

# MONITORING CHANGES IN STRESSED ECOSYSTEMS USING SPATIAL PATTERNS OF ANT COMMUNITIES

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**Abstract.** We examined the feasibility of using changes in spatial patterns of ants-distribution on experimental plots as an indicator of response to environmental stress. We produced contour maps based on relative abundances of the three most common genera of ants based on pit-fall trap captures. Relative abundance of *Conomyrma* spp. decreased, relative abundance of *Solenopsis* spp. increased, and relative abundance of *Pogonomyrmex* spp. remained relatively unchanged. The contour maps showed long-term changes in foraging activity and/or distribution of colonies of ants in response to grazing by domestic livestock. This study demonstrated that analysis of spatial patterns of ant activity derived from relative abundances of ants in pit-fall traps provided interpretable data for developing an indicator of exposure to ecosystem stress.

## 1. Introduction

Assessing and/or monitoring the health of arid ecosystems requires a suite of indicators. That suite of indicators should include measurements that relate to important ecosystem functions such as the redistribution of water and nutrients, productivity, and the maintenance of biodiversity (Herrick *et al.*, 1995). The measurements that are incorporated into the calculation of indicators may provide information on all or a few of these ecosystem functions. In arid ecosystems, ants affect ecosystem functions such as water infiltration, soil nutrient distributions, and composition of the soil seed bank (Whitford and DiMarco, 1995; Carlson and Whitford, 1991; J. Herrick, unpublished data). Ants have also been used to examine the effects of changes in ecosystems on biodiversity (Roth *et al.* 1994, Perfecto and Snelling, 1995). However, in some arid ecosystems, ants were poor indicators of exposure of the ecosystems to stress (Whitford *et al.*, in press). The results of those studies suggested that changes in spatial patterns resulting from altered behavior of selected genera may be better indicators of exposure to stress than quantitative estimates of relative abundances of species and/or species richness.

Ant species differ with respect to the physical characteristics of the sites chosen for construction of nests. For some species, the distribution and characteristics of the vegetation may be less important than soil characteristics such as depth and texture. For other species, the presence of tall plants that provide shade may be an important environmental variable determining where nests are constructed (Burbidge *et al.*, 1992, Roth *et al.*, 1994, Perfecto and Snelling, 1995). We hypothesized that some ant species would respond to changes in vegetation characteristics by relocating their colonies, or by modifying their foraging behavior (Whitford and Ettershank, 1975).

In this paper we present the results of a multi-year spatial analysis of ant communities exposed to intensive, short-term grazing by cattle and to vegetation restructuring resulting from removal of woody shrubs in a shrub grassland mosaic. We hypothesized that analysis of spatial patterns would provide information that could be used in interpreting the effects of stressors on ecosystem function. This study provided a test of the feasibility of using spatial patterns of ant abundances as an indicator.

### 2. Study Site and Methods

The study site was located on the Jornada Experimental Range, 40 km northeast of Las Cruces, NM. Eighteen 0.5 ha plots were established in a grassland pasture that had been grazed at light stocking rates, only during the winter, for more than 30 years. The study plots were arranged in two rows of nine plots that were blocked along the long axis (Figure 1). The treatments were a combination of two factors: (1) removal and non removal of the mesquite shrubs (*Prosopis glandulosa*) and (2) winter grazing, summer grazing, and ungrazed control. These treatments were used in a randomized complete block design (Figure 1). The study area was fenced in 1993. Mesquite shrubs were removed from nine plots in January and February 1994, and there was no grazing in 1994. Winter-grazed plots were grazed on 15-16 February 1995 and 9-12 January 1996. The plots were grazed at a stocking rate that removed 65-80% of the vegetation in a 24-hour period. Ant communities were sampled in September of each year beginning 1993. In 1996, we sampled ant communities one week prior to summer grazing (August 16) and again on September 10, three weeks post summer grazing.

