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A COMPARATIVE STUDY OF ARACHNID COMMUNITIES IN REHABILITATED BAUXITE MINES

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A COMPARATIVE STUDY OF ARACHNID COMMUNITIES IN REHABILITATED BAUXITE MINES *

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ABSTRACT

A study was made of arachnid (araneid, opilionid, and scorpionid) communities in rehabilitated bauxite mines operated by Alcoa of Australia Ltd., and in surrounding jarrah (*Eucalyptus marginata*) forest at Jarrahdale, 45km south-east of Perth, Western Australia.

Pitfall trapping, litter sampling, and unit-area visual searches were used to sample the arachnid populations of three rehabilitated bauxite minesites and two natural jarrah forest sites, each with differing histories.

Measurement of species diversity and richness within the populations indicate that at least 8 years is required for the habitats within a rehabilitated bauxite minesite to reach a level of development where they are capable of supporting an arachnid community comparable with that of the surrounding undisturbed jarrah forest.

Habitat features such as leaf litter depth, percentage ground cover, and the number of trees taller than 1.5m were found to have a significant influence on the number of species and individuals in the community.

Suggestions are made as to how more rapid development of complex communities in the rehabilitating bauxite minesites can be achieved.

INTRODUCTION

The management of forests as complete ecosystems has become an important practice in recent years due to the increase in forest land uses. No longer are forests simply a source of commercial timber, they must also serve the needs of tourism, science, water resources, mining and conservation.

* From an Honours thesis by Mawson (1983).

** Agriculture Protection Board, Forrestfield, 6058.

Bauxite mining operations in the Darling Range of Western Australia by Alcoa of Australia Ltd. directly affect the natural jarrah (*Eucalyptus marginata*) forest of the region. Alcoa of Australia Ltd. has a programme to rehabilitate the areas affected by its operations. Objectives similar to those applied to forest management are applied to the rehabilitation programmes in order to restore the mined land.

Following the initiation of rehabilitation programmes, careful monitoring of community development is necessary to obtain a measure of progress in these sites. The importance of invertebrates in land reclamation has recently been recognised, with several studies showing the numerous roles vital to ecosystem development which these organisms fulfill (Neumann, 1973; Duffey, 1978; Koch and Majer, 1979; Nichols and Bunn, 1980; Coyle, 1981; Nichols and Burrows, 1981). The fact that the behaviour, density, and population dynamics of spiders have been indicated as important stabilising agents in terrestrial arthropod communities (Coyle, 1981) suggests that these predatory invertebrates, and others like them, may serve as useful biological indicators for evaluating the rehabilitation programmes currently being undertaken by Alcoa of Australia Ltd.

Alcoa of Australia's rehabilitation programme has been in operation since 1966 (Tacey and Glossop, 1980), providing an opportunity for any successional development within the rehabilitated minesites to be studied and evaluated. Community parameters such as diversity and evenness can provide measures of community structure which in turn can be used in interpreting the development and dynamics of arachnid communities. Therefore, a sampling programme was undertaken to examine the community structure of arachnid (araneid, opilionid, and scorpionid) populations in a variety of habitats associated with rehabilitated bauxite mines and unmined jarrah forest.

MATERIALS AND METHODS

Study Area

Five sites were chosen for the study of arachnid recolonization of bauxite minesites. Three of the sites are in rehabilitated mine pits at the Alcoa of Australia Ltd. Jarrahdale facility 45km south-east of Perth, the other two sites are in the surrounding jarrah forest (Figure 1).

Site No. 1 : A bauxite mine pit, rehabilitated in early 1982 (1 year old).

After cessation of mining operations the pit walls were battered down to conform with the surrounding landscape. Fresh topsoil stripped to a depth of 50mm from a new mine pit, was spread to the same depth on the old mine pit floor. The pit floor was deep-ripped to aid root penetration and drainage. The area was then seeded with a seed mix of native plants, and planted with tree seedlings, most of which are resistant to the fungal disease *Phytophthora cinnamomi*. Seeding was carried out at the rate of 1 kg per ha. Super-phosphate fertiliser was concurrently applied to the area at the rate of 450 kg per ha. The seed mix was dominated by *Acaçia* species and the ground covers *Kennedia prostrata* and *K. coccinea* with further plant species constituting a smaller portion of the seed mix. Six species of *Eucalyptus* seedlings were also planted out at the rate of 640 per hectare. Each seedling was given 100 g of mono-ammonium phosphate, at 3 and 9 weeks after planting.

Site No. 2: A bauxite mine pit, rehabilitated in early 1981 (2 years old).

The same landscaping techniques and soil replacement programme as for Site No. 1 were used. The area was seeded with a seed mix at the rate of 0.5 kg per hectare. The major species in the seed mix were five species of *Acacia*, the two species of *Kennedia*, and *Hardenbergia comptoniana*. A further fifteen species constituted the remainder of the mixture. The application of fertiliser was again at the rate of 450 kg per ha.

