

**A PRELIMINARY ASSESSMENT OF MINESITE REHABILITATION IN THE PILBARA IRON ORE PROVINCE USING ANT COMMUNITIES AS ECOLOGICAL INDICATORS**

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**Introduction**

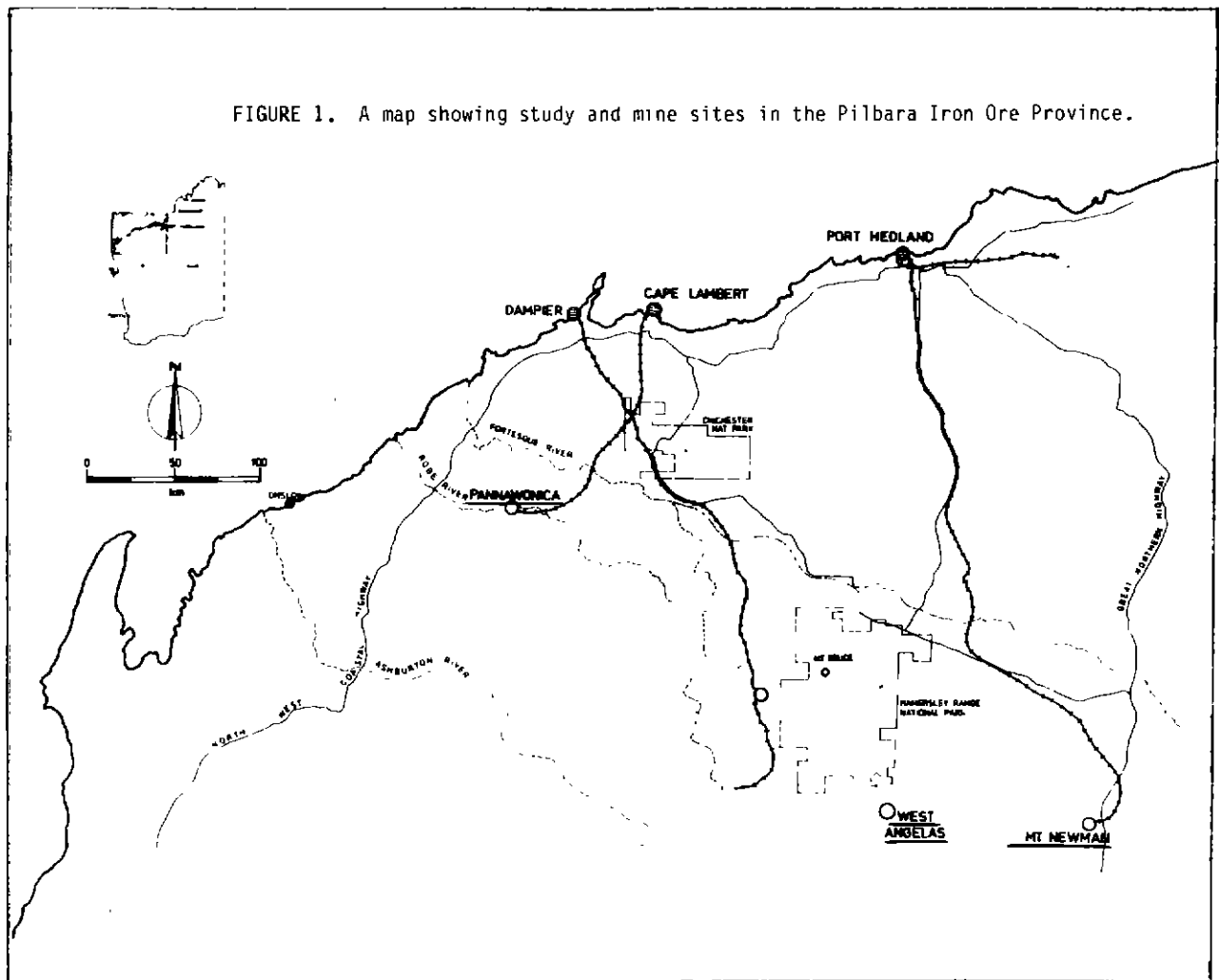
None of the existing iron ore mining operations in the Pilbara district of Western Australia have in their Agreement Acts any provision requiring ecosystem recovery on affected areas. Some companies, in particular Mt Newman Mining since 1975, Cliffs Robe River since 1981 and recently Hamersley Iron Pty Ltd, have attempted rehabilitation on a limited scale. These efforts are likely to increase in the future as more mined-out areas and completed waste dumps become available. An assessment of ecosystem recovery on the treated sites is now of some importance, because provision for ecologically defined rehabilitation will almost certainly be contained in subsequent agreements for currently proposed mines in the region.

