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Use of ants to monitor environmental impacts of salt spray from a mine in arid Australia

J.L. READ
Olympic Dam Operations, PO Box 150, Roxby Downs, South Australia

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The habitat preferences, seasonal activity cycles and optimum sampling protocols of an ant community in the Australian arid zone were assessed by pitfall trapping. Diversity and abundance of ants peaked in the hotter summer months and varied greatly between different habitats. Sand dunes vegetated with tall perennial shrubs proved to be the most useful habitat for environmental monitoring using ants. Dominant ant genera were suppressed by environmental stresses caused by salt spray from an underground mine. Remediation of the salt spray resulted in a general, yet inconsistent, recolonization of dominant ants at the expense of opportunistic genera. A greater understanding of the ecology of key ant species is required before ants can be used as unequivocal indicators of environmental condition at the Olympic Dam mine site.

Keywords: ants; monitoring; environmental impacts.

Introduction

Ants are the dominant and arguably the most important faunal group in arid Australia (Andersen, 1990). They are sensitive to environmental change, occupy several trophic levels within the environment (Greenslade, 1979) and are easily sampled (Andersen, 1991). Functional groups of ants, which respond in predictable patterns to different environmental conditions, have been categorized using the basic ecological properties of the major ant genera (Greenslade, 1978, Andersen, in press). Opportunistic colonizing genera typically characterize highly disturbed sites whereas pristine open habitats, especially in the arid zone, usually support stable communities dominated by abundant and aggressive Dolichoderine ants. Therefore, ants are potentially ideal bio-monitoring organisms and have proven to be valuable indicators of environmental conditions at several Australian localities (Yeatman and Greenslade, 1980; Majer, 1983; Andersen, 1990) and rehabilitation success at a number of mine sites (Majer, 1978a; 1984; 1985; Majer *et al.*, 1984; Andersen, 1993). Ants have been selected as potentially useful indicators of the extent and degree of environmental impacts at the Olympic Dam mine site (Read, 1994).

Olympic Dam Operations (ODO) manage an underground copper, uranium, gold and silver mine and metallurgical plant at Olympic Dam, 520 km north of Adelaide, in arid South Australia. The total mine infrastructure including the tailings retention system, roads and drill pads occupies less than 5% of the 280 km^2 lease (Badman, 1992) and the remainder of the lease is fenced off from domestic stock and off-road vehicle access. Physical disturbance to the local environment is therefore confined to a small area and strictly controlled by a thorough environmental management programme (Olympic Dam Operations, 1993a). The principal potential impact of ODO on the local environment therefore arises from aeolian contaminants from the mine and metallurgical plant. One of the major sources of these contaminants are the ventilation shafts which aerate the mine (Olympic Dam Operations, 1993b; Olympic Dam Operations, 1993c). Salt water from a sub-artesian aquifer becomes entrained in exhaust air from the underground mine and is expelled to the environment via exhaust fans. Defoliation, which sometimes caused the death, of salt sensitive plant species has been detected within 200 m of the exhaust fans (Fatchen and Associates, 1989).

The suitability of using ants as indicators of environmental disturbance at the Olympic Dam mine site required confirmation since the rationale was quite different from the aforementioned mining studies. Previous studies have investigated the response in the ant community to gross changes in vegetative cover and floristic composition as a result of physical disturbance followed by rehabilitation (Majer 1978a; 1984; 1985; Majer *et al.*, 1984; Andersen, 1993). The aim of this study was to assess the suitability of using ants to measure ecosystem change induced by pervasive aeolian contaminants in a largely undisturbed environment. In order to accomplish this aim, the optimum habitats and seasons for monitoring ants at the Olympic Dam were first determined. Second, a trial monitoring programme was established to determine the response of the ant community to salt spray.

Spatial and seasonal distribution of ants

METHODS

Pitfall traps have been demonstrated to be an efficient and valid collection technique for ant communities in open spaces (Andersen, 1991) and hence were used to monitor ant populations in the Olympic Dam region. Glass test tubes, with a 12 mm internal diameter, placed flush to the ground surface inside snug fitting PVC envelopes, served as the pitfall traps.

