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Effects of repeated drought on soil microarthropod communities in the northern Chihuahuan Desert

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Abstract Soil microarthropods were sampled in plots centered on creosotebushes (*Larrea tridentata*) and in plots centered on mesquite (*Prosopis glandulosa*) coppice dunes. Nine plots in each area were covered by rain-out shelters with greenhouse plastic roofs which excluded natural rainfall and nine plots received natural rainfall. There were differences in the abundance of several mite taxa in soils from the mesquite coppice dune plots. Some taxa (Stigmaeidae, Nanorchestidae, and Entomobryidae) occurred in significantly lower numbers in the soils of the drought plots. Other taxa (Tarsonemidae and Cunaxidae) were more abundant in the drought plots in the mesquite coppice dunes. There were no significant differences in the abundance of any of the dominant taxa of soil microarthropods in the drought and control plots centered on creosotebush. In the creosotebush habitat, there were significantly fewer Prostigmata in the plots exposed to drought. In an area with both creosotebush and mesquite, there were no significant differences in microarthropod population responses to drought and in recovery from drought. The differences in responses of soil microarthropods to drought in creosotebush and mesquite habitats are attributed to the differences in soil stability, litter accumulations, and microclimate associated with the shrubs.

Key words Desert · Drought · *Larrea tridentata* · Soil microarthropods · *Prosopis glandulosa*

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Introduction

In the northern Chihuahuan Desert, large areas that were formerly grassland have been replaced by shrub-dominated communities (Buffington and Herbel 1965). The establishment of shrubs changed the spatial and temporal distribution of soil resources (water and nutrients) by forming self-re-enforcing resource islands (Charley and West 1975, 1977; Barth and Klemmedson 1978, 1982; Elkins et al. 1986; Martinez-Meza and Whitford 1996). The below-canopy soils of creosotebush are nutrient enriched in comparison to soils of the intershrub spaces (Whitford et al. 1997). In an early study of the distribution of soil microarthropods in the Chihuahuan Desert, Santos et al. (1978) reported that soil microarthropods were abundant in below-canopy soils but very sparse in soils of the intershrub spaces.

In deserts, soil fauna are dramatically affected by abiotic variables (Whitford et al. 1981; Steinberger et al. 1984; MacKay et al. 1986; Cepeda and Whitford 1989). Experimental studies of abiotic variables affecting soil microarthropod communities have been conducted using irrigation to supplement natural rainfall (MacKay et al. 1986; Whitford et al. 1988). Those studies demonstrated that soil temperatures were more important than soil moisture as a determinant of relative abundance and species composition of the soil microarthropod community. Utilizing a study designed to examine the functional attributes of shrub resource islands, we were able to examine the effects of repeated drought on the soil microarthropod faunas associated with creosotebush (*Larrea tridentata*) and mesquite (*Prosopis glandulosa*). Because of the soil modifications (moderate soil temperatures and high soil organic matter) produced by the presence of shrubs, we hypothesized that repeated drought would have no significant effect on the below-shrub-canopy soil microarthropod communities.

Methods

The studies were conducted on the Chihuahuan Desert Rangeland Research Center and the Jornada Experimental Range which are located approximately 40 km NNE of Las Cruces, N. M. The climate is arid, with a mean annual precipitation of 220 mm, of which 64% occurs during the summer months (June-September) from brief convectional storms. Summer maximum air temperatures frequently exceed 40 °C, and winter minimum air temperatures are frequently below 0 °C.

Studies of soil microarthropods associated with creosotebush were made on a piedmont area where the dominant shrubs were *L. tridentata*. Twenty-four individual creosotebushes that were a minimum of 2 m from the nearest neighbor creosotebush were selected and assigned at random to either drought or control. A perimeter 0.6 m from the canopy edge was trenched to a depth of approximately 1.5 m and lined with landscape plastic sheeting to isolate the root system of the shrub from the surrounding soil. Rain-out shelters were constructed over 16 plots. The rain-out shelter consisted of a steel framework covered with a roof of greenhouse plastic. Each rain-out shelter was constructed to provide a 1.5 m perimeter around the trenched plots. This perimeter was sufficient to eliminate virtually all of the wind-blown rainfall from the trenched plots. The shelter roofs varied from approximately 70 cm to more than 100 cm above the canopy of the shrub depending upon the size of the shrub. The plastic roofs were placed on the frames in June and removed each September.