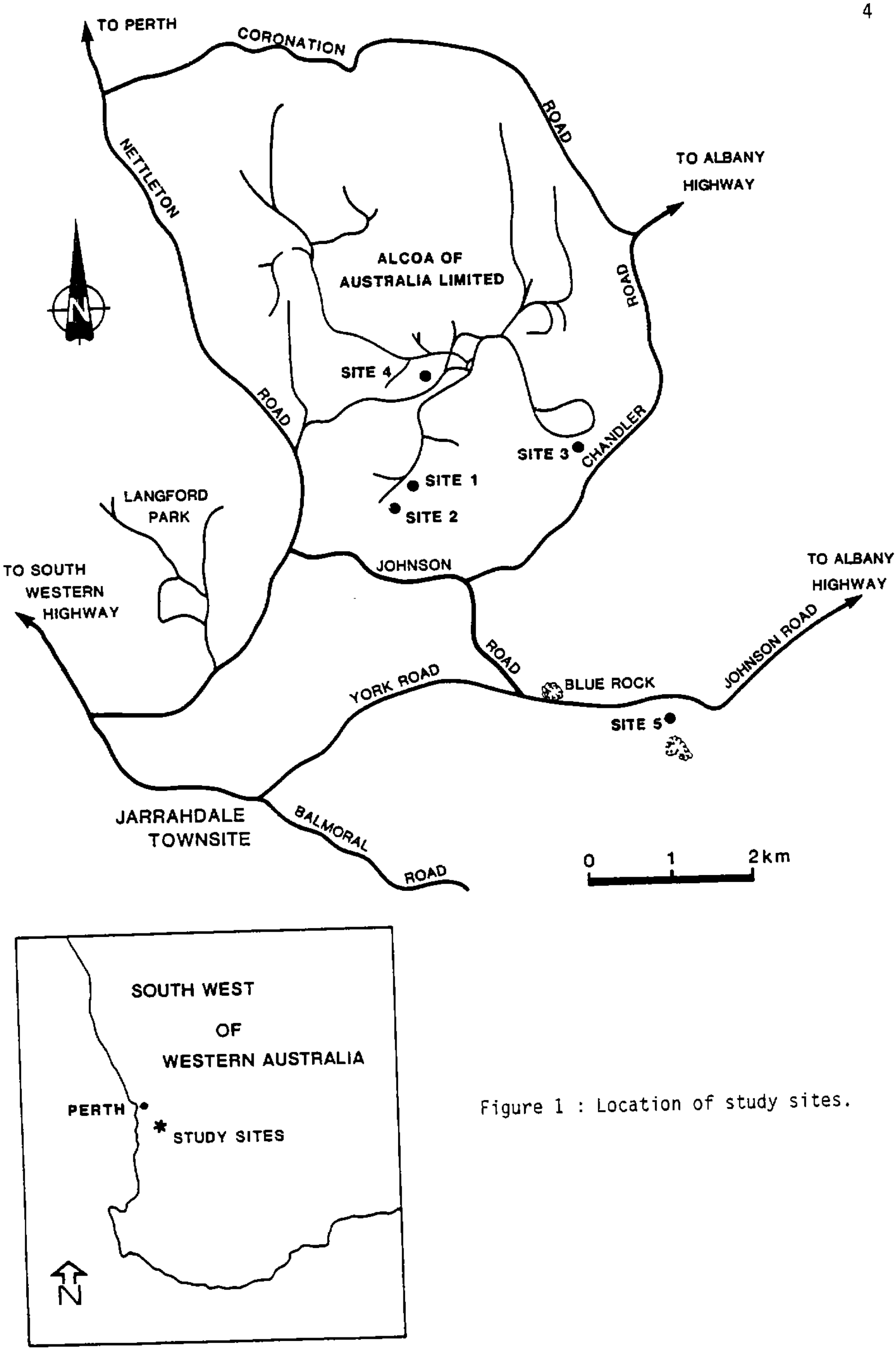

Figure 1 : Location of study sites.

Three species of Eucalyptus were planted out as for Site No.1, with the addition of E. marginata seeds being scattered throughout the site at a rate of 250 per ha.

Site No.3 : A bauxite mine pit, rehabilitated in early 1975 (8 years old).

The area was prepared as for Sites No. 1 and No.2. Fertiliser was applied at the rate of 450 kg per ha, and a seed mix was sown at the rate of 7 kg per ha. The seed mix consisted of five species of Acacia, K. prostrata, Trymalium ledifolium and Bossiaea aquifolium. Only two species of eucalypts (E. calophylla and E. resinifera) were planted, again at the rate of 640 trees per ha.

Site No. 4 : An area of jarrah forest.

This was bordered on one side by a main road, and on the other side by an established plot of Eucalyptus trees. The area was logged in 1980 and burnt in the same year. Prior to this it had been under a controlled burning regime with a 5 year cycle. No attempt has been made to introduce or replace any plant species, and at present Xanthorrhoea preissii dominates the site.

Site No. 5 : Another area of jarrah forest.

This was 5km south-east of the other four sites. The area was logged in 1974 and was last burnt in 1981. Prior to this it had been under a controlled burning regime with a 5 year cycle. As with Site No. 4, no revegetation efforts have been made. At present the dominant species on the site are E. marginata, X. preissii, Banksia grandis and several herbaceous plant species.

Floristic and Habitat Survey

At each of the five sites a line transect 100m x 1m was marked out. Each transect was surveyed for plant species numbers and relative species abundance, and the vegetation height profile of each specimen was recorded in four categories.

(i)	0 - 10 cm high	-	Ground cover
(ii)	10 - 50 cm high	-	Herbs and small shrubs
(iii)	50 - 150 cm high	-	Small bushes
(iv)	Over 150 cm high	-	large bushes and trees

All floristic taxonomic nomenclature is after Green (1981). A complete taxonomic list of all species recorded is given in Appendix 1.

On three occasions in 1983 (February 26, May 10, and August 6) the percentage ground cover and the depth of leaf litter was recorded in ten random quadrats (each $0.25m^2$) along each of the 100m x 1m transect.

Fauna Survey

The arachnid fauna was sampled using three methods: pitfall trapping, litter sampling, and visual searches. All the collected specimens were preserved in 75% Ethanol.