Studies of these early experiments in rehabilitation should provide essential information on the potential for ecosystem development on mined lands in the region and on the efficacy of various rehabilitation techniques. They should also lead to the development of environmental assessment criteria based on the monitoring of ecological indicators.

To this end a preliminary investigation was carried out in January 1984 at Pannawonica on the Robe River Mesas and at Mt Whaleback, Newman (Figure 1). The study involved sampling treated (rehabilitating) and untreated mined mesa tops and an overburden dump at the Robe River, and a treated waste dump at Mt Whaleback.

**Methods**

Ants were sampled by pitfall trapping at each study site using 20 (42 mm internal diameter) plastic jars set out at 5-m intervals along a 100 m transect. Each jar contained about 30 ml of alcohol/glycerol (70/30v/v) preservative. Traps were set for 48 hours at each site with all Pannawonica sites sampled simultaneously.



At Pannawonica each study site was searched for one half hour in daylight during the cooler parts of the day and again for the same period in darkness. During the search all ant species detected were collected and notes made on the species behaviour and microhabitats. No hand collecting was undertaken at Mt Whaleback.

Ants from pitfall traps were sorted by species and counted, and a species list for each site compiled. Hand collections were examined and any species not recorded in the traps were added to the species lists for the sites.

## Description of Study Sites

### Robe River Mesas

At the Robe River, pisolitic iron ore was stripped from the tops of mesas, leaving at the termination of mining, a compacted pavement of underlying bedrock. On the edge of the mined mesas there is normally a wall of rock rubble or unmined residual faces. The slopes of the mesas are covered with blasted rubble to at least 1/3 of their height. Five study sites were established on two closely adjacent mined mesas. These are described below. Vegetation description follows the life-form density classes of Muir (1977).

**Site 1An:** Mining ceased at this 10 ha site 12 years prior to the study and no rehabilitation treatments had been attempted. The sampling transect was over bare ground, mostly compacted, although with some pockets scattered with fine scree. There was no vegetation on the site, the nearest appearing on the edge of an overburden dump (Site 1Ao) about 40 m away.

**Site 1At:** This site of about 2 ha was mined until 12 years before the study. It was treated in 1979 by ripping at 10 m x 10 m intervals to a depth of 0.5 m. Then in November 1982 the rip lines were sown with local legumes, principally *Petalostyles labicheoides*. Vegetation cover was confined to rip-lines and consisted of *Acacia pachyacra* and *Petalostyles labicheoides* shrubs to 1.5 m, but contributing less than 5% cover over the site. Also established in the rip lines were *Ptilotus* spp. and clumps of the bunch grass *Cymbopogon ambiguus*. Along the rip lines were the only pockets of friable soil and stoney mullock. Deposits of leaf litter occurred under the shrubs. Between the rip lines the surface was bare and compacted.