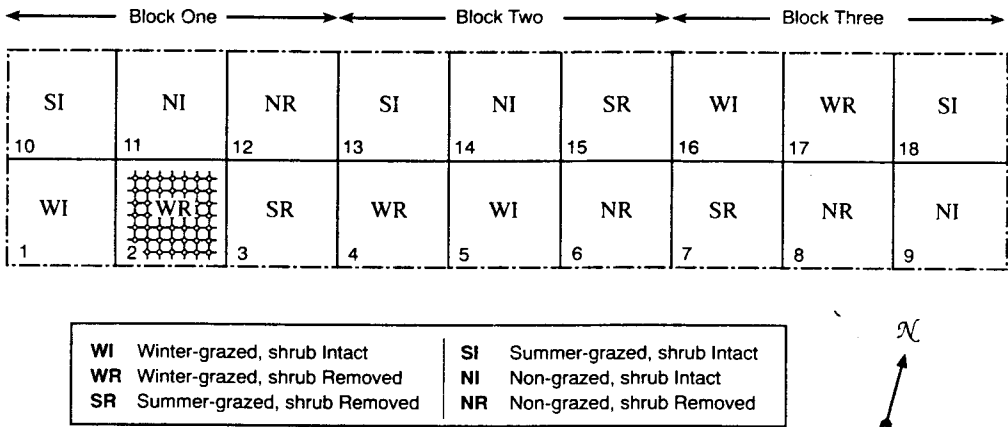


Fig. 1. Multiple Stressor Exclusion plots and grid layout for pitfall sampling of ants. Numbers in the left lower corners denote the plot number. Pitfall ants sampling grids is given in plot 2.

Ants were sampled by pitfall traps arranged in 7 x 7 trap arrays with 9.14 m spacing between traps on each of the 0.5 ha plots (see plot 2, Figure 1). Pitfall traps (38 x 70 mm tall plastic vials) were filled to a depth of 30 mm with a mixture of 70 percent ethanol and 30 percent 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 prior to processing.

All ants in a vial were identified by species or by operational taxonomic unit (e.g. *Pheidole* spp. with no major workers) and counted. The data used in the analysis were a) percentage of traps in which selected genera were found and b) number of individuals of a species in a vial (relative abundance). The feasibility of using spatial analysis was examined by using data from only the winter-grazed plots.

### 3. Data Analysis

We analyzed the spatial distribution patterns of only the three most common genera (*Solenopsis* spp., *Conomyrma* spp., and *Pogonomyrmex* spp.). These genera differ sufficiently in foraging behavior and nest placement (Whitford 1978, Holldobler and Wilson 1990) to provide a reasonable test of the feasibility of this analytical approach. We used contour mapping to look for the spatial distribution patterns with the time. We used Surfer software (Golden Software, Inc. 809 14th st., Golden CO 80401-1866) for contour mapping. Mapping was done using kriging when the number of traps were  $\geq 20$ . Mapping was done using an inverse distance technique when the number was  $< 20$ .

### 4. Results and Discussion

In 1993, before any of the treatments was imposed, *Conomyrma* spp. accounted for 96.6 percent of all the ants trapped on the plots and were found in 96.3 percent of the traps that were recovered. In each of the winter-grazed shrub-removed plots, there were dramatic reductions in relative abundance of *Conomyrma* (Figure 2). Fire ants, *Solenopsis*, which occurred at low abundances prior to the imposition of treatments, showed a dramatic increase in relative abundance (Figure 2). There was little change in the relative abundance of seed-harvester ants, *Pogonomyrmex*, following the shrub-removal and grazing treatments (Figure 2).

The response of *Conomyrma* is what is expected for a liquid-feeding ant that tends homopteran insects on vegetation. Shrub removal during the winter 1994 eliminated mesquite (*Prosopis glandulosa*), a host plant for homopterans that is phenologically predictable and that provides a food source of cell contents and phloem sap for sucking herbivores such as homopteran throughout the growing season. The growing seasons of 1994 and 1995 was characterized by drought with virtually no leaf production by the grasses. Thus, during 1994-1995 there was virtually no foliage for the sucking insects that *Conomyrma* rely upon for food. An examination of the spatial distribution of *Conomyrma*