(a) Pitfall Trapping

The group of wandering or cursorial spiders, which includes such families as Lycosidae, Clubionidae, Gnaphosidae, Ctenidae, and several others, have been the subject of many ecological studies. However, a major problem associated with such research has been the lack of accurate sampling techniques. The most common methods employed have been pitfall trapping and quadrat sampling. Although pitfall trapping provides continuous samples through time, its efficiency depends on the numbers and activity of the animals. The activity patterns of cursorial spiders is influenced by the type of ground cover and by the weather Duffey (1972). In contrast, quadrat sampling provides an estimate of absolute density, but it too is influenced by the activity of animals during the limited sampling period. Further limitations are that the presence of the investigator may result in many spiders running away and that many cursorial spiders are active at night when sampling techniques other than pitfall trappings are less efficient.

Uetz and Unzicker (1976) compared pitfall trapping and quadrat sampling, and concluded that pitfall trapping gives a closer estimate of the total number of species in a community. In addition they recommended that six conditions be met if accurate data are to be collected from pitfall trapping, one of which is that pitfall trapping be backed by a second method (i.e. quadrats, time-search, sight-count) etc. For this reason, pit trapping was selected as the principle survey technique, and supplemented with litter sampling and visual searches.

In the pitfall trap programme, a line transect of 20 pitfall traps, at intervals of 5 metres, was used at each site. The traps were P.V.C. containers 120mm in diameter and 120mm deep (model K30, Advance Containers Pty Ltd). Each trap was buried vertically at ground level and filled with 150ml of Salt's solution. This preservative has proved to be neither an attractant nor a repellant to arachnids. The mixture used contained:

25g Sodium chloride
10g Potassium nitrate
10g Chloral hydrate
3 drops of glycerol

dissolved in 1000ml of water.

The contents of the pitfall traps were collected every 5 to 6 weeks and the traps were then reset. Trapping was conducted from February 26 to August 6, 1983.

(b) Litter Sampling

Leaf litter samples were taken at each site to supplement the pitfall trapping. This method was not used to obtain quantitative data but rather to yield new species, particularly small spiders having limited movement. On each of the three sampling trips, a series of five random samples (each $0.09m^2$) were taken along each transect. The samples were placed in plastic bags and later sorted by hand. Collected specimens were preserved in 75% ethanol for later identification.

(c) Visual Searches

In order to collect non-cursorial spiders it was necessary to make visual searches of a variety of substrates, such as fallen trees, decaying logs and stumps, foliage, bark, and flower heads. Visual searches can be made in two ways, per unit time or per unit area. Since variation in habitat complexity creates different substrate surface areas, time-based searches are unsuitable if comparisons are to be made between areas of differing structural complexity (see Southwood, 1966). Therefore all visual searches conducted during the study were made on a per unit area basis. At each site, three areas (5m x 1m) chosen from random number tables were searched and the specimens collected. To accommodate the tendency for arboreal spiders to be nocturnal in habit, an equal number of searches was made at night, between 2000 hours and 2400 hours. Different sections of the transects were searched during the day and night, on each sampling trip.

The monthly climatic data recorded at the nearby Karnet weather station for the duration of this study are shown in Appendix 2.

Taxonomy

All the arachnids were examined using a stereo microscope (x 7.5 to x 87.5). Wherever possible specimens were classified to species level. The state of the taxonomy of Australian arachnids is fairly good, although many species of spiders (and possibly opiliones) are still to be described or require taxonomic revision. As such, those specimens which could not be determined to genus or species have been attributed to family level and assigned code numbers for genus and species. A classified reference collection, in addition to all other specimens collected, has been lodged with the Zoology Department of the University of Western Australia. A complete taxonomic list of all species collected is given in Appendix 3.

Of the other orders of Arachnida collected, classification of the opiliones and scorpions was made to species level for all specimens. Acarina (mites and ticks) were omitted from this study because of their very low abundance, patchy distribution, and the difficulties associated with their taxonomy.

Analytical Methods

(a) Floristic Analysis

The floristic communities of the study sites have been described using Brillouin's index (Pielou 1966), since the collections are small enough for all members to be identified and counted. Brillouin's index is given by:

$$H = \frac{1}{N} \log_x \frac{N!}{N_1!\,N_2!\ldots N_s!}$$

where N = the total number of individuals in each collection, and N_1 to N_s = the number of individuals in the i^{th} species. In this study the logarithm to the $base_{10}$ was used.

Pielou's measure of evenness (J) gives a measure of the evenness with which individuals are divided among the species in the collection. This value is maximum (equal to one) when for a given number of species the individuals are distributed as evenly as possible among those species. Conversely, if only a few species contain a large majority of the individuals, evenness is low. Evenness is defined by :

$$J = \frac{1}{N} \log_x \frac{N!}{\{[N/s]!\}^{s-r}\{([N/s]+1)!\}^{r}}$$

where [N/s] is the integer part of N/s, N = the total number of individuals in the collection, s = the number of species in the collection, and r = N - s [N/s]

Comparisons between communities in time and space can also be made on the basis of the relative similarity of their species composition. Sorensen's index of similarity (Southwood, 1966) was used in preference to other indices in this study because Huhta (1979) points out that this index is more suitable for detecting successional trends. The index is given by :

$$QS = \frac{2c}{a+b}$$

where a and b are the numbers of species in sample A and sample B and c is the number of species in common.

(b) Fauna Analysis

The species diversity and evenness for each site was calculated using Brillouin's formula and Pielou's measure of evenness, as in the previous section. Calculations were made for ground dwelling species from pitfall trap data, and for all species obtained by all three sampling methods. As in the floristic analysis, Sorensen's similarity index was used to calculate community species similarity. The index was applied to the data pooled from the three sampling trips invovling all three sampling methods.

Habitat structure, and the resulting microclimate it creates, has been found to affect arthropod distribution (Cloudsley-Thompson, 1962). In view of these findings, determining the similarity between the habitats of the five sites is appropriate. This can be done using a selection of artificial binary characteristics which describe various aspects of habitat. Using Sorensen's index, coefficients of similarity can be calculated, and a dendrogram constructed.

