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FIRE EFFECTS ON SMALL MAMMAL COMMUNITIES IN DINOSAUR NATIONAL MONUMENT

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ABSTRACT.—Resource specialists at Dinosaur National Monument utilize both planned and unplanned wildland ignitions in big sagebrush (*Artemisia tridentata*)–dominated plant communities to restore successional processes, maintain vegetation vigor, and promote diversified landscapes. Short- and long-term effects of prescribed burning on small mammal populations are not well understood. The objectives of this study were to (1) compare small mammal species richness, similarity, and diversity between paired burned and unburned treatment plots, and (2) assess long-term trends of small mammal community responses to burning. Five paired burned/unburned sites having similar vegetation, soils, elevation, and annual precipitation were selected. Prescribed or natural fires occurred on all sites between 1981 and 1995, followed by periodic small mammal removal (trapping) sampling (1–12 years post-burn). Small mammal species richness and diversity were generally higher on unburned than burned plots across post-burn sampling years and sites. Increased abundance of the deer mouse (*Peromyscus maniculatus*) following burning resulted in decreased community diversity. Species similarities between burned and unburned plots were low in early post-burn years but increased in later post-burn years. Short-term shifts in diversity and species similarity resulted from increased deer mouse abundance after burning. However, burning had no long-term impact on species richness and similarity, indicating minimal effect to other small mammal species.

Key words: burning, sagebrush, small mammal richness, community diversity.

On drier, mid-elevation benches within Dinosaur National Monument (DNM), big sagebrush (*Artemisia tridentata*)–dominated plant communities have replaced grassland communities over time. These late succession big sagebrush communities are often dense, monotypic stands with limited plant species richness, diversity, and understory herbaceous cover (Johnson et al. 1996, West 1999). Anecdotal accounts by early residents suggest large areas of DNM, now dominated by big sagebrush, were once perennial grasslands prior to settlement. Domestic livestock grazing in DNM began in the 1870s, reaching a peak authorized level of 35–40,000 AUMs on 56,000 ha in the mid-1940s, then declining to 5,000 AUMs by 1973. Resource specialists believe that exceptionally heavy grazing from the 1920s through the 1950s, coupled with extreme drought during the 1930s and the onset of fire suppression policies in the late 1930s, all contributed to a shift from grassland to big sagebrush communities during the 1940s and 1950s.

Under a 1916 congressional mandate to conserve and protect the natural resources of the U.S. National Park system, DNM resource specialists began a complex fire management program in the early 1980s to restore grassland communities on big sagebrush–dominated areas, maintain herbaceous plant vigor, and promote landscape vegetation diversity. That program included management-ignited prescribed burning and natural fire management techniques. Prescribed natural fires (PNFs), in conformance with agency policy, are natural ignitions allowed to burn within strict constraints of location, proximity to park boundaries, and threats to life and property. In contrast, management-ignited prescribed fires are conducted under specific objectives and desired fire effects, and within prescribed locations, size, fuel loads, weather, and fire behavior conditions.

Since the implementation of a fire management program in the early 1980s, DNM resource specialists have monitored small mammal community responses to fire. Objectives of this project were to (1) compare small mammal species richness, similarity, and diversity between burned and unburned (control) treatment plots, and (2) assess long-term trends of small mammal responses to burning.

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STUDY AREA DESCRIPTION

DNM, comprising 855 km^2, is located within the Uinta Mountains in northwestern Colorado and extending into northeastern Utah. The area, centered on the confluence of the Green and Yampa Rivers, has bench and canyon topography with elevations ranging from 1700 m to 2740 m.

Five previously burned sites (East Cactus, Iron Springs Bench, Success, West Cactus I, and West Cactus II) having similar elevation, topography, annual precipitation amounts, soil type, and vegetation associations were selected for study. Elevation at these sites is approximately 1950 m, with average annual precipitation of 20–25 cm. Soils are primarily Mollisols, formed under historic grasslands, with a preburn Wyoming big sagebrush (*A. tridentata* ssp. *wyomingensis*) and mixed-grass–dominated plant community. Dominant grass species comprise bluebunch wheatgrass (*Pseudoroegneria spicata*), bottlebrush squirreltail (*Elymus elymoides*), Indian ricegrass (*Oryzopsis hymenoides*), muttongrass (*Poa fendleriana*), needle and thread grass (*Stipa comata*), prairie junegrass (*Koeleria pyramidata*), thickspike wheatgrass (*Agropyron dasystachyum*), and western wheatgrass (*Pascopyrum smithii*). Plant taxonomic nomenclature follows Goodrich and Neese (1986) and Dorn (1992).