**Site 1Ao:** This was an overburden dump covering about 3 ha on which the last layers of blasted and scraped material would have been deposited more than 12 years ago. The dump was not treated in any way, but vegetation has become established apparently due to the

friable substrate, stoney mullock surface and the presence of stored seed in the overburden. The shrub stratum resembles that of adjacent unmined mesa tops (Site 1Au) consisting of sparse to mid-dense low scrub A (Muir 1977) of *Acacia pachyacra* and *Petalostyles* sp. The sub-stratum, unlike unmined mesa tops, consisted of open short bunch grassland of *Cymbopogon ambiguus* and *Themeda australis* and some short-lived herb species including *Ptilotus* spp. and *Corchorus walcottii*. There was little regeneration of *Triodia*. Vegetation cover was patchy by comparison with unmined mesa top vegetation.

**Site 2At:** This was an entire mesa top of about 20 ha on which mining ceased 10 years prior to the study. Almost the entire area was ripped to a depth of 0.5 m and at 1.0 m intervals in November 1981 and was immediately sown with seed collected using a vacuum cleaner from adjacent unmined mesa top vegetation. The area sampled was vegetated with sparse herbs, *Ptilotus* spp., *Cleome viscosa*, *Corchorus walcottii* and sparse grasses principally, *Themeda australis* and *Cymbopogon ambiguus*. There were occasional shrubs from 1.0 m to 1.5 m of *Acacia pachyacra*, *Grevillea wickhamii* and *Acacia* aff. "clementii". Most of the ground surface was friable due to ripping and was scattered with stoney mullock.

**Site 1Au:** This was an unmined area of mesa top of about 15 ha. The area sampled was about 120 m from a mine face. Mining ceased on the mesa 12 years before the study. The area was vegetated with *Acacia pachyacra* dwarf scrub C (Muir 1977) over *Triodia wiseana* hummock grassland and mid-dense hummock grassland. The substrate consisted of weathered bedrock with some surface scree. Leaf litter deposits occurred under the shrubs and there was some sparse deadwood. There was no evidence of recent fire.

### Mt Whaleback Waste Dump

Sampling at Mt Whaleback was undertaken on waste dump W06A, an area of 4.4 ha. This site is illustrated in Figure 2. W06 has 3 sections (A, B, C) totalling 7.3 ha, it is the most intensively managed rehabilitation site on the Pilbara iron ore mines. It was treated in November 1978, 5 years before the present study.

The surface of the dump was ripped to a depth of 1.0 m and at 1.0 m spacing. Over the area sampled fresh topsoil had been spread and seed of local legumes and chenopods broadcast. The site was then irrigated for six weeks with the amount of watering diminishing progressively until it was terminated.



FIGURE 2. Area W06-A used to trap ant species.

The sampling transect passed through patchy vegetation. Most of the line was in *Acacia bivenosa* scrub over mid-dense *Triodia wiseana* hummock grassland, but some jars were in open grassy areas or patches of chenopod open low scrub. The substrate throughout was friable and strongly hummocked by the ripping process. Many large stones were scattered across the surface. Deposits of leaf litter were associated with *A. bivenosa* shrubs and the larger *Triodia* hummocks. The areas which have now been colonised with hummock grassland resemble unmined hilltops although the shrub cover tends to be of higher density.

## Results and Discussion

### Species Richness

Table 1 shows the ants collected at five of the sampling sites in January 1984. No ants were collected from the fallow, mined mesa top (site 1An). Thirty species were collected during the survey from the control site, overburden dump, two treated mine surfaces and the treated waste dump.

Species richness was highest on the undisturbed control and the 5-year treated waste dump at Mt Whaleback, both with 16 species. After 12 years the overburden dump on mesa 1A had accumulated 15 species.

The recently treated mine surfaces, sites 1At and 2At, had lower numbers of species. Although of similar age since seeding, site 1At was richer than 2At. This may be attributable to the larger size and greater concentration of shrubs here. These perennials would provide a more stable environment by supplying a continuous source of honeydew and leaf litter. Site 2At was dominated by short-lived or ephemeral dwarf shrubs, herbs and grasses.

### Dominance Index

The apportionment of individuals (from pitfall trap captures) amongst the various species at each site was measured using the dominance index:

$$C = \frac{\sum n_i^2}{N}$$

where:

$n_i$  is the number of individuals of the  $i$  species captured at each site, and

$N$  is the total number of ants captured at the site.