Hummon's (1974) index which uses shared species diversity between communities, was applied to the ten most abundant species recorded during the study. This index is given by :

$$S_H' = 100(2c) / [(a + b) + \sqrt{(b - a)}]$$

where $c = H_S' = (3.321928/N)\ (S \log s - \Sigma s \log s)$, $a = b = H_D' = (3.321928/N)\ (N \log N - \Sigma n \log n)$ N = the total number of individuals in each collection, n = the number of individuals in each species, s = the minimum percentage similarity of abundances between common species in two sites, $S = \Sigma s$ for all species in the collection and $b > a$. For the stepwise procedure in calculating S_H' see Hummon (1974).

The species richness of each site during the study period, measured at each sampling interval, provides a simple but useful expression of community stability and the seasonal fluctuations in the community structure.

Dominance-diversity curves (see Whittaker, 1965) can be generated for each site by plotting the log of the relative abundance, expressed as a percentage, against the rank of a species (most to least abundant). These curves illustrate both components of diversity: richness on the ordinate axis, and eveness by the slope of the curve.

Groups of organisms with similar predatory strategies and habitat choices have been referred to as 'syntrophiums' (Balogh and Loksa, 1948), and more recently as 'guilds' (Root, 1967). Analysis of community structure based on guild associations can demonstrate temporal changes as might be expected in successional communities. Analysis of the relative guild composition throughout the study period using Kendall's coefficient of concordance (W) was performed in an attempt to show any such changes (see Siegel, 1956).

Simplistically, habitat can be divided into two components; a ground level component which includes the percentage ground cover, leaf litter depth, and structural complexity; and an above ground component consisting of vegetation abundance, complexity, and density. The different aspects of these two components can be correlated with numbers of animal species and absolute abundances of animals in an attempt to elucidate their influence on arachnid communities.

RESULTS

Flora

Analysis of the floristic component of the study sites shows that the plant community that results from the rehabilitation programme gradually approaches that found in the surrounding jarrah forest (Table 1). The diversity of each of the rehabilitated sites shows a strong positive association with species richness ($r^2 = 0.98$, $p < 0.001$).

TABLE 1

PLANT DIVERSITY (H), SPECIES RICHNESS (S), AND EVENNESS (J) FOR EACH STUDY SITE.

Site No.	H	S	J	Total N
1	0.7459	14	0.7149	100
2	0.9125	19	0.7734	149
3	0.8451	16	0.7678	116
4	1.0687	29	0.7917	199
5	1.0568	28	0.8086	141

Site No. 1, still in its infancy with regards to its rehabilitation, affords a harsh environment, with total exposure to the sun and wind. The diversity and evenness values recorded are the result of topsoil handling, planting and the composition of the seed mix. With 89 percent of the plants at the site less than 50 cm high, leaf litter and ground cover have not had the chance to accumulate (Figure 2, Table 2). The ground cover present is Kennedia coccinea and K.prostrata.

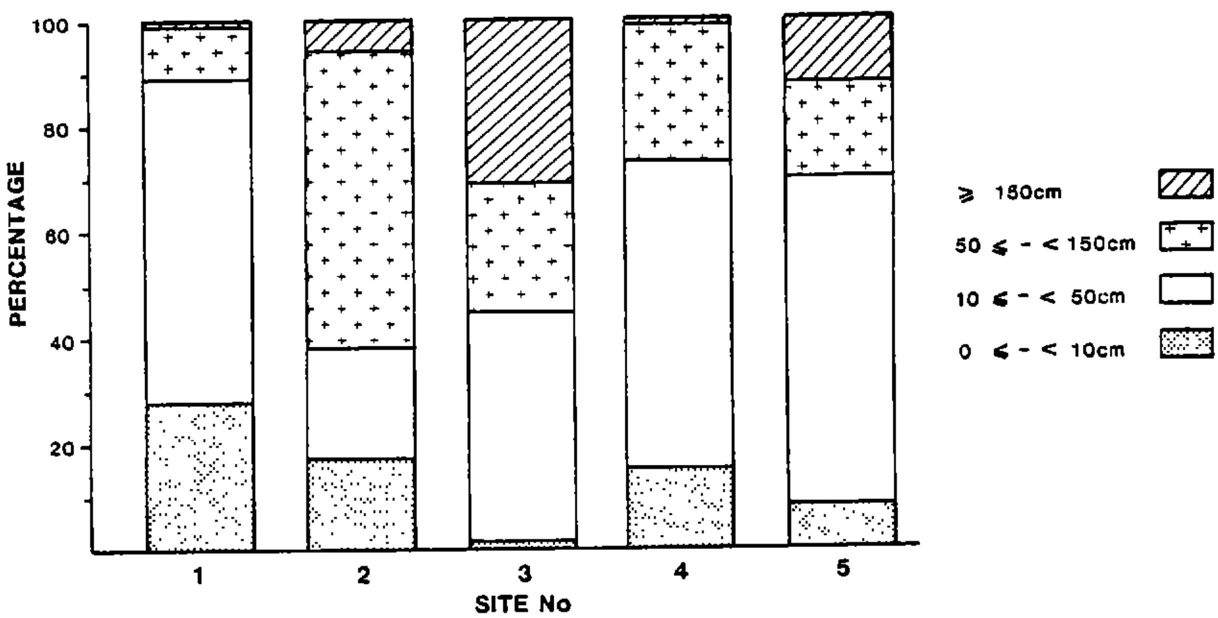

Figure 2: Vegetation height profile distributions for each site, expressed as a percentage.

TABLE 2

PERCENTAGE GROUND COVER AND LEAF LITTER DEPTH (MM) FOR THE STUDY SITES (X ± S.E., N=30).

