

## Understanding an Ecological System: An Example of Temporal and Spatial Variability of *Dorymyrmex (Conomyrma) insana* in a Stressed System

Maliha S. Nash and <sup>1</sup>Walter G. Whitford

U.S. Environmental Protection Agency, Environmental Sciences Division, Landscape Ecology Branch, 944 East Harmon, Las Vegas, NV 89119; <sup>1</sup>USDA-ARS Jornada Experimental Range, MSC 3JER, New Mexico State University, Las Cruces, N. M. 88003

---

**Abstract:** The responses of pyramid ants *Dorymyrmex (Conomyrma) insana* (Buckley) to structural change (removal of an invasive shrub species) and to an environmental stress (short-term intense grazing by cattle) are presented from an experiment study in Chihuahuan Desert grassland. Spatial and temporal responses of *D. insana* were examined by analysis of variances, kriging maps and regression analyses. There were no significant responses of *D. insana* to grazing. The numerical and spatial responses of ants recorded from pit-fall trap data were the same as those recorded from mapping ant nests. The spatial distribution of *D. insana* nests was a function of the canopy cover of the invasive, woody shrub, honey mesquite (Fabaceae: *Prosopis glandulosa* Torrey) ( $r = 0.82$ ) and explained 68% of the variability in nests distribution. The dominant liquid feeding ant species (*D. insana*) responded numerically and spatially to structural change and environmental stress. Spatially referenced data are as important or more important for monitoring ecosystem change than are numerical data.

**Key words:** ants; biological indicator; spatial and temporal variability; kriging; ANOVA; mesquite shrub; multiple stressor; grazing

---

### Introduction

To understand the behavior of biota, it is necessary to study that biota in the context of space and time variability. If some species or group of species is to be used as ecological indicators, their responses to environmental stress must be examined both spatially and temporally. Biological indicators may respond directly or indirectly to environmental stress. Indirect responses may include behavioral changes or numerical changes. Numerical responses are typically examined by classical statistics where mean values are used to test for differences between treatments. However, behavioral responses may best be examined by the theory of regionalized variables using a geostatistical method (Matheron, 1963, 1971) in order to obtain an explicit solution for spatial variability. During the last decade, the need for biological indicators to assess the condition of an ecological system was introduced (NRC, 1994). These indicators needed to be sensitive to disturbance (e.g., livestock grazing) and to be consistently applied across large areas. In arid rangelands, ants were used as a biological indicator, because ants affect ecosystem processes such as water infiltration, soil nutrient distributions, and compositions of the soil seed bank. Ant species can differ with respect to the physical characteristics of the sites chosen for the construction of nests (Hölldobler and Wilson, 1990; Lobry de Bruyn and Conacher, 1990; Whitford and DiMarco, 1995). For some species, the distribution and characteristics of the vegetation may be of less importance than soil characteristics such as depth and texture. For other species, the presence of tall plants that provide shade may determine where nests are being constructed (Burbidge *et al.*, 1992; Roth *et al.*, 1994; Perfecto and Snelling, 1995). Species respond, therefore, differently to ecosystem structural changes by relocating their colonies or by modifying their foraging behavior (Nash and Whitford, 2001). In this paper, results from a multiyear spatial analysis of pyramid ants (Formicidae: *Dorymyrmex insana* Buckley) communities exposed to intensive, short-term grazing by cattle and to vegetation restructuring resulting from the removal of honey mesquite, a woody shrub (Fabaceae: *Prosopis glandulosa* Torrey) in a shrub grass land mosaic will be discussed. *D. insana* is a small, liquid feeding ants that is abundant and widely distributed in most habitats on the Jornada Experimental Range. The honey mesquite shrubs not only provide a reliable food source for liquid feeding ants, their shade also modifies the soil microclimate (Chew, 1995). An analysis of spatial patterns may provide information that could be used in interpreting the effects of stressors on ecosystem function. Results from the analysis will be used to test a hypothesis that the nest distribution of *D. insana* is not independent of the honey mesquite shrub cover.