Following Majer (1978b), the envelopes were dug several weeks prior to sampling and corked to reduce the 'digging in' effect, whereby ants are disproportionately attracted to freshly disturbed areas (Greenslade, 1973). The pitfall traps were quarter filled with ethylene-glycol, a non-attracting, non-evaporating preservative (Greenslade and Greenslade, 1971). However, permanent corked PVC envelopes were often either excavated by foxes, cats or rabbits or buried or exposed by sand-drift on partially mobile dunes and proved to be unsuitable for long-term monitoring. Traps therefore often had to be dug at the time of sampling which created a considerable zone of disturbance, particularly at sites with hard clay soils. Disturbance was minimized at sandy sites by inserting test tubes into holes left by hammering in and removing a stake at each sample location.

Sites were chosen in eight major vegetation types in the Olympic Dam region; White Cypress Pine (*Callitris glaucophylla*) woodland, Western Myall (*Acacia papyrocarpa*) woodland, Dead Finish (*A. tetragonophylla*) and Mulga (*A. aneura*) savannah, Umbrella Wattle (*A. ligulata*) shrubland, Hopbush (*Dodonaea viscosa*) shrubland, Bladder Saltbush (*Atriplex vesicaria*) shrubland, Low Bluebush (*Maireana astrotricha*) shrubland and *Sclerolaena* plains (Fig. 1). These sites were named Cagl, Acpa, Acte, Acli, Dovi, Atve, Maas and Schl, respectively, after the dominant plant species in each vegetation type. Sites were sampled in June, September and December, 1989. Ten ant pitfall traps were placed at two metre intervals at each site along transects selected to be representative of the surrounding habitat. Traps were open for five days in winter when ant activity was low and for three days when ants were more active in both spring and summer.

A standard five day trapping period was not used in spring and summer because hot dry winds during these seasons tend to fill the sampling tubes with sand if they are left open for extended periods. The *in situ* PVC envelopes were resealed with corks when not in use.

Ants from each pitfall trap were sorted to species level, and identified to genus using Greenslade (1979) or voucher specimens of undescribed species which were lodged with the South Australian Museum. In order to allow for particularly high numbers of ants which may have resulted from trapping on ant trails or near nests, raw counts of each ant species per trap, were converted to an abundance scale (see Andersen, 1991) where 1 = 1