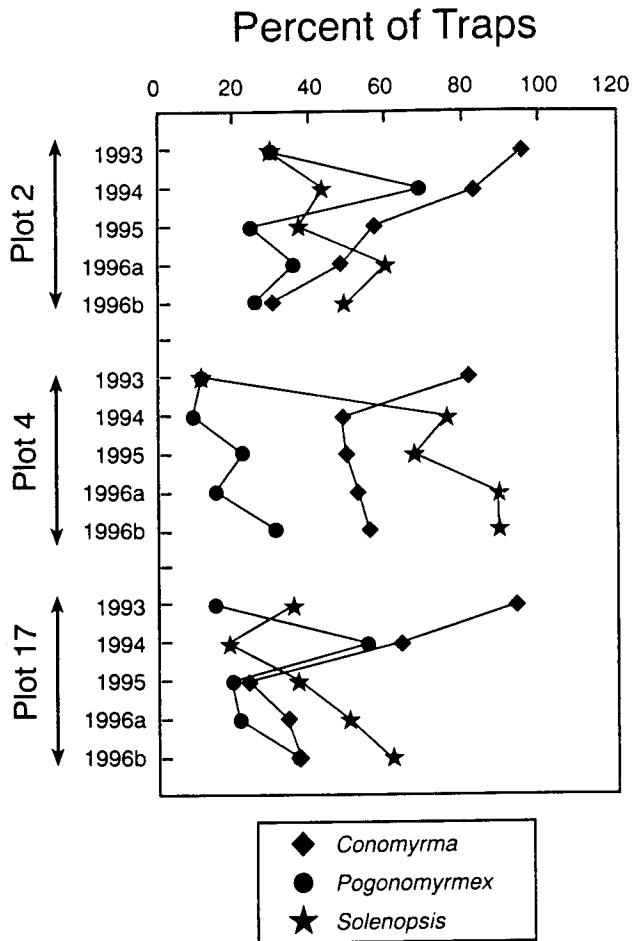


Fig. 2. Percent of traps of *Conomyrma*, *Solenopsis*, and *Pogonomyrmex* in winter-grazed shrub-removed plots with time.

in plot 2 over time showed that their activity was concentrated at the edges of the plots. This pattern is clearly the result of *Conomyrma* foraging out from the nests located within plot 2 to plants located in adjacent plots where shrubs were not removed (compare Figure 3a vs. 3b, 3c, and 3d). This spatial pattern became more pronounced following removal of grass and forb foliage by livestock grazing. *Conomyrma* are known to recruit rapidly to food sources and to exclude other species from food sources (Holldobler and Wilson, 1990). Thus, the change in spatial patterns of activity is consistent with the biology of the species and should not be interpreted as resulting from the death of colonies at the center of the plots.

The increase in abundance of *Solenopsis* occurred spatially in a pattern that was distinctly different from the pattern seen in *Conomyrma*. The *Solenopsis* tended to clump with higher abundance in the center of the plots. *Solenopsis* are generalists that feed on seeds as well as on liquids (field observation). This generalist feeding behavior should