Site No.	Percent ground cover	Leaf litter depth
1	17.6 ± 9.1	0.0 ± 0.0
2	52.9 ± 6.6	4.6 ± 0.1
3	75.6 ± 2.5	13.4 ± 0.1
4	39.7 ± 3.2	5.5 ± 0.2
5	84.4 ± 1.7	7.8 ± 0.2

Despite having had the lowest seeding rate (0.5 kg per ha), Site No.2 has the highest species richness of the three rehabilitated sites. The extra years growth (in comparison to Site No.1) has resulted in 62 percent of the plants reaching a height of 1.5 m or more (Figure 2,). As a result, leaf litter accumulation has progressed rapidly (Table 2) and, coupled with the presence of the two species of Kennedia (live and dead), the percentage ground cover has increased to more than 50 percent.

By contrast Site No.3, which received the highest seeding rate, has a lower species richness and diversity. This is probably because a much lower number of species would have been seeded in 1975 (Site No.3) than in 1981 (Site No.2), when 24 species were added. The high closed canopy of Acacia extensa in Site No.3 greatly reduced light penetration to the lower understorey region, but contributed extensively to the luxuriant leaf litter deposits and the high percentage of ground cover of the site (Figure 2, Table 2).

The logging and hot burn to which Site No.4 was subjected have resulted in a very low, open stand of vegetation which is composed mainly of small shrubs, herbaceous plants and X. preissii (Figure 2). With the removal of nearly all the jarrah and banksia trees, leaf litter has not accumulated to any extent, the existing ground cover being mainly bark and charcoal. The higher diversity and evenness values are due to the large number of small herbaceous plant species, several of which were not recorded at any of the other sites.

Site 5 can probably be considered representative of much of the northern jarrah forest. Selective felling has meant that the diversity of the site has not been greatly affected, consequently litter accumulation and ground coverage are fairly substantial.

Comparisons between the floral communities on the basis of species common to pairs of sites, shows that the two sites in the jarrah forest are most similar, with the three rehabilitated sites forming a second separate group (Table 3, Figure 3). Within the rehabilitated sites there is a clear successional association. Such a result would be expected since basically the same plant species were present in the seed mixes, and similar pre-planting procedures were applied to each site.

TABLE 3

SORENSEN'S COEFFICIENTS OF SIMILARITY FOR PLANT SPECIES.

SITE NO.	Site No.				
	1	2	3	4	5
1		0.4848	0.4666	0.2326	0.0952
2			0.6286	0.2084	0.1702
3				0.1778	0.1364
4					0.6376

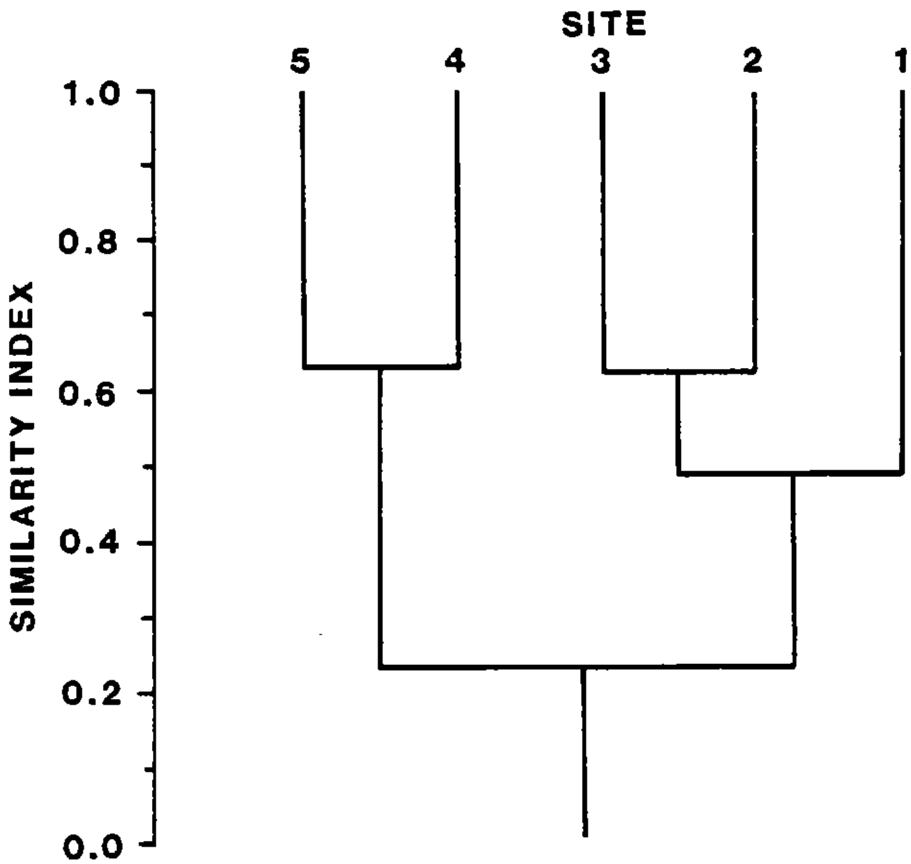

Figure 3: Similarity dendrogram of sites derived using plant species composition.

In terms of the habitat structure, the relationships between the sites differ from those shown in Figure 3. Although the characters used to define the habitats are artificial (see Table 4) they separate the sites effectively. The similarity dendrogram which results is given in Figure 4. On this basis a rehabilitated site only 2 years old represents a similar habitat, in terms of diversity and species richness, to one which has been logged and burnt 2 years previously; and an 8 year old rehabilitation site represents a similar habitat to that found in the surrounding jarrah forest.

TABLE 4

HABITAT SIMILARITY BASED ON ARTIFICIAL, BINARY CHARACTERS.