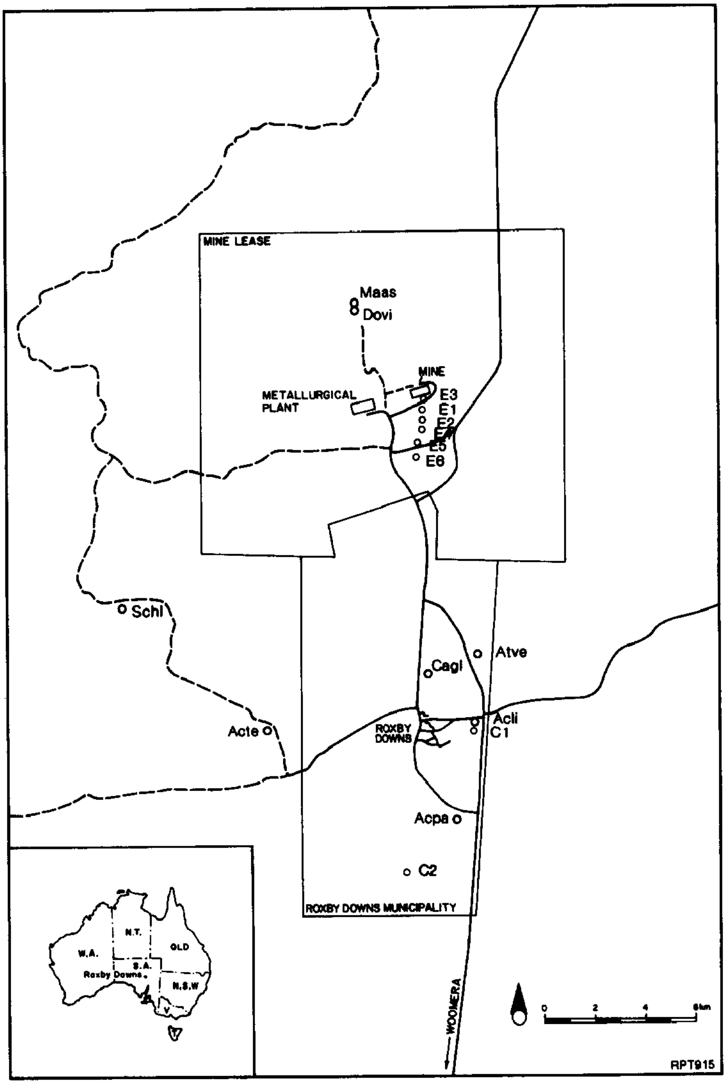

Figure 1. Location of Olympic Dam and ant monitoring sites.

ant, 2 = 2–5 ants, 3 = 6–20 ants, 4 = 21–50 ants, 5 = 51–200 ants and 6 > 200 ants. Abundance scale values of each species were pooled at each site and ant genera were assigned to functional groups using the classification system of Greenslade (1978) modified by Andersen (1996).

RESULTS

Species distribution across sites

A total of 80 species were recorded in the initial survey. *Iridomyrmex* was the most abundant and speciose genera at Olympic Dam with 21 species and 43% of the total abundance class score (Table 1). *Melophorus* (17 species), *Monomorium* (12 species) and *Pheidole* (eight species) were also common, accounting for a further 47% of the ants recorded (Table 1). *Iridomyrmex rufoniger* (species b), which was particularly common in the Umbrella Wattle site, was the most abundant species trapped.

The abundance, along with the species richness and composition of ants, varied considerably between sites in different vegetation types. Swale habitats vegetated with Mulga and Dead Finish, Myall and *Sclerolaena* supported the highest species richness of ants with 35, 34 and 33 species respectively (Fig. 2). In contrast, the species richness of dunes vegetated by Umbrella Wattle and Hopbush was only 12 and 17 species, respectively (Fig. 2). The abundance of ants was not a function of the species richness of ants at particular sites (Fig. 2). Umbrella Wattle, White Cypress Pine and Mulga and Dead Finish habitats supported the highest number of ants whereas the Bladder Saltbush site yielded the least ants.

Seasonal variation

Trapping success as measured by the richness and total abundance class scores generally increased from June to September and was greatest in December at all sites (Fig. 3). The disparity between the winter and spring/summer samples would have been even greater if the sampling period had been constant for all samples. Monitoring in hot summer months therefore maximized both the range of species and the number of ants trapped.

The cumulative total of species recorded at each site in December 1989 is plotted against an increasing number of sample tubes in Fig. 4. This cumulative total was greater than the species richness of the region because many species were recorded at several sites. On average, over half of the ant species per site would have been recorded if only the first three tubes were used and over 92% of species at each site were recorded in the first eight tubes.

Monitoring Programme

METHODS

Ants were sampled at six sites (E1–E6) along a transect passing through Ventilation Shaft 4 and a two control sites (C1 and C2) in ungrazed areas at least 10 km from any mining activity (Fig. 1). The pilot habitat study indicated that sand dunes vegetated with Umbrella Wattle and Hopbush were the most suitable habitats for ant monitoring at the Olympic Dam. Therefore, each site was located on the crest of a dune in the vicinity of at least one Umbrella Wattle and Hopbush. Twelve glass tubes, quarter filled with ethylene-glycol, were pushed into the sand at 2 m intervals at each site. On the basis of the initial study, sampling was conducted for three-day periods each January from 1991 to 1994. Sorting and analysis of the ants followed the same format as described in the initial study.

Table 1. Total abundance score for ants trapped in June, September and December, 1989 at Olympic Dam.