Studies of soil microarthropods associated with mesquite were conducted in an area where sand dunes began forming approximately 80 years ago. The sand dunes are stabilized by multi-stemmed mesquite which form coppices on the dune crests. Mesquite shrubs were selected, trenched, and assigned to drought (covered by a rain-out shelter) or control. Mesquite and creosotebush shrubs were also studied in an area that contained both shrubs and an understory of burro grass (*Scleropogon brevifolia*). Rain-out shelters were assigned at random and all shrubs were trenched and treated as in the other areas. In all areas, the rain-out shelters were covered on the plots from June through September each year for the 3 years preceding our studies. Our studies were conducted in 1994 and 1995.

Microarthropods were sampled by selecting a cardinal direction and taking a single core from the soil at the drip-line of the canopy on each plot. We sampled nine drought plots and nine control plots at each study site. Soil samples were collected during the summer growing season in August or September to compare the effect of drought on the soil microarthropod communities under mesquite and creosotebush. Soil samples were collected from the mesquite coppice dune site in October to examine the short-term effects of drought-breaking rainfall. One set of samples was collected at the mixed shrub site at the end of January 1995, 5 months after the removal of the rain-out shelter roofs.

Each soil core was 6 cm diameter and 11 cm deep. Soil samples were placed into zip-lock plastic bags and transported to the laboratory in an insulated box. Microarthropods were extracted from the soil samples through modified Tullgren funnels into water as described by Santos et al. (1978). Microarthropods were identified to family using keys in Krantz (1978). Comparisons of paired samples were made by Students t test ($df=16$).

Results and discussion

There were differences in the composition of the microarthropod communities in the mesquite coppice dune sites and in the creosotebush dominated sites (Table 1). Six taxa that were recorded from the *P. glandulosa* coppice dunes were not found in the soils under *L. tridentata*. Four taxa recorded from *L. tridentata* soils were not found in mesquite coppice dune soils (Table 1).

Table 1 Mean numbers of individuals of each taxon of soil microarthropod extracted from soil samples from rain-out plots (*RO*) and control plots (*CO*) in mesquite coppice dunes (*Prosopis*) and in creosotebush shrubland (*Larrea*)

Taxa	*Prosopis*		*Larrea*	
	RO	CO	RO	CO
Prostigmata				
Nanorchestidae	2.2	6.7	3.2	5.2
Tydeidae	0.2	0.8	1.1	2.1
Tarsonemidae	2.7	0.9	1.3	1.5
Pyemotidae	1.3	0.8	0.0	0.0
Raphignathidae	0.3	0.0	0.0	0.0
Scutacaridae	0.0	0.7	0.0	0.0
Nematalycidae	0.9	0.7	0.0	0.0
Allochaetophoridae	0.2	0.1	0.0	0.0
Teneriffidae	0.4	0.1	1.0	0.0
Caeculidae	0.3	0.0	0.0	0.0
Bdellidae	0.5	0.3	1.0	0.0
Cunaxidae	1.2	0.8	1.0	0.0
Stigmaeidae	0.0	3.2	1.2	2.0
Penthaleidae	0.7	2.0	1.3	2.0
Linotetranidae	0.0	0.0	0.0	0.8
Samaridiidae	0.0	0.0	1.1	2.5
Eupodidae	0.0	0.0	1.1	2.5
Anystidae	0.4	1.2	0.5	0.8
Trombidiidae	0.0	0.0	1.0	0.0
Mesostigmata	0.2	2.3	0.3	1.0
Cryptostigmata	0.3	0.5	0.3	1.0
Insecta: Collembola				
Entomobryidae	0.3	0.6	0.4	0.9

Many of the differences in abundance of taxa in the rain-out and control plots 1 year after exposure to repeated growing season drought are attributable to time lags for recolonizing the sites from which summer rainfall had been excluded for the previous three summers.