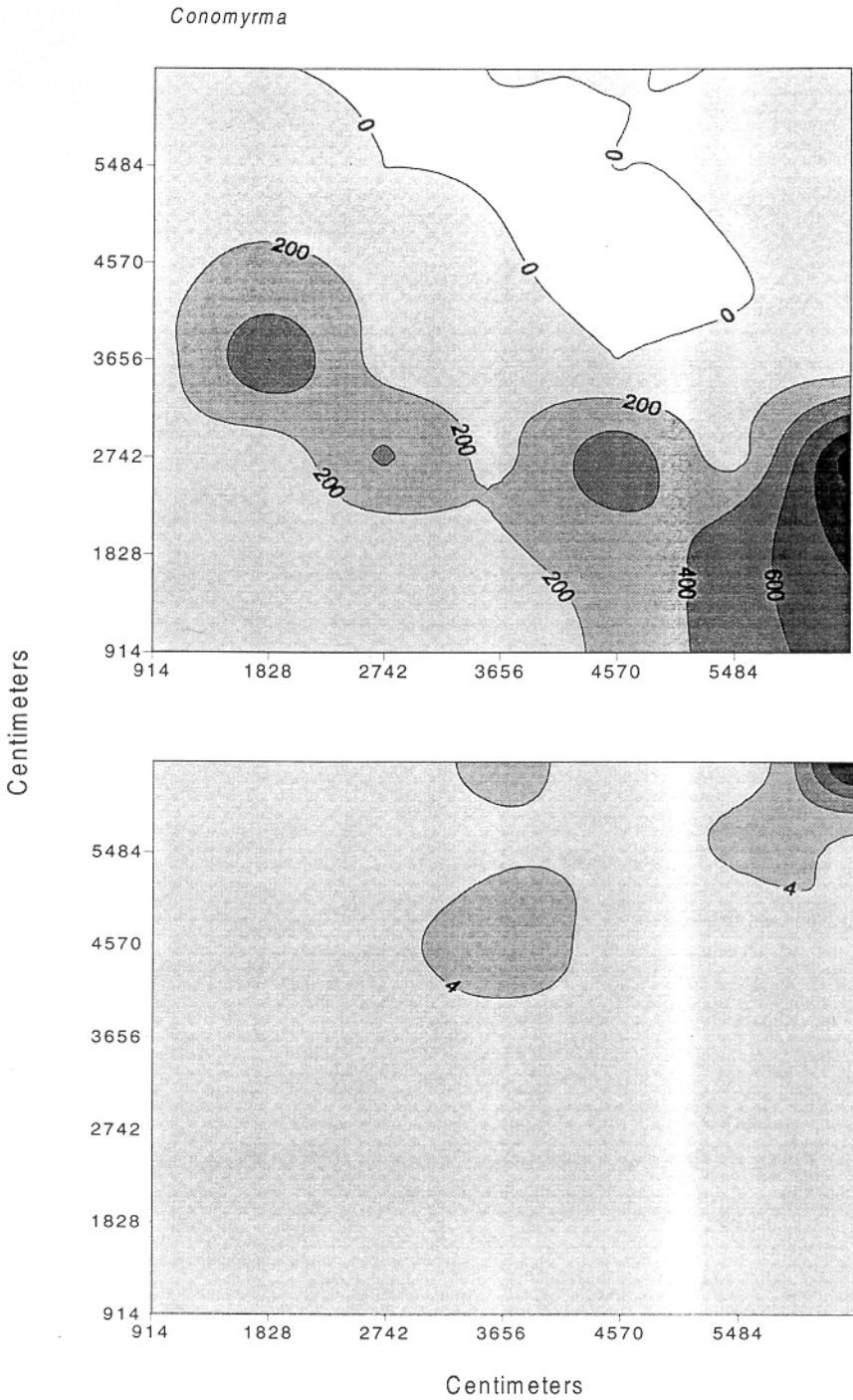


Fig. 3. Distribution of relative abundance (counts) of *Conomyrma* and *Solenopsis* for plot 2 in a) 1994, 20 weeks before grazing, b) 1995, 26 weeks after grazing, c) 1996a, 28 weeks after grazing, and d) 1996b, 31 weeks after grazing. (Increasing relative abundance values from clear to dark).

