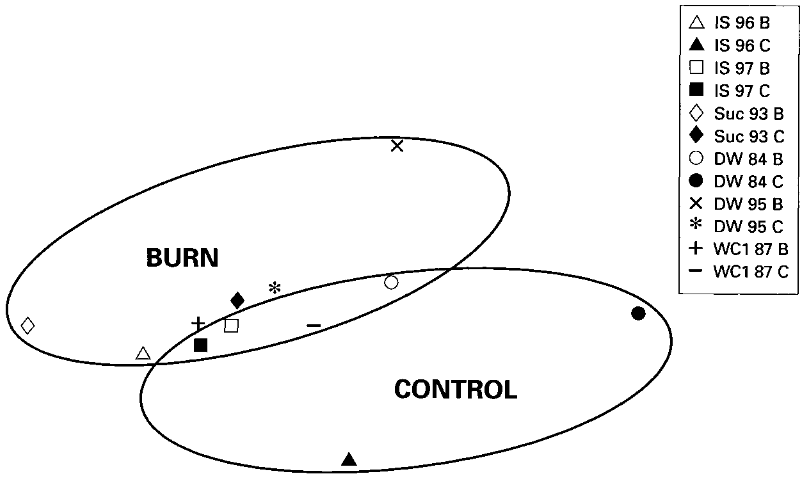

Fig. 1. Bray-Curtis ordination of 6 paired sites with significant Shannon index values (B–burn, C–control; IS–Iron Springs, Suc–Success, DW–Dry Woman, WC1–West Cactus I).

of vegetation class has changed from shrub- to perennial grass–dominated communities. Percent similarity of species richness between paired areas is somewhat variable by year, but expected. Similarity should fall within a natural range of variation since most plant communities are dynamically affected by amount and timing of precipitation events that differentially favor selected species (Sharp et al. 1990). Consequently, a species presence can shift to absence within and between burn and control areas across years. Differences in Shannon-Weiner index values where species numbers are greater in the burn areas than control are exceptions to the general trend. A few species difference may not indicate a difference at all, but may be an artifact of observer bias, different cover assessment methods, and species area curve influences.

The National Park Service is intervening with fire before these sagebrush/grass communities cross a threshold into a very late, decadent, successional stage with characteristic depauperate understories (Laycock 1991, West 1999). Otherwise, the immediate post-burn response of the herbaceous component would not be observed. Landscape diversity has also been improved by creating an alternating, patchy sequence of communities rather than the original, continuous sagebrush matrix. National Park Service goals of maintaining fire as an active ecological process and fostering diversity while protecting soil and vegetation resources have been achieved, and implementation of periodic prescribed burns in these shrub/grassland communities should be continued. Without this intervention in the successional process, these sagebrush/grassland communities will eventually cross a threshold into a stable state dominated by shrubs to the near exclusion of understory vegetation. If wildfire or prescribed fire is introduced into this community stage, additional inputs such as reseeding along with other cultural practices will be necessary. The Park Service should continue this aggressive, proactive management approach.

LITERATURE CITED

ARCHER, S. 1989. Have southern Texas savannas been converted to woodlands in recent history? American Naturalist 134:545–561.

DAUBENMIRE, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43–64.

GAUCH, H.G., JR. 1982. Multivariate analysis in community ecology. Cambridge Press, New York. 298 pp.

JOHNSON, K.H., R.A. OLSON, AND T.D. WHITSON. 1996. Composition and diversity of plant and small mammal communities in Tebuthiuron-treated big sagebrush (*Artemisia tridentata*). Weed Technology 10: 404–416.

LAYCOCK, W.A. 1991. Stable states and thresholds of range condition on North American rangelands: a viewpoint. Journal of Range Management 44:427–433.

OLSON, R.A., J. HANSEN, T. WHITSON, AND K.H. JOHNSON. 1994. Tebuthiuron to enhance rangeland diversity. Rangelands 16:197–201.

SHANNON, C.E., AND W. WEAVER. 1949. The mathematical theory of communication. University of Illinois Press, Urbana.

SHARP, L.A., K. SANDERS, AND N. RIMBEY. 1990. Forty years of change in a shadscale stand in Idaho. Rangelands 12:313–328.

WEST, N.E. 1999. Synecology and disturbance regimes of sagebrush steppe ecosystems. Pages 15–26 *in* P.G. Entwhistle et al., compilers, Proceedings: Sagebrush Steppe Ecosystem Symposium. Bureau of Land Management, Boise, ID. Publication BLM/ID/PT-001001-1150.

WHITSON, T.D., AND H.P. ALLEY. 1984. Tebuthiuron effects on *Artemisia* ssp. and associated grasses. Weed Science 32:180–184.

WINKWORTH, R.E., AND D.W. GOODALL. 1962. A crosswire sighting tube for point quadrat analysis. Ecology 48: 150–152.

ZAR, J.H. 1999. Biostatistical analysis. 4th edition. Prentice Hall, Upper Saddle River, NJ. 663 pp.

Received 6 June 2001
Accepted 19 September 2001