**Site Description:** The experiment was conducted on the Jornada Experimental Range approximately 40 km N-NE of Las Cruces, New Mexico, USA. Eighteen 0.5 ha plots were established in a 1,284 ha grassland pasture that had been grazed during winter and spring at an average stocking rate of 259 AUM (Animal Unit Months) per year since 1957 (an AUM is one adult cow for 30 days). The experimental plots were 0.5 hectares surrounded by 3-strand barbed wire fencing that were constructed in July 1993. The plots were arranged in two rows of nine plots, in three blocks, of six plots per block along the long axis (Fig. 1). Mesquite shrubs were removed from 9 plots in

winter 1994. Six plots (3 with mesquite removed and three with mesquite intact) were grazed during August 1995, 1996 and 1997. Six plots (3 with mesquite removed and 3 with mesquite present) were grazed in January 1995, 1996. Because of the extreme drought, plots were not grazed in the summer of 1994. Plots were winter-grazed in February 1995 and 1996, and summer grazed in August 1995 and 1996. Stocking rate was adjusted for the estimated forage available in the plots. Grazed plots were stocked with between 20 and 40 yearlings per plot for 24-36 hours with the stocking rate adjusted to remove 65-80% of the estimated available forage.

**Data and Analyses:** Ant communities were sampled in September of each year beginning in 1993. Ants were sampled using pit fall traps arranged in a 7x7 trap array with 9.14 m spacing between traps on each of the 0.5 ha plots (see plot 2, Fig. 1). Pit-fall traps (38 mm diameter x 70 mm tall plastic vials) were filled to a depth of 30 mm with a mixture of 70% ethanol and 30% glycerol (Greenslade and Greenslade, 1971). Traps were buried in the soil flush with the surface and left in place for 24 hours. Traps were retrieved, labeled with grid location information, and stored before processing. All ants in a vial were identified as to species and counted. Data and spatial distribution of ant nests were obtained by measuring the distance from reference lines to ant nests on each of the plots. The 7 lines were 10 m apart and extended the full length of the plots. Each nest was identified as to species, where possible, or to genus (depending upon the morphology of the nest). The distance from a point on the line perpendicular to the nest was measured to the nearest centimeter. These data were then plotted by x, y coordinates on maps of the plots and recorded as absolute counts of densities of nests by species in each plot. For the purpose of this paper, counts and nests of the most common species (*D. insana*) were used.

Location, canopy diameter, and height of honey mesquite shrub were measured in each plot. Locations of mesquite shrubs were digitized for mapping. Canopy area of the mesquite shrub was used to express the proportion of soil surface shaded by the shrubs. Data used for the analyses consisted of abundance (counts of individual) and nests of *D. insana* and canopy area for the honey mesquite shrub. Kriging maps were developed for the *D. insana* behavior for two adjacent plots in winter grazed-shrubs intact (WI; Fig. 1, plot 4) and winter grazed-shrubs removed plots (WR; Fig. 1, plot 5). These maps were used to examine the spatial distribution patterns of relative abundance (counts) with time. Nest locations were posted on the maps of the mesquite cover in eight shrub-intact plots to determine the proportion of the nests within the honey mesquite canopy cover of more than 1 m<sup>2</sup> in area. These eight plots were exposed to grazing and previous study indicated that nests of *D. insana* were not affected significantly by the grazing (Nash and Whitford, 2001). Proportions of the number of nests within the coverage of the mesquite, from all these eight plots, were related to the proportions of land shaded by the mesquites using regression (Proc Reg, SAS). Correlation and regression of proportions of nests and mesquite canopy cover will be used to test whether nest distribution with respect to mesquite cover is independent. Mapping was done using Surfer software (Golden Software, Inc. Colorado, USA).

## Results and Discussion

On plots where mesquite shrubs (*P. glandulosa*) were removed, the only green vegetation that supported honey-dew producing insects (Homoptera) were sparse, snakeweed (*Gutierrezia sarothrae*) and a few soaptree yucca (*Yucca elata*) plants. *P. glandulosa* produces new leaves and flowers during late April and May each year independent of the winter rainfall or rainfall of the previous year. Homopteran populations on mesquite reach peak abundance in early summer and populations are maintained at relatively high numbers during the remainder of the growing season (Table 1).