Values range between 1 and 0, where higher figures indicate a concentration of one or a few dominant species thus giving a low evenness. Whilst ant communities in stable environments are usually dominated by an *Iridomyrmex* sp., these communities often show greater evenness than communities in disturbed systems. Thus the dominance index can be used as an indicator of stability. Community evenness varies however with season, so comparisons should only be made between sites sampled at the same time.

The control site (1Au) in undisturbed vegetation had the most even ant community, whilst the 12 years overburden regeneration (1Ao) and the 5-year waste dump rehabilitation (W06) showed similar values. Community evenness was low on the 2 year treated minesites (1At and 2At) which were strongly dominated by one species of *Iridomyrmex* able to utilise honeydew.

TABLE 1. Ants collected on Pilbara Mine environments in January 1984.

+ indicates species collected only by hand.

Ant Species	Robe River Sites				Mt Whaleback W06
	1Au	1Ao	1At	2At	
<b>PONERINAE</b>					
<i>Rhytidoponera</i> sp. JDM 248	20				
<i>Rhytidoponera</i> sp. JDM 65	8				
<b>MYRMICINAE</b>					
<i>Chelaner</i> sp. nov.		88		53	
<i>Monomorium</i> sp. 2 (ANIC)	3	29	6		44
<i>Monomorium</i> sp. JDM 274	1				
<i>Monomorium</i> sp. JDM 276		833	32	86	
<i>Pheidole</i> sp. JDM 306		8	20		
<i>Tetramorium</i> sp. JDM 142					3
<i>Tetramorium</i> sp. JDM 305		1	5		
<b>DOLICHODERINAE</b>					
<i>Iridomyrmex</i> <i>purpureus</i>	19				
<i>Iridomyrmex</i> sp. JDM 9		2			211
<i>Iridomyrmex</i> sp. JDM 327	73	32	8	10	16
<i>Iridomyrmex</i> sp. JDM 463		65			
<i>Iridomyrmex</i> sp. JDM 464	202	84	326	361	43
<i>Iridomyrmex</i> sp. JDM 466	5				
<i>Iridomyrmex</i> sp. JDM 467					5
<i>Iridomyrmex</i> sp. JDM 595	11	267	15		
<i>Iridomyrmex</i> sp. JDM 596		3	74	1	2
<i>Iridomyrmex</i> sp. nov.	66				
<b>FORMICINAE</b>					
<i>Prolasius</i> sp. JDM 471					1
<i>Prolasius</i> sp. nov.					2
<i>Camponotus</i> sp. JDM 184	4	+	3		1
<i>Camponotus</i> sp. nov.	8				24
<i>Melophorus</i> sp. 1 (ANIC)	4	52	2	4	12
<i>Melophorus</i> sp. JDM 24		22	7	8	14

Ant Species	Robe River Sites				Mt Whaleback W06
	1Au	1Ao	1At	2At	
<i>Melophorus</i> sp. JDM 221					1
<i>Melophorus</i> sp. JDM 304	43	9			
<i>Melophorus</i> sp. JDM 472	34				5
<i>Melophorus</i> sp. JDM 474	37				
<i>Melophorus</i> sp. nov.					1
Total pitfall catch	538	1495	498	523	385
Total species richness	16	15	11	7	16
Dominance Index	0.194	0.353	0.474	0.515	0.334

ANIC - Australian National Insect Collection species number.

JDM - Western Australian Institute of Technology species number.

sp. nov. - Not in W.A.I.T. state collection.

## Community Structure

In Figure 3 the community species richness and evenness values for each study site are plotted on parallel scales. Values for four additional control sites from hill top, hummock grassland control sites from West Angelas are also plotted for comparison.