	Total No. species	Abundance score total June	September	December
Dominant Dolichoderinae				
Iridomyrmex rufoniger sp. b	1	126	78	144
other *Iridomyrmex*	20	24	100	129
Subordinate Camponotini				
Campanotus	3	1	1	3
Polyhrachis	1	1	1	2
Hot climate specialists				
Monomorium (Chelaner)	2	2	4	1
Melophorus	17	0	9	285
Meranoplus	2	0	6	6
Cold climate specialists				
Stigmacros	1	0	0	1
Cryptic species				
Brachyponera	1	1	1	1
Opportunists				
Odontomachus	1	1	0	5
Rhytidoponera	2	23	4	22
Tetramorium	5	2	3	17
Tapinoma	1	5	7	9
Generalized Myrmicinae				
Momomorium	11	14	46	158
Pheidole	8	33	65	69
Specialist predators				
Cerapachys	1	0	0	1

Passive salt collection beakers were placed on 1.5 m poles to quantify the amount of salt spray at all sites. These samples were collected quarterly commencing in 1991. All salts were dissolved in distilled water and the amount of NaCl was measured by titration for chloride with silver nitrate.

RESULTS

Salt deposition rates were initially high at the experimental sites but were greatly reduced by engineering mitigatory measures in 1991 (Andryszczak, 1992) (Fig. 5). Sites E1, E2 and E3 which were closest to the ventilation bore consistently recorded much higher salt deposition rates than the more remote experimental sites, E4, E5 and E6, while negligible levels were recorded at control sites (Fig. 5).

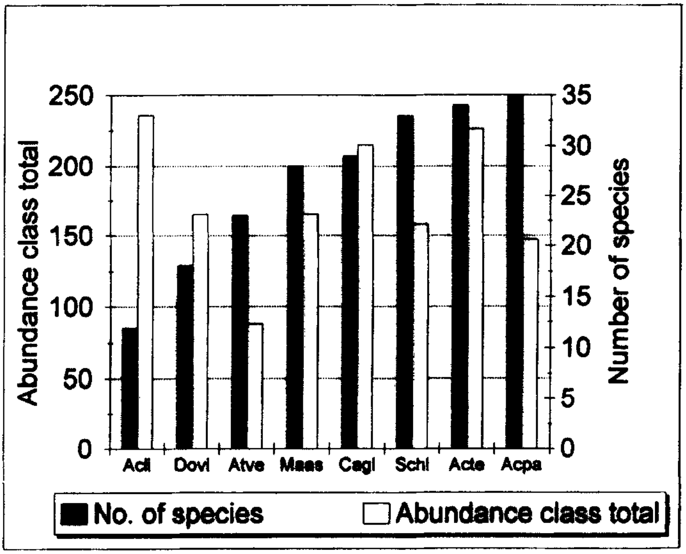

Figure 2. Species richness and abundance of ants recorded in a variety of habitats at Olympic Dam in 1989. Site abbreviations are explained in the text.

The ant populations in both impacted and control sites in the trial monitoring programme exhibited considerable spatial and temporal variability, however several general trends were evident. Control sites ant communities were usually characterized by a

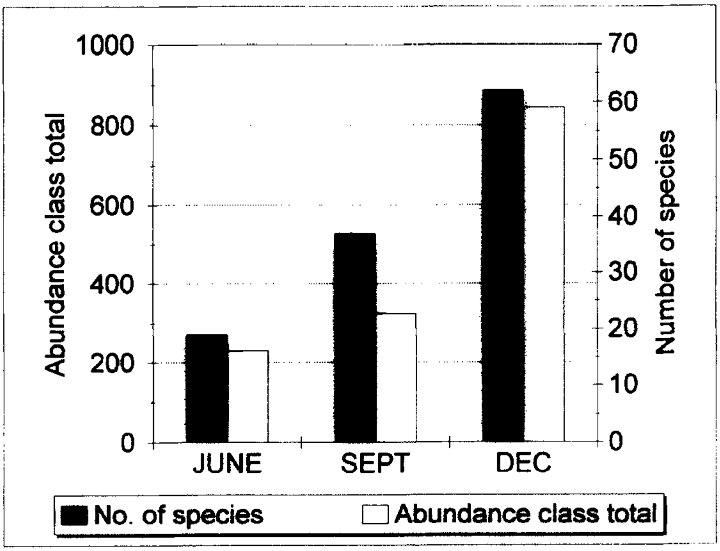

Figure 3. Species richness and abundance of ants in June, September and December, 1989 at Olympic Dam.