The growing seasons of 1994 and 1995 were characterized by drought with no leaf production by the grasses until mid-September. Thus, during 1994 and 1995 there was virtually no grass foliage during the summer months for the honey-dew producing insects that *D. insana* rely upon for food. Sweep samples of the homopterans on grasses following summer rains in 1994 and 1995 yielded an average of only 164 homopterans per m<sup>2</sup> of grass canopy compared to an average density of 363 homopterans per m<sup>2</sup> of mesquite canopy (Forbes *et al.*, In Prep). Growing season drought does not eliminate homopterans from mesquite but homopterans are essentially absent from grasses that are not green and growing (Table 1). Because of the limited sources of food, *D. insana* had to travel (> 15 m) to shrubs outside the plot boundaries or survive on the limited liquids available from the sparse homopteran populations on other woody or fibrous plants (e.g. *Yucca elata* and sub-shrub, *Gutierrezia sarothrae*) (Van Zee *et al.*, 1997). With low rainfall in the growing season of 1994 and 1995, the abundance of *G. sarothrae* was very low (Whitford *et al.*, 1999) creating a very limit source of food for the *D. insana*.

An examination of the spatial distribution of *D. insana* in plot 4 (WR) over time showed that their activity was concentrated at the edges of the plot (Fig. 2). This pattern is clearly the result of *D. insana* foraging out from the nests located within WR to plants located in adjacent plots (plot 5, WI) where shrubs were not removed (Fig. 2). This spatial pattern became more pronounced following the removal of grass and forb foliage by livestock grazing. *Conomyrma* spp. are known to rapidly recruit food sources and to exclude other species from food sources (Hölldobler and Wilson, 1990). Thus, the change in spatial patterns of activity is consistent with the biology of the

Table 1: The effects of growing season drought and average summer rainfall on homopteran abundance and the abundance of ant (*Dorymyrmex* spp. and *Forelius* spp.) expressed as average number per m<sup>2</sup> in plant canopies of grasses and mesquite (*Prosopis glandulosa*) based on data in Whitford (1974). D indicates a drought year in which there was no effective rainfall until late August. A indicates an average rainfall year with sufficient rainfall for grass production from late June through September

Taxon	Plant Type	May		Jun-Jul		Aug-Sep	
		D	A	D	A	D	A
Homoptera	Mesquite	44.1	14.4	4.4	372.1	20.6	20.7
Homoptera	Grasses	0.0	47.2	0.0	12.0	0.0	5.0
Ants	Mesquite	5.5	0.0	10.0	1.7	11.3	0.7
Ants	Grasses	0.0	0.3	1.2	10.4	0.2	0.6

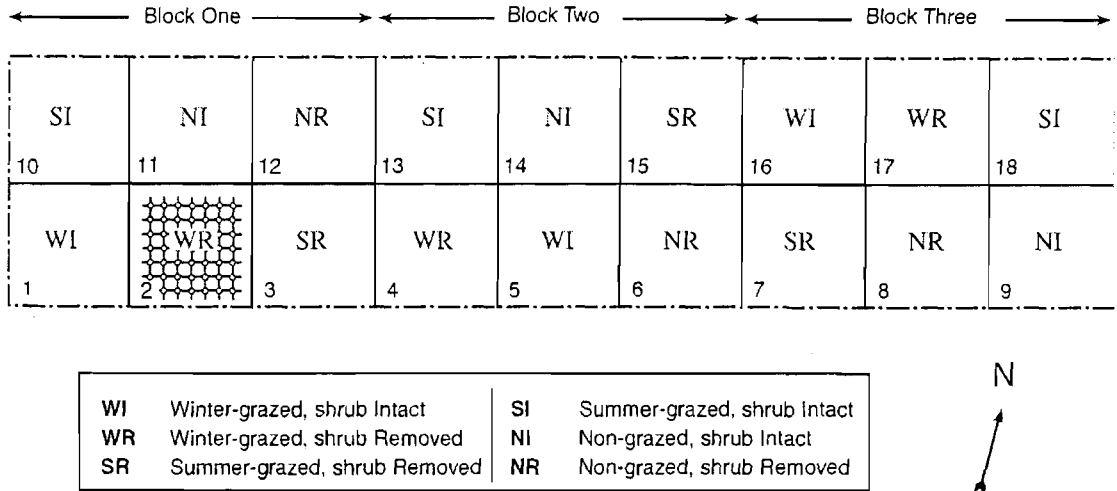


Fig. 1: Multiple Stressor Exlosure plots layout. Number in lower left corner for each plot denotes plot number. A pit-fall ant sampling grid is shown in plot 2. WI = Winter-grazed, shrub Intact, WR = Winter-grazed, shrub Removed, SR = Summer-grazed, shrub Removed, SI = Summer-grazed, shrub Intact, NI = Non-grazed, shrub Intact, NR = Non-grazed, shrub Removed.

species and should not be interpreted as resulting from the death of colonies at the center of the plot. Kriging maps clearly demonstrate that changes in frequency and abundance of the *D. insana* are related jointly with changes in spatial pattern and abundance of the prey. The reduction in relative abundance of *D. insana* in the shrubs-removed plots was attributable to both food resource limitations and loss of soil microclimate heterogeneity by shade from shrub canopies (Fig. 2). Changes in composition and structure of vegetation affected the spatial pattern and abundance of the prey and hence on the *D. insana* (Fig. 2). Numbers of isopleths and their values indicate changes as a response to an environmental stressor.