In the mesquite coppice dune comparisons, prostigmatid mites were more abundant in the control plots than in the drought plots ($t=3.36$, $P<0.01$). There were significantly fewer nanorchestids in the drought plots ($t=2.27$, $P<0.05$). There were also significantly fewer penthaleids and entomobryid collembolans in the drought plots ($t=2.0$, $P<0.08$) (Fig. 1). Stigmaeids were absent in the drought plots sampled in August and in low abundance in the drought plots in the October samples (Fig. 1). Other taxa were more abundant in the drought plots than in the controls, e.g., cunaxids and tarsonemids ($t=2.02$, 2.0 respectively, $P<0.07$). Some of the differences between the drought and control plots disappeared when the plots were sampled in October after all of the plots had received 24.5 mm of rainfall (Fig. 1); however, the relative difference in total abundance between the drought plots and the control plots was the same (drought plots 63% of controls). The taxa that were more abundant in the drought plots were predators and small fungivorous mites. Some taxa of fungi are capable of growth in extremely dry soils and probably provide the food base for the small fungi-

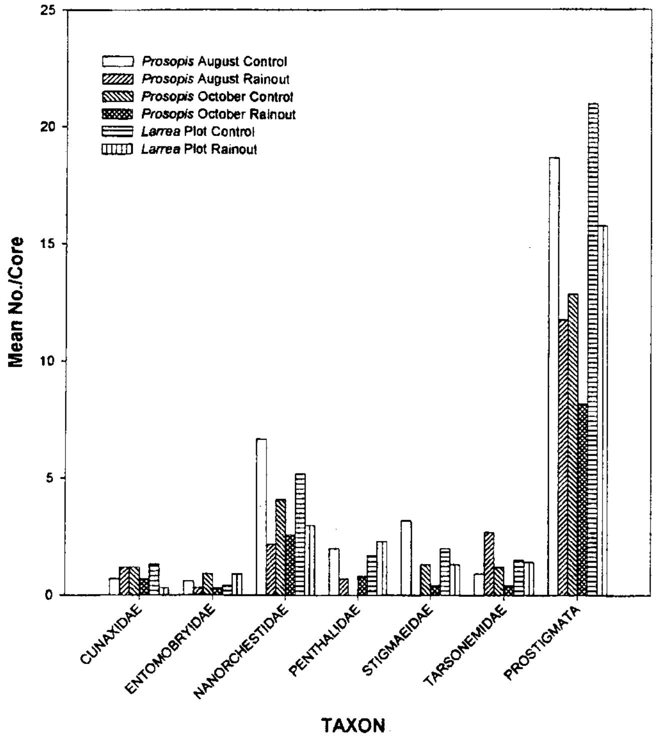

Fig. 1 Average numbers of individuals of microarthropod taxa from plots exposed to repetitive drought and control plots in creosotebush (*Larrea tridentata*) shrubland and mesquite (*Prosopis glandulosa*) coppice dunes in the northern Chihuahuan Desert