Following are the burning date and area burned for each study site: East Cactus, July 1987, 301 ha; Iron Springs Bench, September 1995, 260 ha; Success, June 1981, 495 ha; West Cactus I, July 1986, 81 ha; and West Cactus II, August 1988, 207 ha. The Success burn was a natural fire, whereas the other sites were prescribed fires.

Prescriptions for prescribed burns replicate weather and fire behavior conditions observed during natural fires. Pre-burn vegetation on all sites consisted of Wyoming big sagebrush with 15–30% foliar cover, 30–50 cm canopy height, and 70–100% live fuel moisture with a perennial grass understory (10–20% foliar cover). Following burning, shrub species were essentially eliminated across all sites, representing <3% cover, while cover of perennial native grass species was 10–35% higher (Perryman et al. 2002). In contrast, mean shrub cover in adjacent unburned areas averaged 21% across all sites. Mean forb cover varied from 2% to 23% across all burned sites (Perryman et al. 2002). Burning resulted in conversion from a late succession, big sagebrush–dominated community to a perennial, native grass–dominated community across all sites.

METHODS

DNM resource specialists conducted small mammal population surveys on the 5 study sites from mid-June to mid-August at specific post-burn intervals listed in Table 1. Small mammal community characteristics were evaluated using snap trap removal methodologies, following protocols established by the National Park Service. Within each paired burn and control plot, we established a trapping grid consisting of three 200-m parallel Calhoun lines spaced 10 m apart, representing a 0.60-ha trapping area (Grant 1990). Trap sets, consisting of 1 rat trap and 2 museum specials, were placed at 10-m intervals along each trap line. Trapping was conducted for 3 consecutive nights at each site, resulting in 540 trap-nights (3 trap lines $\times$ 20 trapping stations $\times$ 3 traps per station $\times$ 3 trapping nights).

Traps were baited with a mixture of oatmeal and peanut butter during late evening hours to minimize bait stripping by insects. We checked the traps in early morning and collected specimens before heat deterioration or damage by insects and scavengers occurred. Specimens were identified, frozen, and transported to the National Ecology Research Centers in either Albuquerque, New Mexico, or Fort Collins, Colorado, for species verification.

Species richness (number of species) and abundance (individuals by species) were summarized by treatment type (burn, control), sample year, and site. For each site, we compared the numbers of species on paired burn and control plots across years using a paired t test. Percentage of species similarity ([number of shared species / total species] $\times$ 100) was evaluated between paired plots at each site by year. Shannon-Weiner diversity (species richness and evenness) assessments (Krebs 1999) were performed using abundance data for each identified species in each set of paired plots by site and year. Differences in diversity indices between paired plots were tested for each site by year using a 2-sided randomization test ($P \leq 0.5$) described by Solow (1993). Diversity indices were plotted for sites with the longest period of post-burn sample data (East Cactus, Success,

TABLE 1. List of sites, post-burn sample years, species richness (number of species), percent species similarity, and diversity index by treatment type at Dinosaur National Monument, Colorado.

		Number of species		Species similarity			Diversity index		
Site[a]	Year	Burn	Control	Total	Shared	% similar	Burn	Control	P-value[b]
East Cactus	1991	2	2	3	1	33	0.40	0.25	0.136
	1992	1	3	3	1	33	0.00	0.30	<0.001*
	1994	3	2	4	1	25	1.01	0.20	<0.001*
	1998	2	2	2	2	100	0.50	0.20	<0.001*
Iron Springs Bench	1996	2	4	4	2	50	0.20	0.37	0.223
	1998	1	1	1	1	100	0.00	0.00	
Success	1988	1	2	2	1	50	0.00	0.69	<0.001*
	1993	1	3	3	1	33	0.00	1.01	<0.001*
West Cactus I	1998	1	3	3	1	33	0.00	0.36	<0.001*
West Cactus II	1990	2	3	4	1	25	0.40	0.80	0.005*
	1993	1	5	5	1	20	0.00	0.60	<0.001*
	1995	3	3	5	1	20	1.04	0.68	0.008*
	1998	2	2	2	2	100	0.20	0.25	0.378

[a]Burn dates: East Cactus, 1987; Iron Springs Bench, 1995; Success, 1981; West Cactus I, 1986; West Cactus II, 1988.
[b]Significant (*) at $\alpha = 0.05$, Solow (1993) 2-sided randomization test.

and West Cactus II) to assess long-term trends in diversity following burning.

RESULTS

Species Richness

The number of species on paired plots across years at all sites was low, ranging from 1 to 5 (Table 1). Mean number of species (all sites, all years) on burned plots was 2.5 and on control plots was 3.0. Although there was no significant difference in number of species between burn and control plots across years at East Cactus ($P = 0.72$), Iron Springs Bench ($P = 1.00$), Success ($P = 0.14$), or West Cactus II ($P = 0.28$), the number of species on control plots was equal to or higher than burn plots across sites and years except for East Cactus, 1994 (Table 1).

