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Spatial distribution of litter and microarthropods in a Chihuahuan desert ecosystem

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Plant litter accumulated along the edges of small water courses where plants caused formation of eddy currents during heavy rains. Only small amounts of plant litter accumulated under shrubs on sloping erosional areas when compared to shrubs on flat areas. Microarthropod densities ranged from $146.\mathrm{m}^{-2}$ in unvegetated areas to $3103.\mathrm{m}^{-2}$ under shrubs in small water courses. Microarthropod density was directly correlated with amount of surface litter ($r = 0{\cdot}987$). Prostigmatid mites of the family Nanorchestidae were found in all habitats and Prostigmatids were the most numerous Acarina in all but one area. Collembola were found only in unvegetated areas of a large wash.

Introduction

In most deserts of the world, transitions between topographic elements are characteristically abrupt and watercourses which are dry most of the time tend to dissipate their occasional waters within local basins (Smith, 1968). Occasional torrential rainfall, characteristic of most desert regions, washes loose debris into watercourses or transports this material by sheet flow depositing it in and along the shores of ephemeral lakes. These physical processes result in a redistribution of dead plant material (litter), effect the distribution of soil water and create a heterogeneous and patchy biotic community. Therefore, before the dynamics of desert ecosystems can be adequately understood, the spatial relationships must be elucidated. In the Chihuahuan desert, spatial relationships have been described for many groups of organisms (Johnson & Whitford, 1975; Schumacher & Whitford, 1976; Whitford, 1976; Whitford, 1977; Whitford & Creusere, 1977) but soil microarthropods remain unstudied.

There have been few studies of litter distribution and/or the soil fauna in any of the world deserts (Wallwork, 1976). Wood (1971) surveyed the soil fauna in a number of Australian arid and semi-arid ecosystems. Wallwork (1972) made some studies of the microarthropod fauna in the California Mojave desert and Edney *et al.* (1974, 1975, 1976) studied abundance and distribution of soil microarthropods in the Mojave desert in Nevada. This paucity of information prompted Noy-Meir (1974) to state "more quantitative information is needed about the fate of dead organic material (macro- and micro-decomposition, erosion and redistribution) in arid ecosystems". The lack of such information represents a glaring gap in our knowledge of desert ecosystems. As part of our continuing program of studies of the structure and dynamics of Chihuahuan desert ecosystems, we designed the studies reported here to try to understand the relationship between litter redistribution and the spatial distribution and composition of the soil microarthropod community.

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Study site

These studies were conducted on the Jornada Validation Site, 40 km NNE of Las Cruces, Dona Ana County, New Mexico. The Jornada Validation Site is a desert watershed which drains into a small dry lake. The watershed varies in elevation from *c.* 2000 to 1000 m. The 100 year annual rainfall average ±1 standard deviation at the New Mexico State University Station, Las Cruces, New Mexico, is 211 ± 77 mm (Houghton, 1972), with most of that rainfall occurring during late summer from convectional storms. Summer maximum temperatures reach 40 °C and freezing temperatures are recorded from October through mid-April (data for the Jornada Validation Site Weather Station).

The site is a bajada (alluvial piedmont sloping from Mt. Summerford on the west to the Jornada basin on the east and north) with creosotebush (*Larrea tridentata* (Cov.)) as the dominant shrub. The bajada is drained by a large dry wash (arroyo) which flows south to north bisecting the study area. The west side of the large wash is heavily dissected by small arroyos (dry washes) which drain into the large wash. On the east side there are several shallow broad arroyos which drain to the northeast. Of the total 25 ha study area, the large wash constitutes 0·75 ha and the small arroyos make up 3·25 ha. The soils are gravelly to sandy loams. The soils on the west side have a high lime content with a lime-cemented hardpan (caliche) at 1 m or less from the surface. The creosotebushes on those soils are small (average 0·5 m or less in height), in comparison to those along the arroyos and on the east side (average 1 m or more in height). The caliche layer on the east side is more than 1·2 m below the surface.

The differentiation in soils and drainages produces distinct assemblages of perennial vegetation. Non-arroyo areas have an essentially monotypic cover of creosotebush, *Larrea tridentata*, 23 per cent cover. The arroyos are lined with mesquite, *Prosopis glandulosa* Torr.; tarbush, *Flourensia cernua* D.C.; desert willow, *Chilopsis linearis* (Cav.) Sweet; Apache plume, *Fallugia paradoxa* (D. Don) Endl.; soaptree yucca, *Yucca elata* Engelm.; and banana yucca, *Yucca baccata* Torr. Shrub cover at the arroyo edges approaches 100 per cent and along the edges of the large wash, clumps of *F. paradoxa* form large dense thickets.