The nests of the *D. insana* were synchronized with the periphery of the invasive honey mesquites (*P. glandulosa*) in eight shrub-intact plots (Fig. 3). The nests were clustered in the plot in a non-random pattern, which is strongly correlated with canopy cover (correlation ( $r$ ) = 0.82,  $p > t$  = 0.0134). The dependence of the nests on shaded soil from honey mesquite canopies is significant as indicated by the regression model (Fig. 4). Sixty eight percent of the variability in nest distribution is attributable to the amount of the shrub canopy cover as explained by the regression model.

The mapped nests of *D. insana* were clustered around mesquite shrubs (Fig. 4; plot 5) in a pattern similar to that of the pit-fall trap data (Fig. 3; WI). Pit-fall trap data can, therefore, offer similar information as the actual mapping of ant colonies. Pit-fall trapping requires less time and provides data on relatively rare species that cannot be obtained by mapping or sampling visible colonies.

The behaviors of *D. insana* that may be responsible for differences in spatial patterns derived from pit-fall trap data are: (1) cessation of surface activity by some or all of the colonies, (2) moving the nest entrance, (3) and changing direction, duration, and intensity of foraging. Various ant species (e.g., *D. insana*; Whitford, pers. obs.) frequently move nest entrances. Since nest entrances are generally moved 2 m or less, the behavior of frequent nest moving