The most abundant species on all treatment plots was the deer mouse (*Peromyscus maniculatus*). Other species included the montane vole (*Microtus montanus*), western harvest mouse (*Reithrodontomys megalotis*), Ord's kangaroo rat (*Dipodomys ordii*), Colorado chipmunk (*Eutamias quadrivittatus*), sagebrush vole (*Lemmiscus curtatus*), northern grasshopper mouse (*Onychomys leucogaster*), piñon mouse (*Peromyscus truei*), olive-backed pocket mouse (*Perognathus fasciatus*), least chipmunk (*Eutamias minimus*), and thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*).

Species Similarity

The trend in percent species similarity (percent of shared species) between paired plots by site showed lower percent similarity during early years following fire and higher similarity in later years (Fig. 1). Success was the only site displaying a decline in percent species similarity from year 7 to year 12. The number of shared species between paired plots by site was 1, the deer mouse, except at East Cactus, 1998; Iron Springs Bench, 1996; and West Cactus II, 1998, where 2 species were shared (Table 1).

With the exception of the Success site, deer mouse numbers were higher on control compared with burn plots across sites and years (Table 2). There was no distinct trend in deer mouse abundance across years by site following burning. However, among burn plots, relative deer mouse abundance on all sites was generally higher at later post-burn years (Table 2).

Diversity

Differences in diversity index values ($P \leq 0.05$) occurred in 9 of 13 paired plot analyses by site and year (Table 1). Most paired plot differences occurred in post-burn year 5 or later at all sites. With the exception of East Cactus, diversity indices were higher on control than burn plots across years at each site.

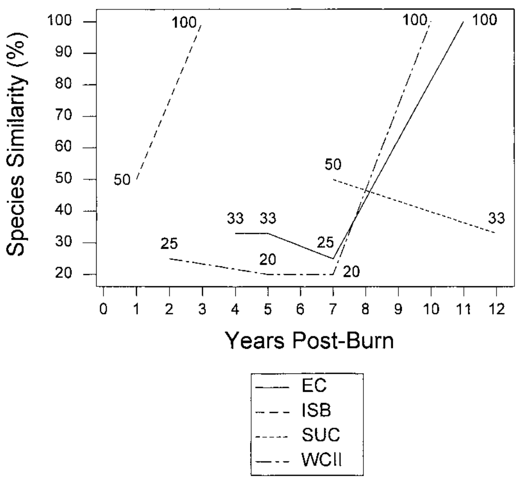

Fig. 1. Trend in percent species similarity of burned and control (unburned) plots for post-burn sampling years at East Cactus (EC), Success (SUC), Iron Springs Bench (ISB), and West Cactus II (WCII) sites at Dinosaur National Monument, Colorado.

TABLE 2. Number and relative abundance (%) of the deer mouse (*Peromyscus maniculatus*) by site, year, and treatment type at Dinosaur National Monument, Colorado.

		Number (%)	
Site	Year	Burn	Control
East Cactus	1991	12 (85.7)	16 (94.1)
	1992	10 (100.0)	27 (93.0)
	1994	3 (50.0)	20 (95.2)
	1998	8 (80.0)	38 (95.0)
Iron Springs Bench	1996	20 (95.2)	34 (91.9)
	1998	3 (100.0)	19 (100.0)
Success	1988	7 (100.0)	1 (50.0)
	1993	14 (100.0)	3 (50.0)
West Cactus I	1998	14 (100.0)	21 (91.2)
West Cactus II	1990	6 (85.7)	7 (70.0)
	1993	9 (100.0)	33 (84.6)
	1995	2 (50.0)	7 (77.8)
	1998	18 (94.7)	38 (92.7)

Long-term trends in diversity indices of burn plots reflected sharp declines at East Cactus and West Cactus II to post-burn sample year 5, followed by subsequent increases in diversity during later post-burn years (Fig. 2). Although not plotted, the diversity index at Iron Springs Bench fell sharply from post-burn year 1 to 3, consistent with trends at East Cactus and West Cactus II (Table 1). In contrast, diversity indices remained relatively constant across post-burn years of control plots at East Cactus, Success, and West Cactus II (Fig. 2).

DISCUSSION

In this study higher small mammal species richness and diversity on control plots was probably related to greater habitat structure and complexity (Germano and Lawhead 1986, Kerley 1992) compared with burn plots. Prescribed burning at DNM resulted in a shift from late successional, big sagebrush–dominated communities to earlier successional, subclimax grassland communities. Absence of shrub cover reduced habitat complexity and subsequent coexistence of sympatric small mammal species (M'Closkey 1976). Although not a study objective, absence of shrub cover on burn plots may also increase predation rates, which may explain lower deer mouse numbers on burn plots compared to control plots in this study.