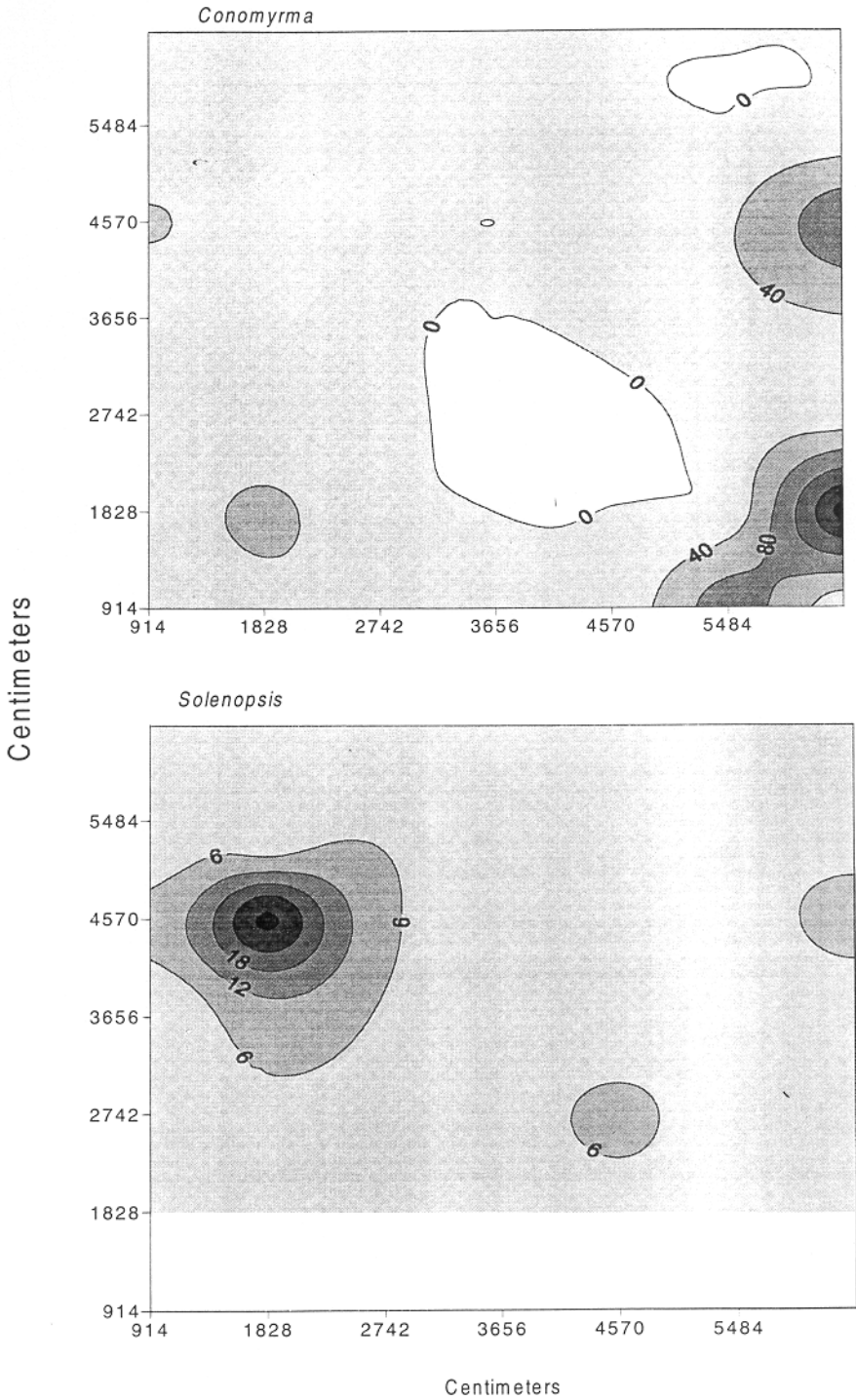


Fig. 3b

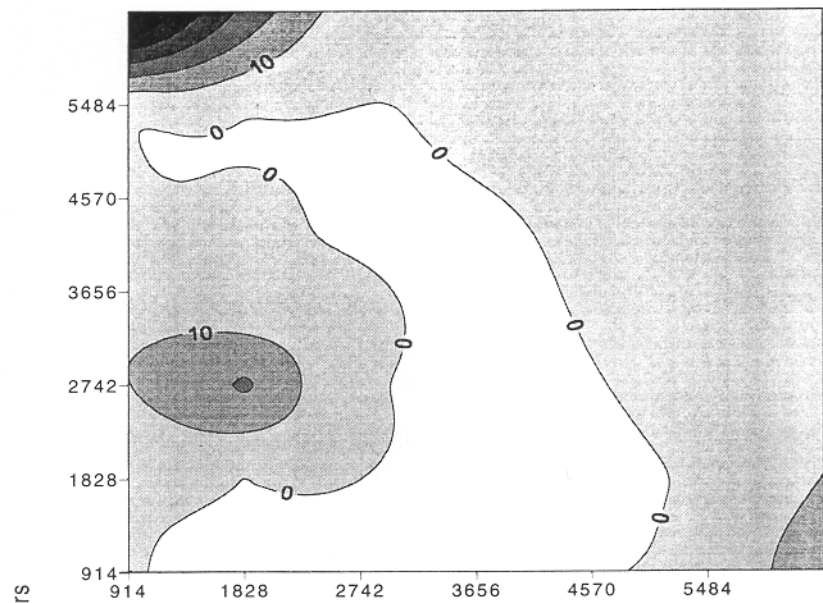