The values for species richness and dominance index obtained for the Pannawonica control site, both fall within the ranges recorded from West Angelas. Natural summer undisturbed hummock grassland values for ant richness fall between 10 and 18 species, although four of the five values lie between 16 and 18 species. Dominance index values for control sites were between 0.25 and 0.19. These values would indicate complete ecosystem recovery at a rehabilitation site following summer sampling, provided the species compositions are similar.

None of the mine sites studied has achieved complete recovery, although site W06 after 5 years and the overburden dump site (1Ao) after 12 years appear to be approaching recovery. However, an analysis of the types of ants which have colonised the overburden dump site indicates that a normal ant community structure has not developed.

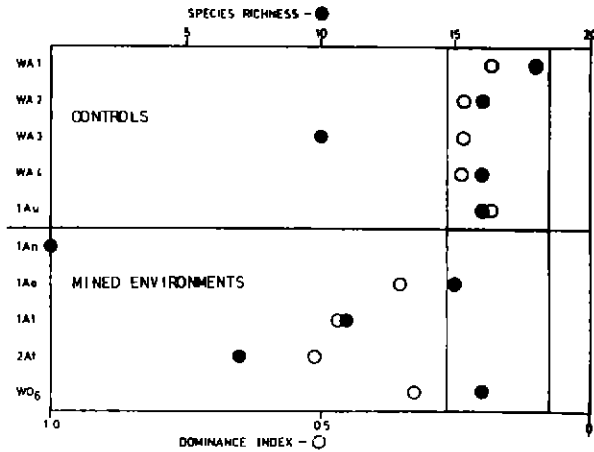


FIGURE 3. Species richness (●) and dominance index (○) values for five undisturbed hummock grassland sites and five hilltop iron ore minesite environments in the Pilbara.

Figure 4 shows the proportion of individuals captured in pitfall traps at each site in each of seven ecological groups defined by Greenslade and Thompson (1981). These are described below:

#### ANT ECOLOGICAL GROUPS

Group Taxonomy and Ecology

##### 1. Dominant *Iridomyrmex* active on ground.

Over the greater part of Australia, competing colonies of dominant *Iridomyrmex* set up a mosaic pattern with which the rest of the ant community conforms.

##### 2. Subordinate camponotine formicinae

Members of the genera *Camponotus*, *Polyrhachis*, *Calomyrmex* and *Opisthopsis* commonly co-exist with *Iridomyrmex* due to differences in worker size, foraging time, evasive behaviour and mimicry.

##### 3. Taxa whose occurrence depends on physical properties of climate and soil type.

*Melophorus* is particularly conspicuous during the hot season in the Pilbara. Tolerance of extremely high ground temperatures allows these ants to forage when *Iridomyrmex* is inactive.

##### 4. Cryptic soil and litter ants

This group is not well represented in Pilbara hummock grasslands.

##### 5. Opportunists

These species, best represented by *Rhytidoponera* in the Pilbara, have wide physical tolerances, generalised diets, and are ubiquitous although rarely abundant in undisturbed habitat.

##### 6. Generalised myrmicines

Members of the genera *Crematogaster*, *Pheidole*, *Monomorium*, *Chelaner* and *Tetramorium* are mostly small ants which are ecologically generalised. Some are important harvesters of small seed.

##### 7. Large, solitary foragers

Species which, as a result of their large size, are insulated from interaction with many other ants.