Methods

A stratified sampling scheme was used to sample the three main topographical regions: the large wash, the small arroyos and the non-arroyo areas, both east and west of the large wash. Samples were taken in open areas and under shrubs. All surface litter on three, one meter square (1 m^2) plots was collected by a vaccuum device (D-Vac) and two core samples, 5 and 10 cm in depth and 12·5 cm diameter, were taken from the cleared quadrat on each topographic area. Samples were sorted into the following categories: stems, leaves and leaf parts, roots, reproductive parts, feces, animal material and sand with unidentified litter. Each category was weighed and the sand with unidentifiable litter was ashed in a muffle furnace at 600 °C to estimate the amount of organic material. Soil cores were also ashed to estimate the amount of organic matter present. Samples were collected in May, following the spring winds and in November after the fall rains.

Soil samples for extraction of microarthropods were collected during the last week in June and early July 1977, by pushing a 0·012 m^2 circular corer into the soil to an approximate depth of 15 cm. Soil samples were transported to the laboratory in plastic bags in an insulated container. The following samples were collected for extraction: middle of large wash, 12; under *Fallugia paradoxa* at edge of wash, 4; west of wash under creosotebush, 8; east of wash under creosotebush, 8; unvegetated west of wash, 8; unvegetated east of wash, 8; under shrubs at edge of small arroyo west side, 4; under *Yucca elata*, 16 (8 west side, 8 east side). Microarthropods were extracted from 500 cc of thoroughly mixed soil from each sample in a modified Tullgren funnel. Samples were extracted for 72 h at 60 W which provided a temperature gradient of 38–31 °C in the soil column. Microarthropods were collected in containers of water because we found that mites and collembolans remained on the surface due to surface tension and were easily separated from the soil particles. When we attempted to collect microarthropods in isopropol alcohol or ethanol, separation of organisms from soil particles was nearly impossible.

Results

Although the sample size (3) for any one topographic area was small, the variance between samples from any one area was also small. Therefore, we feel the data presented in Table 1 accurately reflect the distribution patterns of litter on the study site. With the exception of the open sections of small arroyos on the west side, there was an accumulation of surface litter over the growing season. Non-arroyo areas on the west side had much less litter accumulation than non-arroyo areas on the east side. There was little difference in litter accumulation on open areas even in the large arroyo (Table 1). Since there was no difference in organic content of the upper 10 cm of soil in any of the topographic areas, all samples were averaged: 2·2 per cent, range 0·8–4·2 per cent.

Table 1. *The topographic distribution of plant litter on the Jornada Validation Site, Dona Ana County, New Mexico*

		Surface samples ($g.m^{-2}$)			
		May sample		November sample	
Area	Litter	West*	East*	West*	East*
Non-arroyo					
Under shrub	Stems	14·85	47·57	25·67	56·45
	Leaves	5·54	42·63	20·37	50·60
	Feces	0·01	3·45	2·16	2·79
	Total	35·88	124·42	57·95	132·27
Unvegetated	Stems	5·02	9·38	16·50	12·09
	Leaves	1·58	11·26	4·66	9·13
	Feces	0·23	2·16	1·08	2·60
	Total	22·97	37·27	27·34	29·86
Small arroyo					
Under shrub	Stems	131·24	78·77	288·25	144·42
	Leaves	193·86	123·57	77·80	82·32
	Feces	2·10	2·27	1·46	1·77
	Total	369·90	231·61	429·35	255·00
Unvegetated	Stems	5·00	1·91	4·71	6·36
	Leaves	9·20	2·39	4·93	8·99
	Feces	0·65	0·52	0·02	0·99
	Total	23·29	16·38	12·41	18·94

May samples were taken after the windy season and November samples after the rainy season.

There was an almost perfect correlation between the average weight of surface litter and density of soil microarthropods (Fig. 1) ($r = 0{\cdot}987$). The regression ($y = 28{\cdot}41 + 7{\cdot}55x$), where y is mite numbers $.m^{-2}$ and x is litter in $g.m^2$, is highly significant ($t = 15{\cdot}07$, $P < 0{\cdot}001$). Densities ranged from 3103$.m^{-2}$ under shrubs in small arroyos on the west side to 146$.m^{-2}$ in open areas on the east side. The highest microarthropod densities were encountered under the thickets of *Fallugia paradoxa* at the edges of the large wash ($\bar{x} = 6477 \pm 1208.m^{-2}$). Although we did not collect litter from under *Fallugia* thickets, the surface is covered with a solid 1·5–2·5 cm layer of litter. In 12 samples from unvegetated areas in the middle of the large wash, we extracted only Collembola ($\bar{x} \pm$ S.D. $= 916 \pm 176.m^{-2}$).