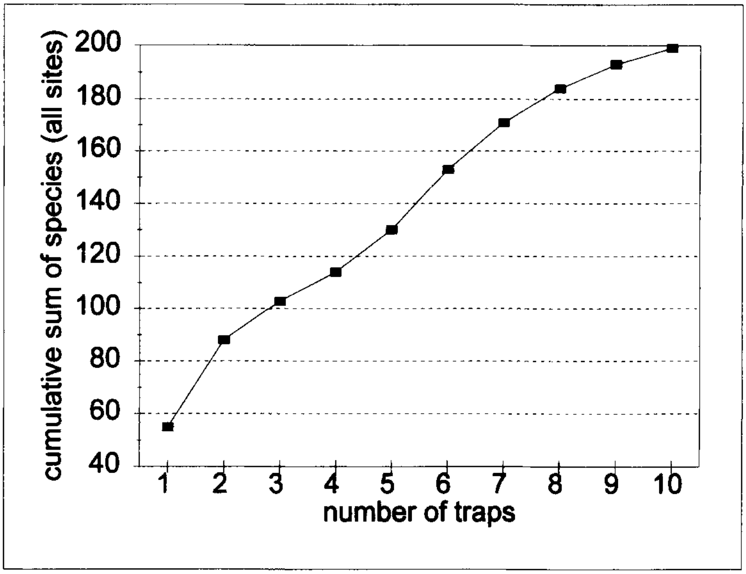

Figure 4. Cumulative number of ant species richness per tube at all sites.

low opportunist/dominant ant ratio (Fig. 6) which was primarily influenced by high numbers of *I. rufoniger* sp. b. (Fig. 7).

The ratio of opportunistic to dominant ants was strongly positively related to predicted salt concentrations in January 1991 ($p = 0.00$, $r^2 = 0.898$). Two sites in 1992 and one site in 1994 were removed from the analysis because they exhibited low capture rates (abundance class total < 50), thus reducing the validity of the ratio calculation. Even with these low

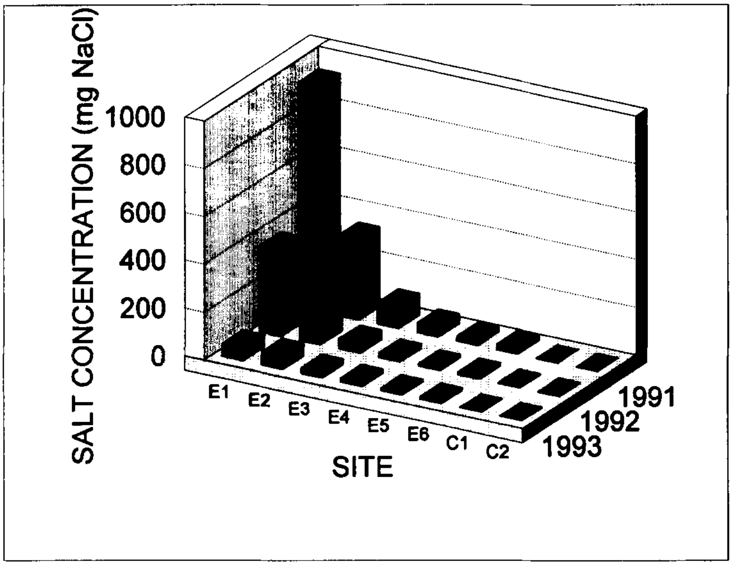

Figure 5. Salt deposition at ant monitoring sites at Olympic Dam from 1991 to 1993.