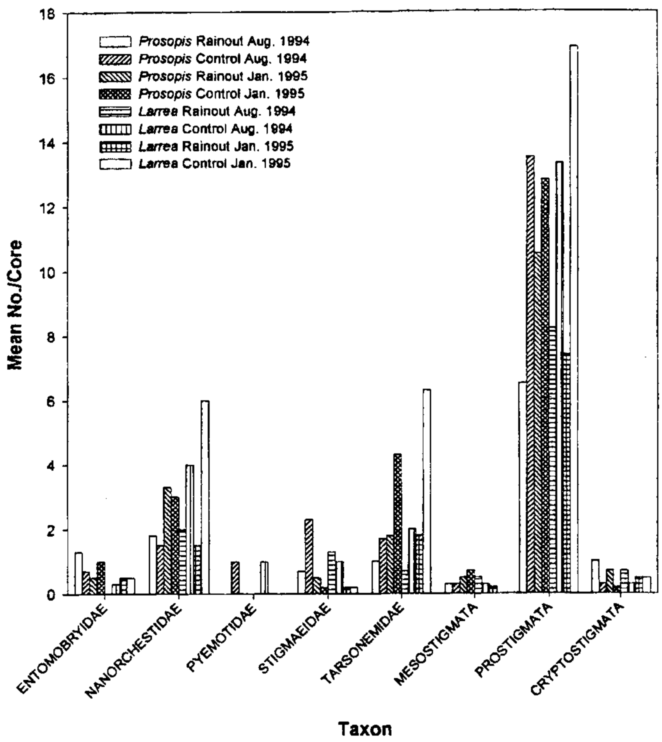

Fig. 2 Average numbers of individuals of microarthropod taxa from plots exposed to repetitive drought (rainout) and control plots in an area with creosotebush (*Larrea tridentata*) shrubs and mesquite (*Prosopis glandulosa*) shrubs with a grass understory. August 1994 samples represent 3 months into a growing season drought, and January 1995 samples represent 5 months' exposure to natural rainfall following removal of the rain-out shelter roofs

vorous mites (Whitford 1989). The reductions in abundance of the nanorchestids are probably related to the effects of the extremely dry soil on the soil algae and other microorganisms upon which nanorchestids feed. Collembolans are very dependent upon moist soils. In other studies in the Chihuahuan Desert, the most abundant soil collembolans were Isotomidae (Cepeda and Whitford 1989). The absence of isotomids in both creosotebush and mesquite coppice dune habitats may have been due to the natural drought experienced in the region during the period of this study. The natural rainfall during 1994 was only 48% of the long-term average for the summer growing season.

The differences in microarthropod abundance and community composition were not as great in the creosotebush plots as in the mesquite coppice dune plots (Fig. 1, Table 1). The drought plots had 75% of the number of microarthropods recorded from the controls. There were significantly lower populations of prostigmatid mites in soils of the rain-out plots than in the controls ($t=3.32$, $P<0.01$). There were no statistically significant differences in the abundance of any of the taxa in the drought-control comparison.

In the area with both mesquite and creosotebush shrubs, there were no differences in the taxonomic composition of the microarthropod communities from soils under the shrubs. Here, the morphologies of the mesquite and creosotebush shrubs were similar. The effect of drought on the soil microarthropods was similar under both shrubs (Fig. 2). There were significantly fewer prostigmatids ($t=2.6$, $P<0.05$) in soils from the *L. tridentata* rain-out plots at the end of the summer drought treatment in August 1994 and 5 months after drought recovery in January 1995. There were no significant differences among other taxa from the rain-out or control plots under either shrub species in August or January because of the large sample variances. Differences between drought plots and control plots were small after 3 months exposure to drought and 5 months after exposure to natural rainfall. The soils under both species of shrubs in this area were stable because of the grass cover. In this area, the shrubs of both species accumulated a sparse litter layer below the canopy. The absence of differences in the microarthropod communities under mesquite and creosotebush in this area is attributed to the similarity in soil, litter layer, and subcanopy microclimate.

Although drought affected the abundance of soil microarthropods in both the creosotebush and mesquite coppice dune habitats, the effects were more dramatic and affected more taxa in the coppice dunes than in the creosotebush habitats. These differences may be attributed to the differences in the structural characteristics of the resource islands in these habitats. The soil on the flanks of the coppice dunes is unstable and is moved during high winds. Wind causes the leaf litter to accumulate in the center of the coppice stems on the dunes. In the creosotebush habitats, litter is retained under the shrub canopies of those shrubs that have a hemispherical morphology (more than half of the shrubs in this study) (de Soyza et al. 1997). The soils under creosotebush canopies are not subject to wind erosion. In studies of the effects of varying concentrations of leaf litter and soil moisture on soil microarthropod populations, Steinberger et al. (1984) found that the quantity of leaf litter was more important than soil moisture as a determinant of abundance of microarthropods. Other studies demonstrated that soil tempemture was more important than soil moisture as a determinant of abundance of soil microarthropods in the surface soil (Mackay et al. 1986). The differences in canopy structure and litter retention patterns of creosotebush and coppice mesquite affect soil temperature because of the lower shade potential of coppice mesquite, and litter layer. When these variables are added to the mobile soil on the dune flanks, the different responses of the soil microarthropod populations in these habitats to drought becomes clear. Drought affects both the abundance and taxonomic composition of the microarthropod community, but the magnitude of the effect is a function of the degree to which the dominant shrubs modify the microclimate and contribute to the stability of the surface soil characteristics.

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