There were no differences in microarthropod densities under yucca logs on either side of the arroyo ($\bar{x} \pm$ S.D. $= 2775 \pm 736.m^{-2}$). Eighty-four per cent of the microarthropods were

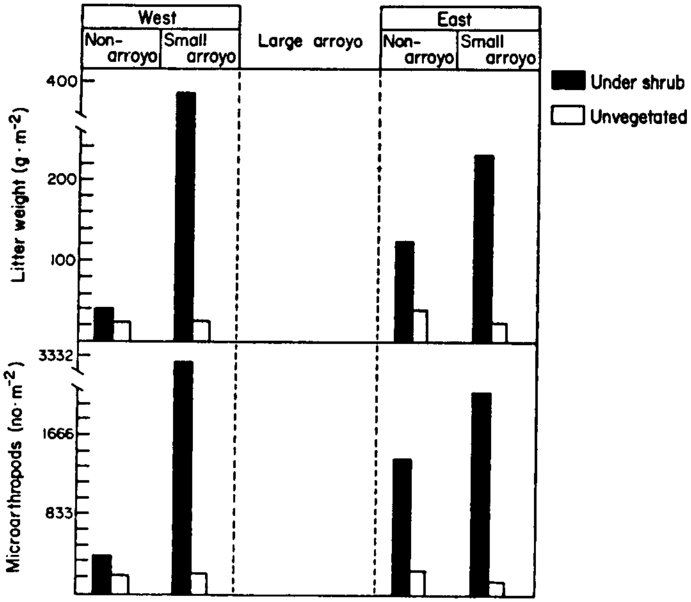


Figure 1. The distribution and relationship of plant litter and microarthropods on the Jornada Validation Site, Dona Ana County, New Mexico.

found under *Yucca* spp. were divided between two families of mites: Stigmatidae (Prostigmata) and Ascidae (Mesostigmata).

In addition to differences in densities of microarthropods there were marked differences in diversity and species composition from the various topographic areas which also appeared to be related to litter accumulation (Fig. 2). In areas with no canopy cover mites of the family Nanorchestidae (Prostigmata) were virtually the only microarthropods in the soil.

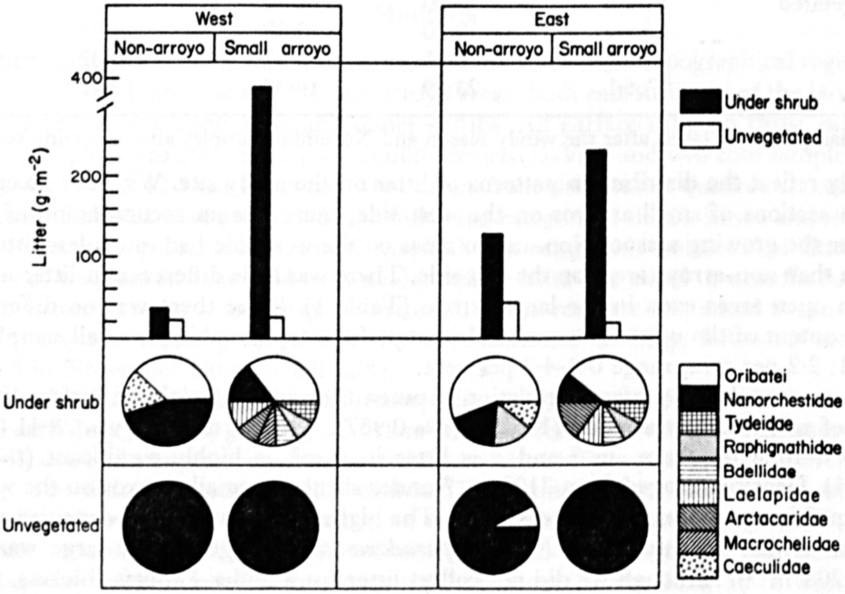
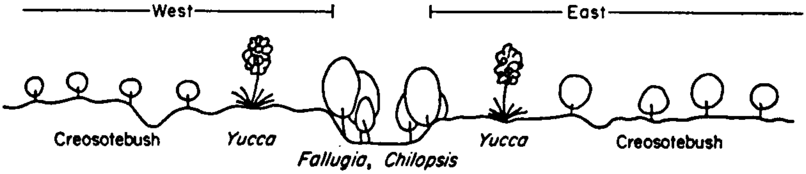


Figure 2. The distribution and relationship of families of soil mites (Acarina) to plant litter on the Jornada Site. The percentage of the total number represented by a given family is shown by the fraction of the circle indicated for that family. For mite densities in the different areas see Fig. 1.