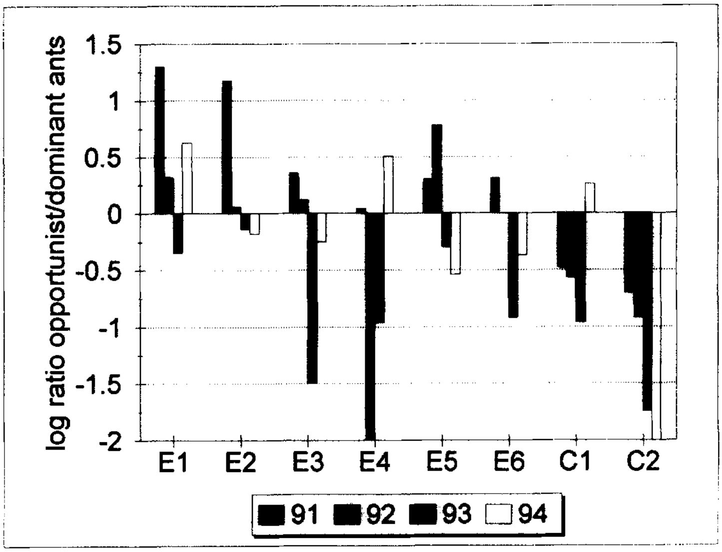

Figure 6. Ratio of opportunist to dominant ants at the Olympic Dam monitoring sites from 1991 to 1994.

capture sites removed, the relationship between measured salt loads and the opportunist to dominant ant ratio was only weakly evident in 1992 ($p = 0.037$, $r^2 = 0.704$, $N = 6$) and was not significant in 1993 ($p = 0.155$, $r^2 = 0.306$, $N = 8$) or 1994 ($p = 0.383$, $r^2 = 0.154$, $N = 7$). Analysis of convariance could not be used to measure temporal changes in the ant community because the opportunist to dominant ant ratio was not related to the low salt loads in the latter years of the survey. However, the change from significant relationships

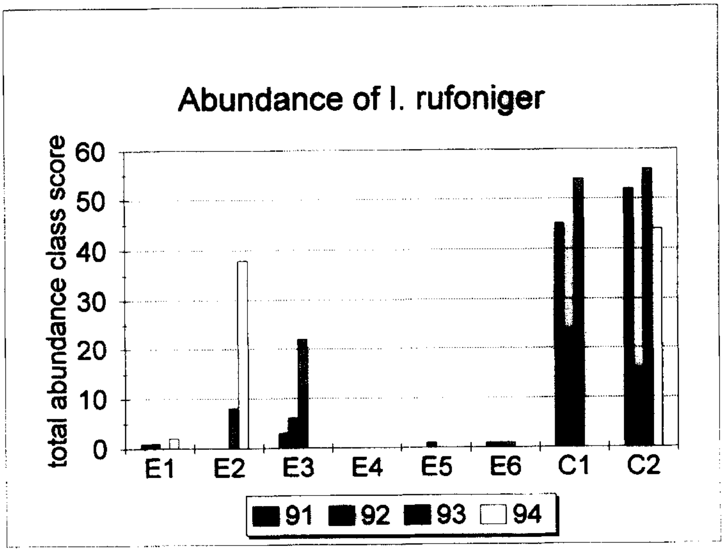

Figure 7. Abundance of *Iridomyrmex rufoniger* (sp. b) at the Olympic Dam ant monitoring sites from 1991 to 1994.

of opportunist to dominant ant ratios with high salt loads early in the survey to insignificant relationships when salt loads had been reduced suggests that opportunist ants were gradually replaced by dominant ants throughout the survey period. In fact this change resulted in dominant ants being more abundant in four of the experimental sites in both 1993 and 1994. This change was largely attributable to colonization of *I. rufoniger* sp. b at two of these sites (Fig. 7).