Character	Site No.				
	1	2	3	4	5
Ground cover ⩾ 35%	-	+	+	+	+
Leaf litter depth ⩾ 6 mm	-	-	+	-	+
No. plant species ⩾ 18	-	+	-	+	+
Height profile proportions of plants ⩾ 25%;					
0 ⩽ – < 10 cm	+	-	-	-	-
10 ⩽ – < 50 cm	+	-	+	+	+
50 ⩽ – < 150 cm	-	+	+	+	-
> 150 cm	-	-	+	-	-

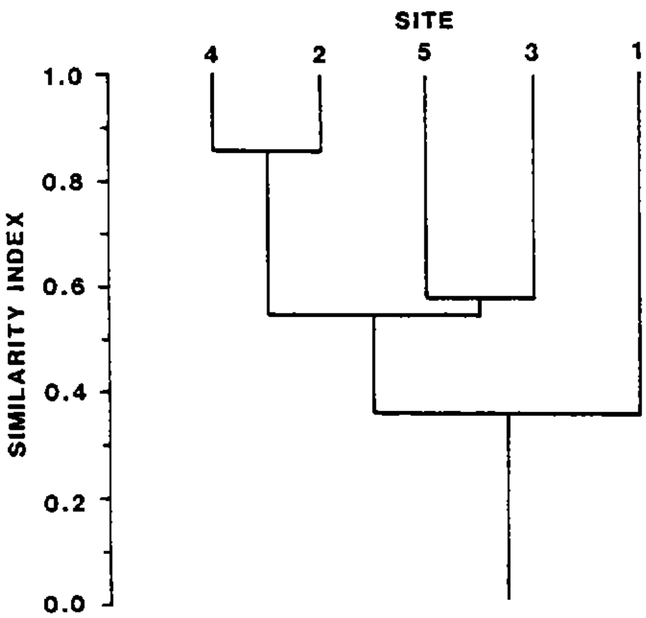

Figure 4 : Similarity dendrogram of sites derived using community habitat structure.

Fauna

A total of 1228 specimens were collected during the study, representing 26 families, 78 genera, and 85 species. Table 5 and Appendices 3 and 4 provide a site-by-site breakdown of the taxonomic distributions of the species collected.

TABLE 5

THE NUMBERS OF ALL COLLECTED ARACHNIDS IN TAXONOMIC CATEGORIES

	SITE NO.					
	1	2	3	4	5	All
No. Families	8	11	18	17	22	26
No. Genera	13	19	39	31	47	78
No. Species	13	21	40	31	52	85
Total N	49	192	460	145	382	1228

Faunal species diversity, evenness, and species richness in the study sites show considerable differences (Table 6). When all arachnid species are included in the analysis it can be seen that generally, diversity and species richness increase together. Site 2 is an exception however, with a low diversity value. The evenness estimates for the collections indicate that the distribution of individuals in Site No.2 and No.3 is far more disproportionate than in the other sites. This trend is more clearly shown in the dominance-diversity curves (Figures 5 - 9). The greater the slope of the curve the less even is the distribution of individuals among the various species. A lognormal distribution of species relative abundances produces an elongated S-shaped curve.

TABLE 6

ARACHNID SPECIES DIVERSITY (H), SPECIES RICHNESS (S), AND EVENNESS (J) FOR ALL SPECIES (TOT.) AND GROUND DWELLING SPECIES ALONE (GR).

Site No.	$H_{Tot.}$	$S_{Tot.}$	$J_{Tot.}$	$H_{Gr.}$	$S_{Gr.}$	$J_{Gr.}$
1	0.8071	13	0.8972	0.7287	9	0.8999
2	0.6022	17	0.5279	0.3660	11	0.3742
3	0.9760	36	0.6184	0.7500	22	0.5188
4	1.0384	27	0.8146	0.9550	21	0.7946
5	1.1779	47	0.7552	1.0627	28	0.9521

A feature of the fauna of the rehabilitated sites is the high proportion of ground dwelling species of arachnids (Table 6). Within the sub-communities of ground dwellers the diversity and evenness vary more than within the whole community. Site No.2 and No.3 have substantially lower diversity and evenness values, while the evenness of Site No.5 increases by almost one-third.

Examination of the temporal variations in species richness during the study shows that all five sites were subject to the same seasonal fluctuations. Species richness increased during autumn and early winter before falling off again during spring (Table 7).