Under shrubs, the Cryptostigmata (Oribatei) made up between 20 per cent and 30 per cent of the microarthropods except on the east side of the arroyo under shrubs where three families of Oribatids made up 54 per cent of the population. The Prostigmata were dominant in all areas except as noted above, making up between 28 and 44 per cent of the total population. Under shrubs in small arroyos and under *Fallugia* in the large wash, the Oribatids were represented by five families. Collembola were found only in the center of the large wash and under *Fallugia.* Both Astigmatid and Mesostigmatid mites made up a small fraction of the under-shrub arroyo populations but were virtually absent in the other areas (Fig. 1). Under *Fallugia* thickets the microarthropod population was: Cryptostigmata (Oribatei) 28·6 per cent (five families); Prostigmata 41·5 per cent (nine families); Astigmata 4·65 per cent (one family); Mesostigmata 15 per cent (five families); and Collembola 10·25 per cent (Fig. 3).



1. Cryptostigmata																			
Oribatei	X		X		X		X		X		X		X		X		X	X	X
2. Prostigmata																			
Nanorchestidae	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Tydeidae			X		X				X		X	/			X		X		
Raphignathidae			X		X				X		X				X		X		X
Paratydeidae									X		X								
Bdellidae			X		X				X		X				X		X		
Tenuipalpidae									X		X								
Pyemotidae									X		X								
Caeculidae	X								X		X								X
Stigmaeidae							X						X						
3. Mesostigmata																			
Arctacaridae			X		X				X		X				X		X		
Macrochelidae			X		X				X		X								
Ascidae							X						X						
Laelapidae			X		X				X		X				X		X		
4. Astigmata																			
Acaridae									X		X								
5. Collemobla									X	X	X								
6. Insect larva									X		X								

Figure 3. The topographic distribution of soil arthropods on the Jornada Validation Site.

Discussion

The data on litter accumulation can best be understood by considering the factors effecting redistribution of litter. Shrubs create eddy currents in wind and/or water resulting in deposits of detritus on the lee side of shrubs. Heavy summer rains transport litter from erosional areas into the arroyo system where deposition occurs wherever flow is disrupted, i.e. at the base of shrubs. The increase in litter between May and November was primarily due to stems, not leaves. The small leaves of desert plants are undoubtedly transported further down the watershed during rainfall runoff. The increase in leaf material between May and November in the litter in the large arroyo was due to the winter deciduous shrubs (*Prosopis glandulosa, Chilopsis linearis* and *Fallugia paradoxa*) which line the wash.

The apparent turnover in woody material between November and May is probably the result of termite activity. Johnson & Whitford (1975) showed that the highest densities of termites were on the east side of the large wash and along small arroyos (areas of detritus accumulation). Termites removed woody material from the surface by their feeding activity and transport it to some unknown depth in the soil. Some organic material is left in the upper 20 cm of the soil as egesta used by termites to build tunnels, but we have no data on this translocation process.

With the marked difference in amounts of litter in the various areas of the study site, we were surprised to find no difference in organic content of the upper 10 cm of soil. We hypothesize that the litter feeders (mites and termites) translocate the organic matter to a deeper level of soil. Since densities of microarthropods and termites are a function of litter accumulation, areas with sparse litter experience little feeding and translocation by litter consumers.

The correlation between microarthropod abundance and litter accumulation was suggested by the studies of Wallwork (1976) and Wood (1971). Edney *et al.* (1976) showed that mite densities in numbers .500 ml could be predicted from percentage of soil carbon by $y = 33{\cdot}95x - 11{\cdot}9$ ($r = 0{\cdot}89$), where y = mite numbers and x = percentage of soil carbon. Our studies show that surface litter is a better predictor of mite numbers than soil carbon and is more easily measured. We clearly demonstrated that in a Chihuahuan desert soil, microarthropod abundance can be predicted from the quantity of surface litter. This is not surprising considering the low organic content of the mineral soil and the effect of litter in modifying the environment of the upper 20 cm of soil. Surface litter probably enhances water retention as well as moderating soil temperatures; both factors that should favor growth of microarthropod populations.