Low species number and high deer mouse abundance across all sites, sample years, and treatments made it difficult to assess the responses of other small mammal species to burning, as fluctuations in deer mouse abundance strongly influenced shifts in similarity and diversity. From this perspective, the trend of lower species similarity between paired burn and control plots during early post-burn years may be attributed to rapid recolonization and production of the deer mouse on burn areas within the first 5 post-burn years, which is consistent with other studies (Tevis 1956, Quinn 1979, Forde 1983, Kaufman et al. 1990). Likewise, higher species similarity between paired plots during later post-burn years probably resulted from some influx of other species as natural succession created increasing habitat complexity and greater coexistence of sympatric small mammal species (M'Closkey 1976). However, deer mouse preference for disturbed habitat (Forde 1983) and high abundance in burned big sagebrush communities (McGee 1976, 1982, Mason 1977), along with naturally high abundance on unburned plots in this study, may explain higher species similarity between paired plots in later post-burn years.

With regard to diversity, as burning promotes increased relative abundance of the deer mouse

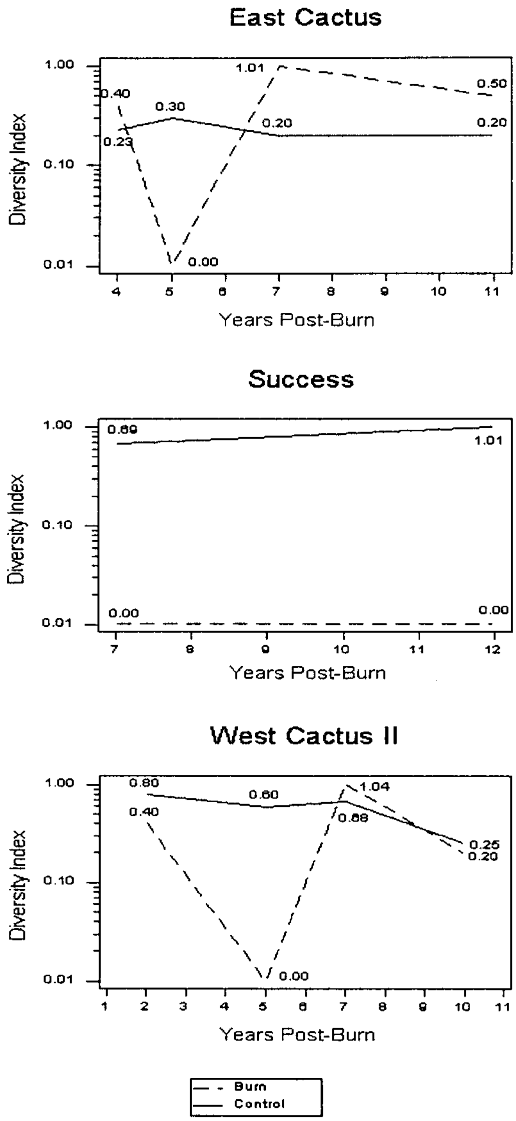

Fig. 2. Trend in small mammal community diversity of burned and control (unburned) plots for post-burn sampling years at East Cactus, Success, and West Cactus II sites at Dinosaur National Monument, Colorado, in logarithmic series.

overall, diversity decreases as evidenced by significantly higher diversity on unburned than on burned plots in this study. This relationship is especially enhanced where low numbers of other small mammal species occur as well. More importantly, however, this study shows some interesting differences in long-term trends of diversity between paired plots. Diversity was relatively constant across sample years on unburned plots, in contrast to fluctuations on burned plots across years. Differences in the trend of diversity between burned and unburned plots were primarily due to high deer mouse abundance at all sites (and treatment plots), favorable response of the deer mouse to fire, and low numbers of other small mammal species present.

Conversion from a late succession, big sagebrush–dominated plant community to a perennial, native grass–dominated community by prescribed burning further increases abundance of an already highly abundant species, the deer mouse, at least in the short term. However, long-term effects of prescribed burning on small mammals at DNM does not appear to be detrimental to community structure. Few other small mammal species exist in these deer mouse–dominated communities, and species similarity between burned and unburned (control) plots was highest in the later post-burn years, indicating little long-term impact to species richness after burning. In this study, differences in species diversity between paired plots were due to fluctuations in deer mouse abundance rather than shifts in abundance of other species.

The National Park Service's prescribed burning program is restoring grassland communities, protecting soil resources, and enhancing landscape vegetation diversity. Periodic prescribed burns in these shrub/grassland communities should be continued.

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