Maliha and Whitford: Understanding an ecological system

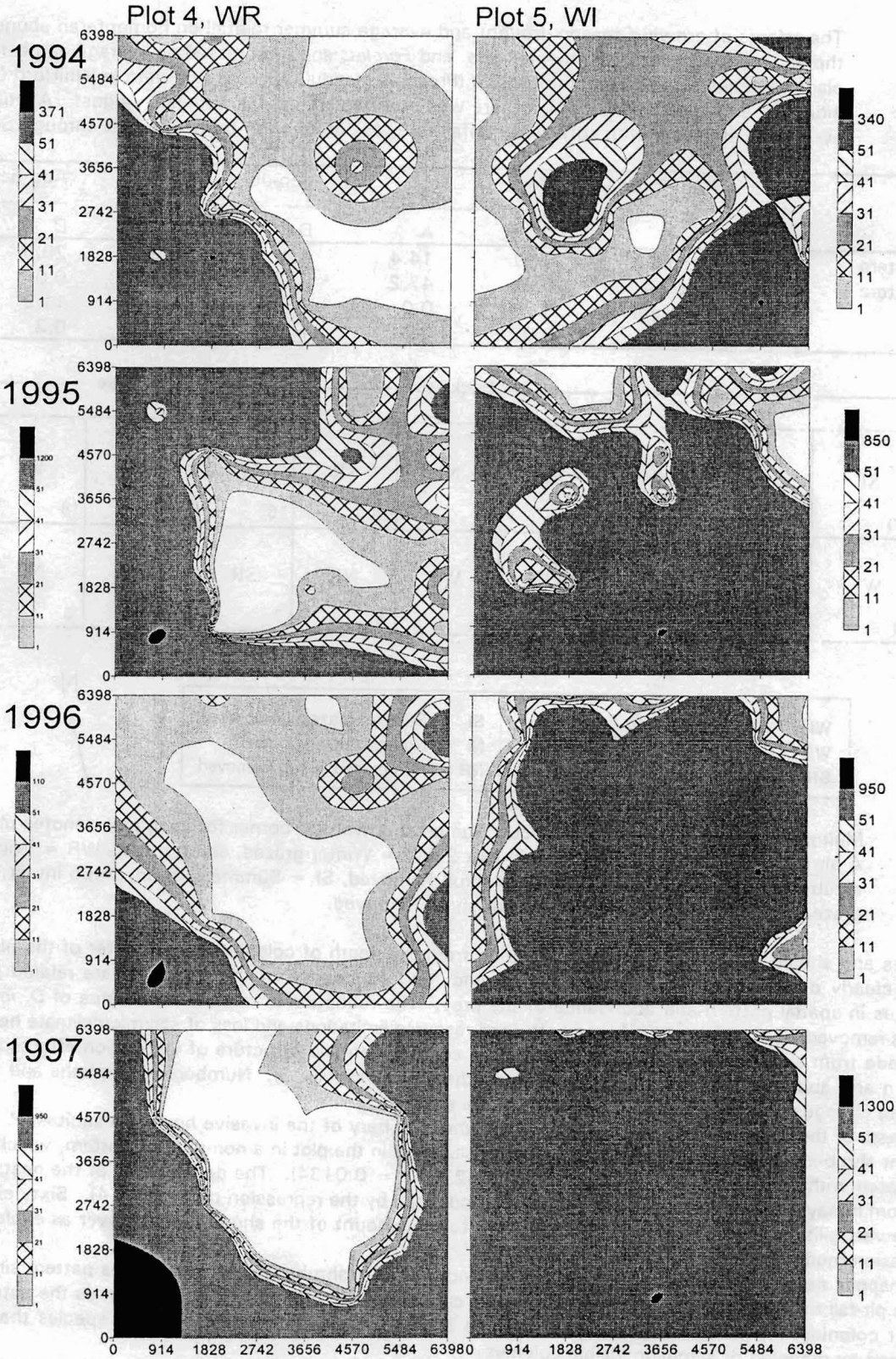


Fig. 2: Spatial distribution of *Dorymyrmex (Conomyrma) insana* abundance (counts) in WI (Winter-grazed, shrub Intact) and WR (Winter-grazed, shrub Removed) plots with time; darkest color indicate the maximum abundance value of ant which are different between plots.