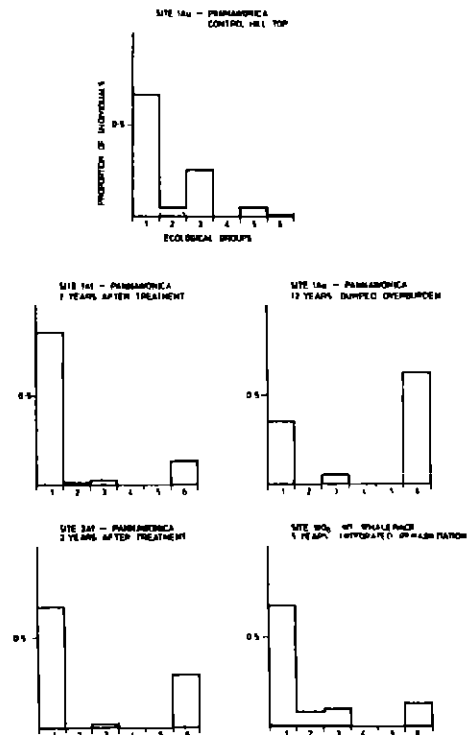


FIGURE 4. Histograms showing the abundance of ants in six ecological classes at a control site and four minesites in January 1984.

The normal summer ant community (1Au) in an undisturbed hummock-grassland was dominated by *Iridomyrmex* (class 1), but *Camponotus* (class 2), *Melophorus* (class 3) and *Rhytidoponera* (class 5) were also well represented. Generalised myrmicines (class 6) were scarce although they became more conspicuous during winter.

The generalised myrmicines were fairly abundant on all the rehabilitation sites and the *Iridomyrmex* sp. (class 1) were generally more dominant than in undisturbed vegetation. Interestingly, *Rhytidoponera* spp. which are ubiquitous in undisturbed vegetation in the Pilbara, were absent from all the mined areas.

The ant community structure of the 12-year overburden site was anomalous when compared to controls in that it was dominated by the myrmicines (class 6). Site W06 on the waste dump at Mt Whaleback most resembles a natural hummock-grassland community structure. The principal difference between site 1Ao and site W06 has been the successful establishment of *Triodia* hummock-grassland at Mt Whaleback. This is probably essential for the development of stable hill top habitats on mined areas.

**Community Similarity**

Similarity in ant species composition between the sites sampled in January 1984 was measured using Sorenson's Similarity Index:

$$I = \frac{2j}{a + b} \times 100$$

where j is the number of species common to sites a and b,

a is the number of species at site a, and

b is the number of species at site b.

The similarity values for each pair of sites are given in Table 2.

TABLE 2. Sorenson's Similarity Indices for each pair of sites sampled in January 1984.

	1Au	1Ao	1At	2At	W06
1Au	-	32.0	44.0	26.0	43.7
1Ao	-	-	84.6	54.5	51.6
1At	-	-	-	66.6	44.0
2At	-	-	-	-	43.4
W06	-	-	-	-	-

These values reflect two trends - higher similarity with proximity of sites, and the nature of the habitat. Thus control site 1Au shows highest similarity with site 1At (a rehabilitation area of the same mesa) and site W06 (a rehabilitation area in an advanced stage of recovery about 400 km away). Interestingly, similarity is low between the control site and site 1Ao which were both on the same mesa and each with 12 years regeneration. This again reflects the anomalous ecological development on this site.

Like all other rehabilitation areas, site 1Ao contained many opportunistic species, particularly myrmicines. The adjacent site, 1At, treated only 2 years prior to the study, had the highest similarity to 1Ao, no doubt having received many colonising species from it.

The remaining comparisons also showed high similarities between rehabilitation sites due to the presence on all sites of colonising opportunists.

**Ecosystem Recovery Rates**

Two factors influence mine rehabilitation rates. These are the climatic characteristics (temperature and rainfall which control biological productivity), and rehabilitation effort and techniques. In some extreme mine environments such as site 1An without any rehabilitation measures, there has been no measurable ecosystem recovery after 12 years.

When appropriate rehabilitation techniques are employed the recovery rates in the first 3 years correlate with rainfall. From the work of Majer et al. (1982), Majer et al. (1984), Fox & Fox (1982), Majer (1984a & b), a species richness of less than 6 species in 3 years might be predicted in the Pilbara. However, the data from this survey plotted in Figure 5 predict a richness value twice as high after 3 years for this region. This may be related to the association of rainfall with higher temperatures and hence greater productivity, but this might be more than offset by the unreliability of the rainfall. It is possible that this semi-arid region has more ants adapted to survive in rather open habitats, similar to those on rehabilitating mines.