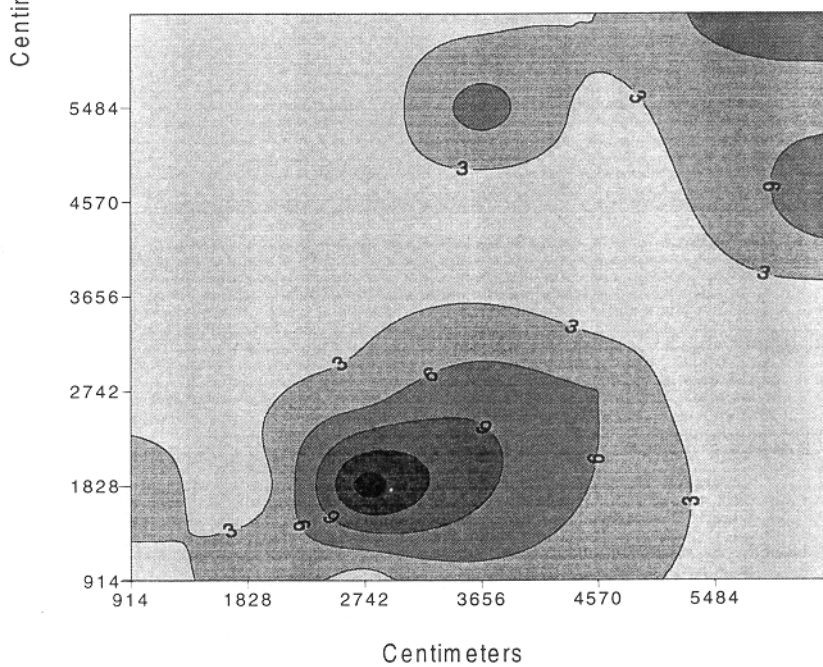
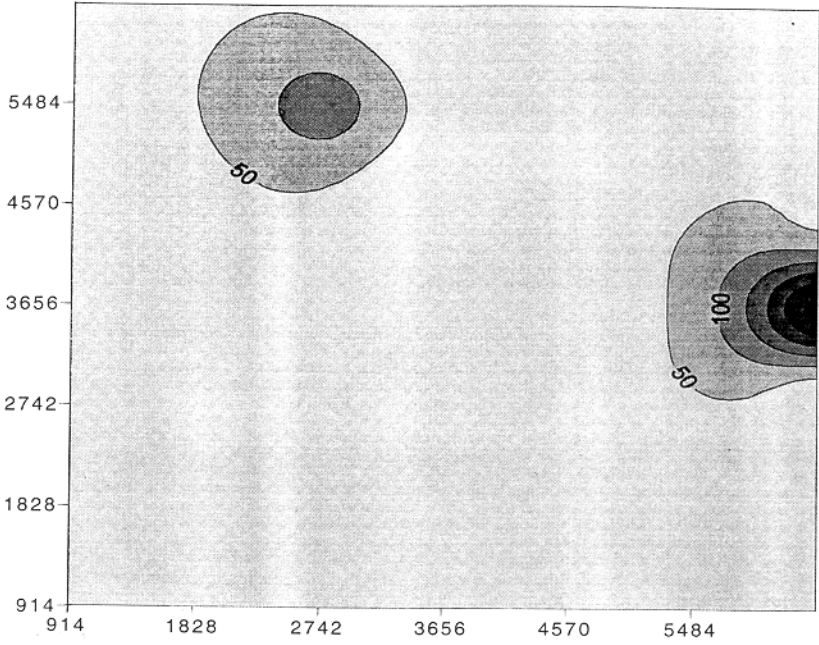
*Conomyrma**Solenopsis*