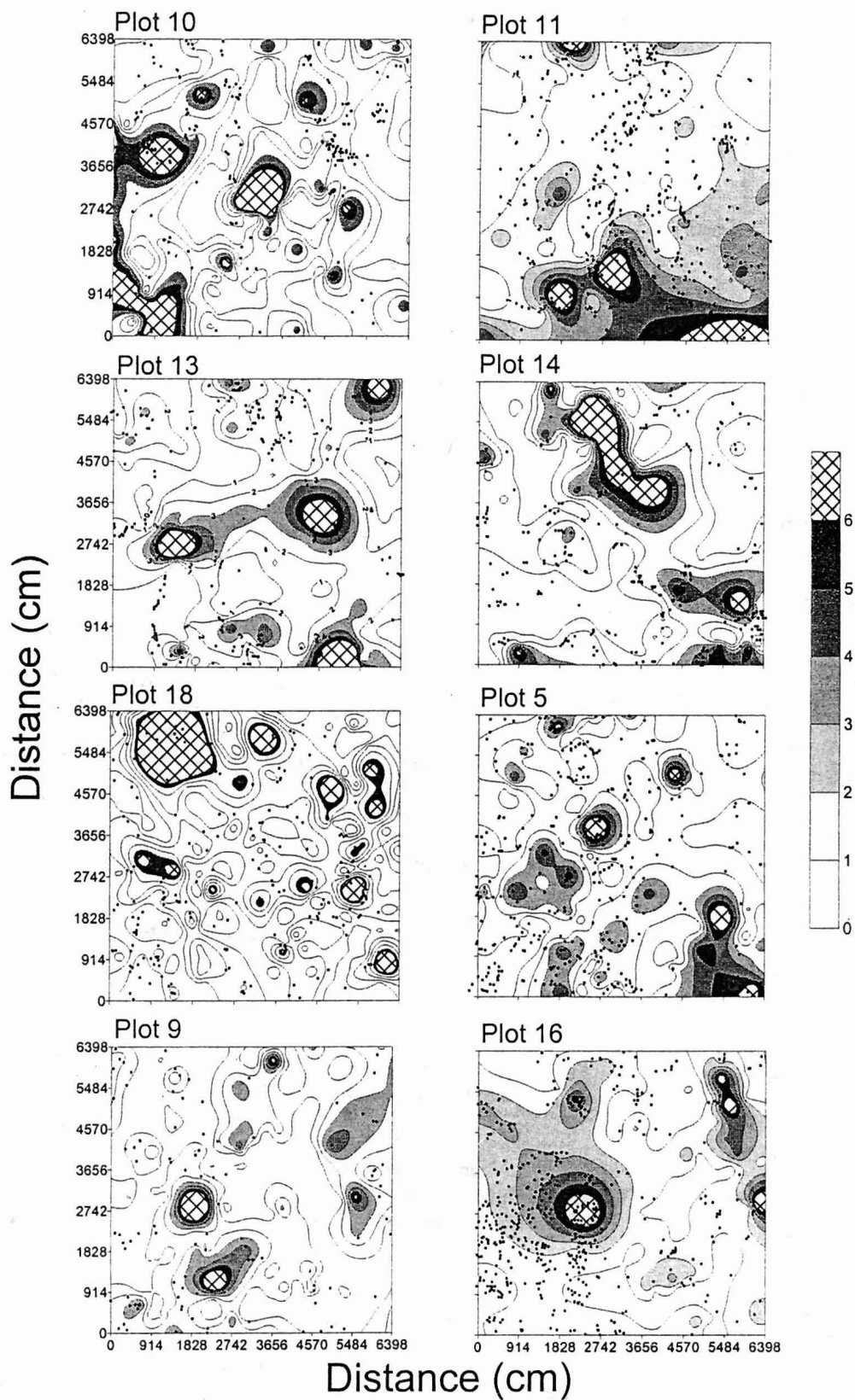


Fig. 3: Spatial distribution of canopy area of the honey mesquite shrub in shrub-intact plots. Dots represent nest locations of the *Dorymyrmex (Conomyrma) insana*. The cross-hatched area indicate canopy area  $\geq 6$  m<sup>2</sup>.

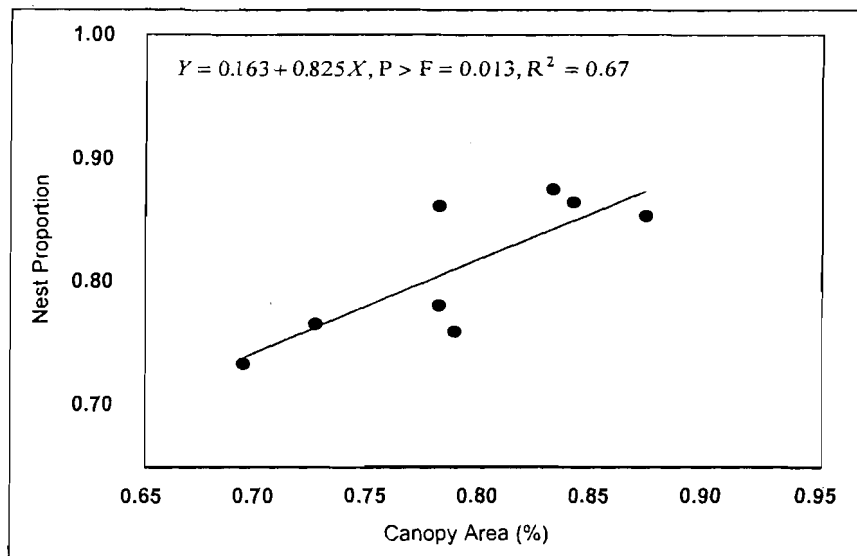


Fig. 4: Proportion of nest that occupied by the *Dorymyrmex (Conomyrma) insana* within the shaded area of the mesquite vs. the proportion of land that is covered with the honey mesquite canopy ( $> 1 \text{ m}^2$ ).

is least likely to be detected by the pattern analysis used in this study. Large changes in some spatial patterns are likely the result of cessation of activity by colonies or marked changes in foraging intensity and direction. Nest relocation may contribute to the spatial patterns recorded by analysis of pit-fall trap data, but actual mapping of nests over time may be required to confirm this.

Classical statistics such as testing for significant differences among means have been used to characterize and evaluate ecosystem conditions. However, some of the more important ecosystem changes may be changes in spatial pattern of ecosystem components. Classical statistical tests tend to lose information on spatial variability (Nash *et al.*, 1998; Nash *et al.*, 2000). However, kriging provided maps that showed changes in the spatial distribution of the ants following the removal of mesquite and intensive overgrazing, resulting in the study area having patchiness in distribution of vegetation and in soil characteristics. As a result of aridity in deserts, the spatial scale of patchiness can vary greatly from one area to another. Analyses that provide meaningful information in arid systems, where heterogeneity is expressed along gradients or at fine spatial scale, may not provide the needed information in arid ecosystems. Maintaining the appropriate patchiness may be the most important measure of management for sustainable desert ecosystems. Because soil nesting ants respond to changes in patterns of heterogeneity in arid systems, ant communities can serve as indicators of heterogeneity. The analyses that are provided in this paper can serve as a tool for monitoring structural change and environmental stress in arid ecosystems.