The densities of microarthropods in some areas in a Chihuahuan desert ecosystem exceed the densities reported by Wood (1971) for desert scelerophyllous grassland and desert steppe, and the densities under *Fallugia* were similar to Australian low-layered woodland and shrub steppe.

Edney *et al.* (1976) reported between 2000 and 48 000 soil arthropods per m^2 for Mojave desert soils in Nevada; densities comparable to the Jornada. Price (1973) reported microarthropod density of 220 739.m^{-2} in a xeric ponderosa pine (*Pinus ponderosa*) forest in Nevada. Douce & Crossley (1977) reported between 5700 and 70 800.m^{-2} soil Acarina for nine tundra soils near Barrow, Alaska. The densities reported here for the Chihuahuan desert are comparable to those reported for other hot deserts. Although the growing season at Barrow, Alaska, is considerably shorter than that at the Jornada, the lowest densities reported by Douce & Crossley (1977) are as high as the highest reported here. Price's data for a xeric, high temperature soil in Nevada plus the other data discussed above suggest that the quantity of litter may be more or equally important to the growth of microarthropod populations as the physical environment.

The microarthropod fauna of the Chihuahuan desert is distributed among the suborders of Acarina more like the microarthropods of the Barrow tundra (Douce & Crossley, 1977) than temperate ecosystems which are dominated by Cryptostigmata, Oribatei (Crossley & Bohnsack, 1960; Block, 1965). The Chihuahuan desert Acarina are dominated by the Prostigmata with the Cryptostigmata making up a smaller percentage of the assemblage. The only area where the Cryptostigmata predominated was under shrubs on the east side of the large wash. All other areas were dominated by Prostigmata. Wood (1971) reported that Prostigmata were the most abundant Acarina in all Australian soils he studied and that the Cryptostigmata and Astigmata approached the density of the Prostigmata only in wet sclerophyll forest and rain forest. Price (1973) reported a preponderance of Prostigmata in a *Ponderosa* pine forest (a xeric forest type). The most widespread mites in the Chihuahuan desert soils are Prostigmatids of family Nanorchestidae. This contrasts with Wallwork (1972) who found that Oribatids predominated in soils under juniper in the Mojave desert. In a survey of the microarthropod fauna in a juniper woodland in northwestern New Mexico (McKinley County), we found that Prostigmatids accounted for 41 per cent and Oribatids for only 12 per cent of the microarthropods under juniper (*Juniperus monosperma*) (Whitford *et al.*, 1977).

Edney *et al.* (1976) found Oribatids to be the most numerous Acarina in a Mojave desert shrub area, but that they occurred in nearly equal percentage with Prostigmatids. The most numerous Prostigmatids in the Mojave desert shrub community were of the family Nanorchestidae.

The dominance of Prostigmatids seems to be related to the harshness of the environment except in the case of the Mojave desert. However, the abundance of the Nanorchestids in the Mojave is similar to that in the Chihuahuan desert. Before we can evaluate the significance of these differences in composition of the microarthropod faunas of arid and semiarid ecosystems, we need to know a great deal more about the biology of Prostigmatids.

Wood (1971), Wallwork (1972) and Edney *et al.* (1976) reported significant numbers of Collembola from the soils they studied. In contrast, we found Collembola only in the unvegetated center of the large wash and under shrubs at the edge of the large wash. Christiansen (1964) concluded that all Collembola studied required a relative humidity in their environment of over 89 per cent to survive for functional periods. It is likely that the only area on the Jornada site that met the moisture requirements of the Collembola was the large wash. Litter bag studies now in progress should help clarify this relationship.

Two families of mites were found only under yucca: the Prostigmatid (family Stigmatidae) and the Mesostigmatid (family Ascidae). Stigmatidae have been reported from straw and leaves (Krantz, 1975) and hence are not unexpected from soil samples. Krantz (1975) classes Ascidae as aerial predators and states that they do not occur in soil. However, he does discuss the phoretic (use of insects and other arthropods for dispersal) behavior of Ascidae. It is possible therefore that the Ascidae dropped off insects associated with yucca. The microarthropod fauna associated with yucca certainly deserves further investigation.

The data from this study clearly demonstrate the need for sampling areas with differing patterns of litter accumulation and for estimating the area occupied by the various categories of litter accumulation when attempting to estimate microarthropod populations. Only when such sampling schemes are used, can we estimate with any accuracy the relative importance of soil microarthropods in the economy of desert ecosystems.

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