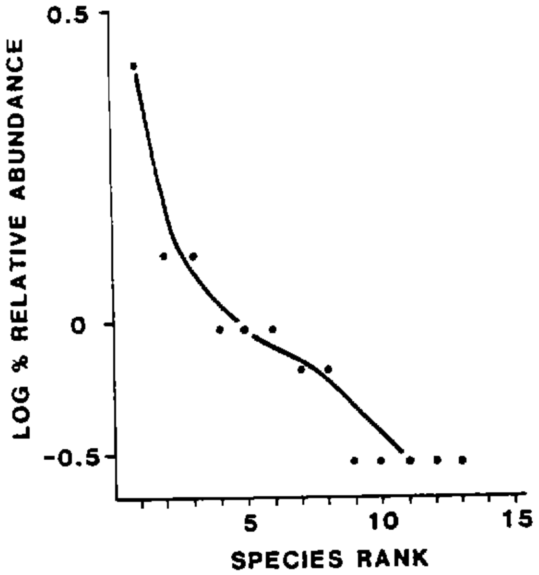

Figure 5: Arachnid dominance-diversity curve for Site No.1

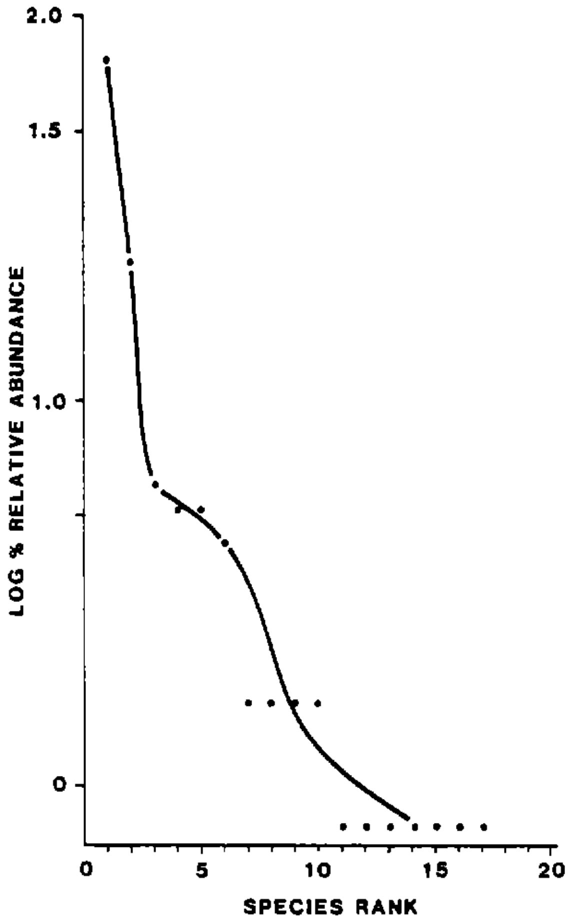

Figure 6: Arachnid dominance-diversity curve for Site No.2.

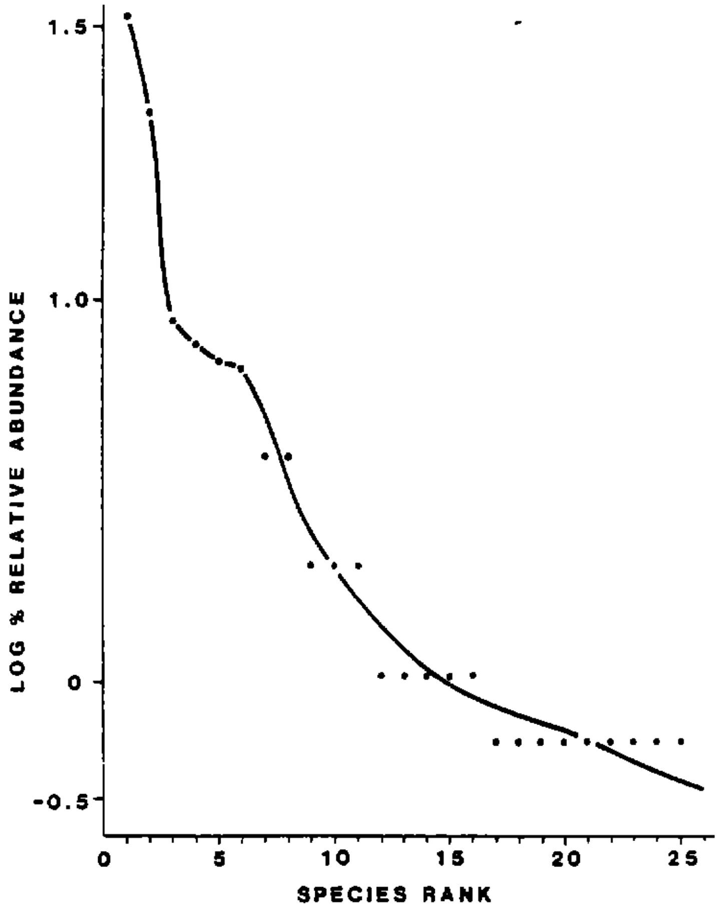

Figure 7: Arachnid dominance-diversity curve for Site No.3.

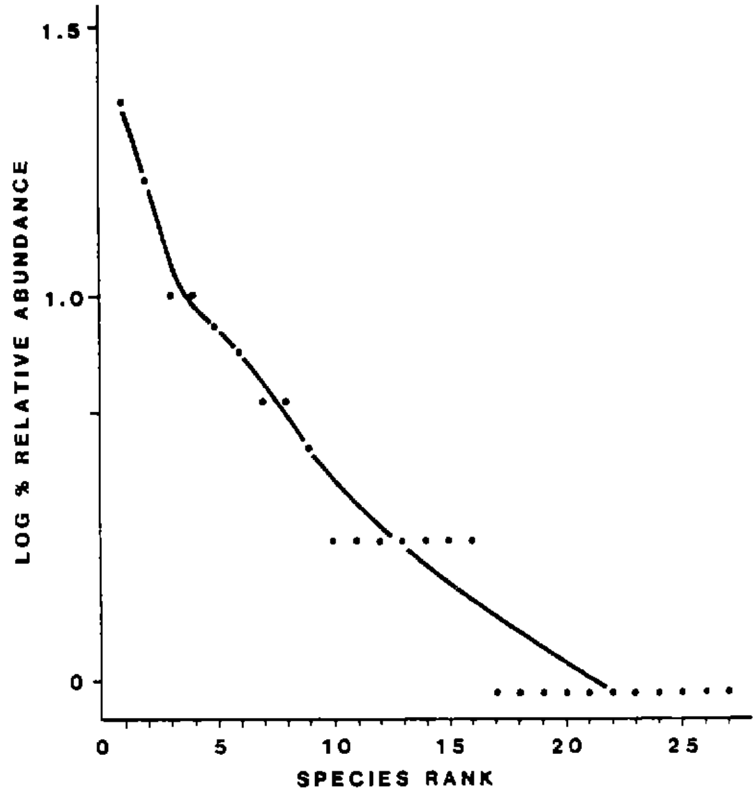

Figure 8: Arachnid dominance-diversity curve for Site No.4.