The *I. rufoniger* sp. b population samples at control site C1 crashed in 1994 after being very abundant. This site did not appear to be impacted by salt spray (Fig. 5) or other disturbance (personal observation) and was not mirrored at control site C2.

Discussion

The ODO ant monitoring programme requires careful structuring due to the high degree of temporal and spatial variability in ant communities. Not surprisingly, summer samples proved to be the most productive at Olympic Dam, as they have elsewhere (Bernstein, 1974; Whitford and Ettershank, 1975; Briese and Macauley, 1980) and hence future ant monitoring was restricted to summer months. Selection of a habitat for monitoring was influenced not only by the richness or abundance of the ant community at different sites but also the types of ants present, the distribution of particular habitats throughout the mine lease and the ease of sampling in different habitats.

The functional group theory of ant community organization predicts that as a result of disturbance the dominance of dolichoderine ants is weakened allowing opportunist species to increase in abundance. Favourable habitats for ant monitoring should therefore be dominated by *Iridomyrmex* ants when undisturbed, so that disturbance induced changes to the ant community are pronounced. The most abundant *Iridomyrmex* at Olympic Dam, and hence the species which is likely to exert a major influence over other species is *I. rufoniger* sp. b. This species was particularly abundant in the Umbrella Wattle habitat and was also common in the Hopbush and Mulga and Dead Finish habitats.

The most widespread and common habitats in the ODO lease were sand dunes vegetated with Umbrella Wattle and Hopbush and interdunal swales supporting chenopod shrublands dominated by Bladder Saltbush and Low Bluebush. These vegetation associations are therefore preferable to more restricted vegetation types for broad scale monitoring programmes. Umbrella Wattle and Hopbush form floristically simple, relatively homogenous communities in the study region compared with the diverse and varied chenopod shrublands. Umbrella Wattle and Hopbush dunes have also proven to be more sensitive to damage from airborne contaminants than woodlands or chenopod shrublands (Fatchen and Associates, 1989). Sand dunes were also the easiest substrate to install pitfall traps and hence the sampling time and degree of localized disturbance around the pits was minimized. Therefore, sand dunes vegetated by Umbrella Wattle and Hopbush were selected as the optimum habitat for long-term ant monitoring at Olympic Dam.

Permanent pit envelopes were considered to be inappropriate for long-term studies in the Olympic Dam region and their use was discontinued. Ten pits adequately sampled the range of ant species at each site in December 1989. However, due to the chance of one or more tubes filling with sand or debris, or being removed by animals during the survey, 12 tubes were used in subsequent surveys.

Interpretation of the ant community response to salt spray is limited firstly by not knowing the predisturbance condition of the community and secondly because the lack of a thorough understanding the ecology of the ant species inhibits speculation as to the cause of the measured response. However, the ant community in the vicinity of ventilation bore 4 exhibited a measurable response to salt spray which, to some degree, accords with that predicted for disturbed sites in arid Australia. Apparent partial recovery of the ant community suggests that ants responded rapidly to remediation of the disturbance.

I. rufoniger sp. b appears to be a key species in the ant community and therefore in the general terrestrial ecology of the Olympic Dam region. The disappearance of *I. rufoniger* sp. b from a control site sample in 1994 and the failure of this species to consistently recolonize reclaimed areas suggests that *I. rufoniger* sp. b populations respond dramatically to factors other than unnatural environmental stresses. *I. rufoniger* sp. b feeds extensively on exudates from sap-sucking homopterans from a variety of bushes (personal observation) and hence changes in the abundance or health of either the homopterans or their host plants will presumably also impact *I. rufoniger* sp. b populations. Effective, robust ant monitoring programmes therefore require many replicate sites to allow for site specific variations in *I. rufoniger* sp. b populations.

This trial monitoring programme revealed that ant communities may respond quickly to environmental stresses and they may be used to monitor the effectiveness of remediation and environmental rehabilitation measures. However, detailed ecological data are required for key ant species before unequivocal conclusions can be drawn concerning environmental conditions from monitoring of ant communities.

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