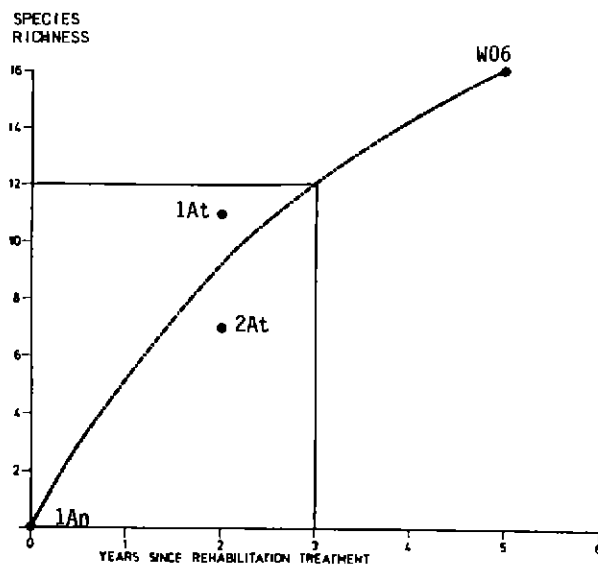


FIGURE 5. The relationship between species richness and years since rehabilitation treatment as indicated by sites sampled in January 1984.

The importance of rehabilitation technique is exemplified by the 12 year old overburden dump. Although not in itself a rehabilitation attempt, it does represent the results of not spreading topsoil. This site has seen 12 years of regeneration but has not recovered. Whether the site reached maximum species richness and then collapsed or has simply been retarded in development is unknown. The high proportion of short-lived plants in the sub-stratum and the absence of hummock grass may make this mine environment unstable. Absence of hummock grass may be a consequence of deep burial of the seed following mine stripping and the dumping of the over-burden.

By contrast, the rehabilitation on waste dump W06 at Mt Whaleback is approaching ecological recovery. It is therefore not surprising that some of the regional vertebrate ground fauna, including two species of marsupial mice (*Dasyuridae*) *Planigale maculatus* and *Ningaul timealeyi*, have colonised the site.

The results of the present study indicate that, using appropriate rehabilitation techniques, significant ecological recovery can take place on sterile waste dumps within 6-7 years.

#### References

- Fox, M.J., & B.J. Fox. 1982. Evidence for interspecific competition influencing ant species diversity in a regenerating heathland. In: *Ant-Plant Interactions in Australia*: 99-110. R.C. Buckley, Ed. Dr W. Junk, The Hague.
- Greenslade, P.J.M., & C.H. Thompson. 1981. Ant distribution, vegetation, and soil relationships in the Cooloola-Noosa River area, Queensland. In: *Vegetation Classification in Australia*: 192-207. A.N. Gillison & D.J. Anderson, Eds.
- Majer, J.D., M. Sartori, R. Stone & W.S. Perriman. 1982. Colonisation by ants and other invertebrates in rehabilitated mineral sand mines near Eneabba, Western Australia. *Reclam. Reveg. Res.* 1: 63-81.
- Majer, J.D., J.E. Day, E.D. Kabay & W.S. Perriman. 1984. Recolonisation by ants in bauxite mines rehabilitated by a number of different methods. *J. Appl. Ecol.* 21: 355-374.
- Majer, J.D. 1984a. Ant return in rehabilitated mineral sand mines on North Stradbroke Island. In: *Focus on Stradbroke*. J. Covacevich, Ed. Boolarong Press, Brisbane.
- Majer, J.D. 1984b. Recolonisation by ants in rehabilitated open-cut mines in northern Australia. *Reclam. Reveg. Res.* 2: 279-298.
- Muir, B.G. 1977. Vegetation and habitat of Bending Reserve. In: *Biological Survey of the Western Australian Wheatbelt, Part 1*. *Rec. West. Aust. Mus. Suppl.* 3: pp. 142.