### Acknowledgments

The research would not have been possible without the contributions of Dr. Kris Havstad and the Jornada Experimental Range technical staff who constructed the fenced plots and moved the cattle in and out of the grazed plots.

The research reported here was supported by an interagency agreement between the U.S. Environmental Protection Agency, Office of Research and Development, and the U.S. Department of Agriculture (Agreement No.: DW1293891501-1). This manuscript has been subjected to the Agency's peer and administrative review and accepted as an EPA publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

### References

- Burbidge, A. H., K. Leicester, S. McDavitt and J. D. Majer, 1992. Ants as indicators of disturbance of Yanchep National Park, Western Australia. *Journal of the Royal Society, West Australia*, 75: 89-95.
- Chew, R. M., 1995. Aspects of the ecology of three species of ants (*Myrmecocystus* spp. and *Aphaenogaster* sp.) in desertified grassland in southeastern Arizona, 1958-1993. *American Midland Naturalist* 134: 75-83.
- Forbes, G. S., J. W. Van Zee, W. Smith, W. G. Whitford. Arthropod Community Structure and Species Richness in a Desert Grassland: Variation Among Years. (In Preparation)

- Greenslade, P. J. M. and P. Greenslade, 1971. The use of baits and preservatives in pitfall traps. *J. the Australian Entomological Society*, 10: 253-260.
- Hölldobler, B., E. O. Wilson, 1990. *The Ants*, Bellnap Press. Cambridge, MA.
- Loby de Bruyn, L. A., A. J. Conacher, 1990. The role of termites and ants in soil modification. *Australian J. Soil Res.*, 28: 55-93.
- Matheron, G., 1963. Principles of geostatistics. *Economic Geology*, 58:1246-1266.
- Matheron, G., 1971. The theory of regionalized variables and its applications. *Les Cahiers du Centre Morphologic. Mathematique de Fontainebleau*, No. 5, Edit. Par L'Ecole National Superieure des Mines de Paris.
- Nash, M. S., W. G. Whitford, 2001. Ants as biological indicators for monitoring changes in arid environments: lessons for monitoring protected areas. *in Research and Management Options for Protected Areas. Proceedings of 1<sup>st</sup> International Symposium and Workshop on Arid Zone Environment Research and Management Options for protected Areas. 23-25 January 2000, Abu Dhabi, United Arab Emirates.*
- Nash, M. S., W. G. Whitford, J. Van Zee and K. Havstad, 1998. Monitoring Changes in Stressed Ecosystems Using Spatial Patterns of Ant Communities. *Environmental Monitoring Assessment* 51: 201-210.
- Nash, M. S., W. G. Whitford, J. Van Zee and K. M. Havstad, 2000. Ant responses to environmental stressors in the northern Chihuahuan Desert. *Environmental Entomology*, 29: 200-206.
- National Research Council (NRC), 1994. *Rangeland health: new methods to classify, inventory, and monitor rangelands*. National Academy Press, Washington, DC USA.
- Perfecto, I. and R. Snelling, 1995. Biodiversity and the transformation of a tropical agroecosystem: ants in coffee plantation. *Ecological Applications* 5: 1084-1097.
- Roth, D. S., I. Perfecto and B. Rathcke, 1994. The effects of management systems on ground-foraging ant diversity in Costa Rica. *Ecological Applications*, 4: 423-426.
- Van Zee, J. W., W. G. Whitford, W. E. Smith, 1997. Mutual exclusion by dolichoderine ants on a rich food source. *The Southwestern Naturalist*, 42: 229-231.
- Whitford, W. G., 1974. *Jornada Validation Site: Validation Studies. US/IBP Desert Biome Research Memorandum 74-4. 104p. Utah State University, Logan, Utah.*
- Whitford, W. G., R. DiMarco, 1995. Variability in soils and vegetation associated with harvester ant (*Pogonomyrmex rugosus*) nests on a Chihuahuan Desert watershed. *Biology and Fertility of Soil*, 20: 169-173.
- Whitford, W. G., D. J. Rapport and A. G. deSoyza, 1999. Using resistance and resilience measurements for 'fitness' tests in ecosystem health. *Jo. Environmental Management*, 57: 21-29.