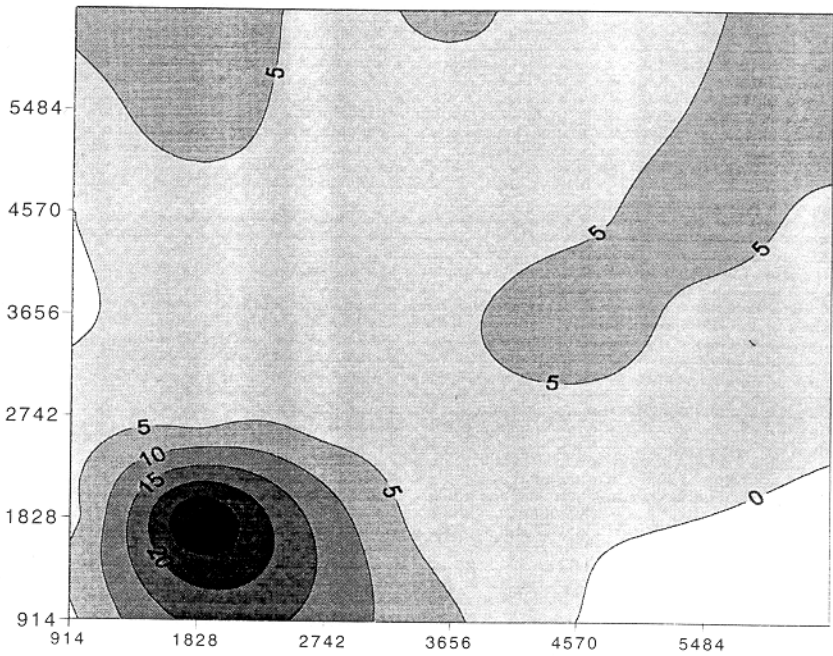
Fig. 3c

*Conomyrma*



Centimeters

*Solenopsis*



Centimeters

Fig. 3d



result in a more random foraging pattern and relatively equal probability of capture in traps anywhere on the plot. However, *Solenopsis* have colonized soil beneath the dung pats which explains their rapid increase in abundance following grazing (Figure 2). The dung pats provide a sheltered environment for shallow nesting species such as *Solenopsis*.

The lack of change in the abundance of *Pogonomyrmex* reflects the resilience of these ants to disturbance and stress. Despite the drought conditions during the summer growing season, there were sufficient winter rains for germination and growth of spring ephemerals. Seeds of spring ephemerals are harvested by these ants, thus providing food resources that did not change with habitat modification or livestock grazing (Whitford, 1978). It is also likely that habitat modification and livestock grazing did not cause the death of colonies and/or induce *Pogonomyrmex* to move their nests.

The spatial pattern analysis showed that there were consistent and interpretable changes in the behaviors of the ant genera selected for study. The changes in spatial pattern exhibited by the ant genera examined in this study demonstrate the feasibility of using spatial pattern analysis of selected genera of ants for monitoring and assessing the effects of chronic and acute environmental stress. The short-term changes recorded in the pre-grazing and post-grazing comparison in 1996 are consistent with changes in foraging behavior and not the result of nest re-location. The behaviors of ants that may be responsible for differences in spatial patterns derived from pitfall trap data are: (1) cessation of surface activity by some or all of the colonies, (2) moving the nest entrance (3) changing direction, duration, and intensity of foraging. Some ant species move nest entrances frequently (*Conomyrma* and *Pogonomyrmex desertorum*; unpublished data). Since nest entrances are generally moved less than 2 m, that behavior is the least likely to be detected by the pattern analysis used in this study. Large changes in spatial pattern are probably 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 pitfall trap data but actual mapping of nests is required to confirm this.

Analysis of spatial patterns of selected ant genera demonstrated that some genera respond to soil surface changes resulting from livestock grazing (*Solenopsis*), some respond to changes in composition and structure of the vegetation (*Conomyrma*), and some are resistant to the short-term changes resulting from grazing and vegetation manipulation (*Pogonomyrmex*). The analysis of spatial patterns of selected genera of ants also provides data on changes in spatial patterns of ecosystem functions, e.g. water infiltration, wind transport of soil, and patterns of soil nutrients (Whitford 1994).

This study shows that spatial analysis can be used to detect changes in behavior of species that respond to environmental stressors. These patterns can be used in developing indicators of exposure to environmental stress. However, we will have to develop statistical tools for analyzing the patterns, and that is beyond the scope of this paper.

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