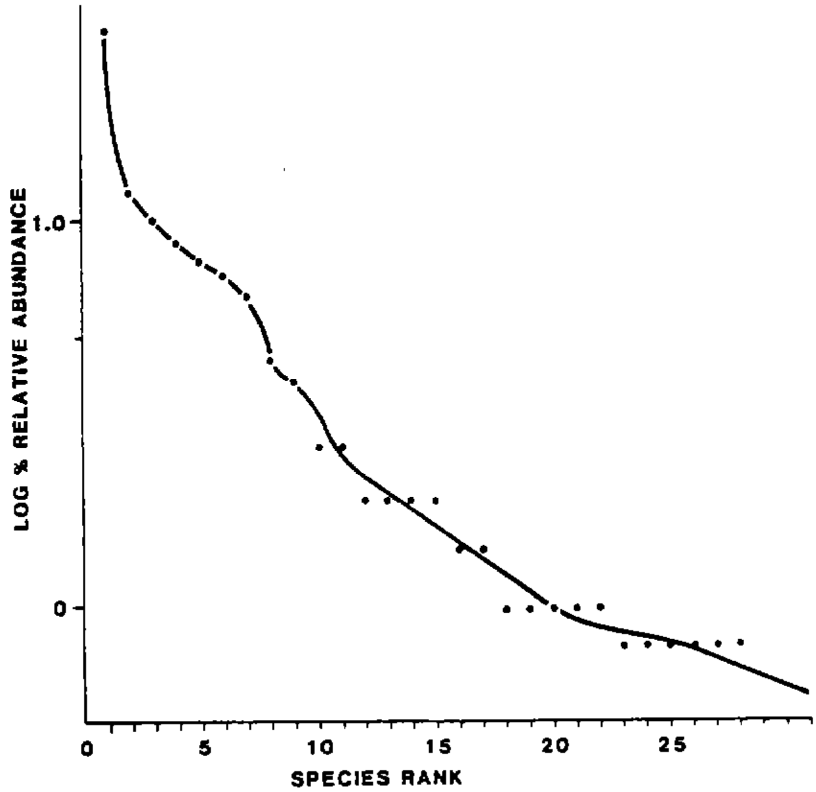

Figure 9: Arachnid dominance-diversity curve for Site No.5.

TABLE 7

TEMPORAL VARIATION IN SPECIES RICHNESS DURING THE STUDY PERIOD (1983): USING ALL SAMPLING METHODS (T) AND ONLY PITFALL TRAPS (P).

		Time of Sampling		
Site No.	Method	Feb. 26	May 10	Aug. 6
1	T	4	9	2
	P	4	5	2
2	T	9	13	5
	P	3	13	3
3	T	18	22	12
	P	11	22	6
4	T	16	17	6
	P	14	17	4
5	T	25	27	18
	P	17	27	8

Associated with the rise and fall in species richness are two different trends. The number of species of ground dwellers increases with the advent of winter, then peaks and falls away with the coming of spring. The reverse occurs in the web building and ambushing species which are most abundant during the late summer-autumn period, decrease in number during the autumn to the point of being completely absent during the winter, and then reappear as newly hatched juveniles in the spring.

Calculations of coefficients of community (Table 8) result in the similarity dendrogram shown in Figure 10. Site No.3 and No.5 are again closely associated, with Site 1 and 2 forming a second group, and Site No.4 separate from these two groups. The overall low coefficients (0.53) suggest that the species constituting each of the communities are, with a few exceptions, somewhat endemic to the particular habitat which each site provides.

TABLE 8

SORENSEN'S COEFFICIENTS OF SIMILARITY FOR ARACHNID SPECIES.

	SITE NO.				
	1	2	3	4	5
1		0.5294	0.3396	0.4545	0.3125
2			0.4590	0.5000	0.3561
3				0.3943	0.4782
4					0.4096

Comparison between sites on the basis of shared species diversity similarity, using the ten most common species, produces a dendrogram which further supports the results obtained from the conventional diversity estimates given in Table 7 (Table 9, 10, Figure 11). Since only ten species were used in the analysis, the differences between the groups of sites is not as marked as in those obtained using Sorensen's index.

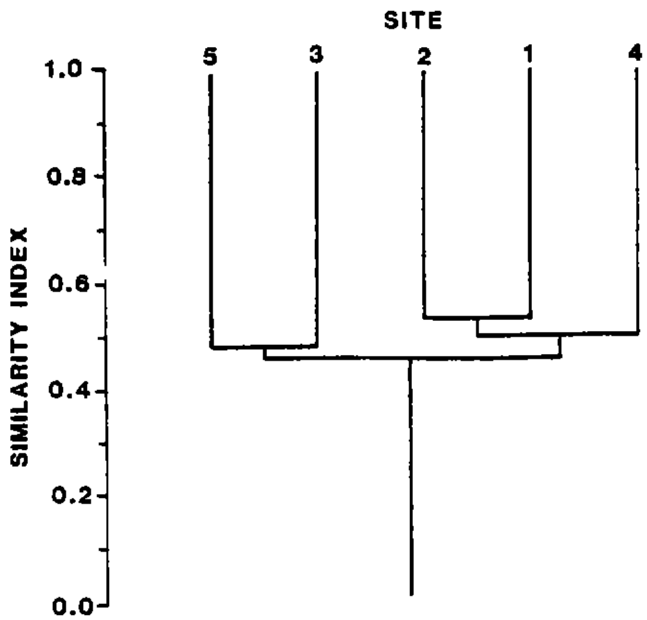

Figure 10: Similarity dendrogram for the five arachnid communities, derived using site species composition.

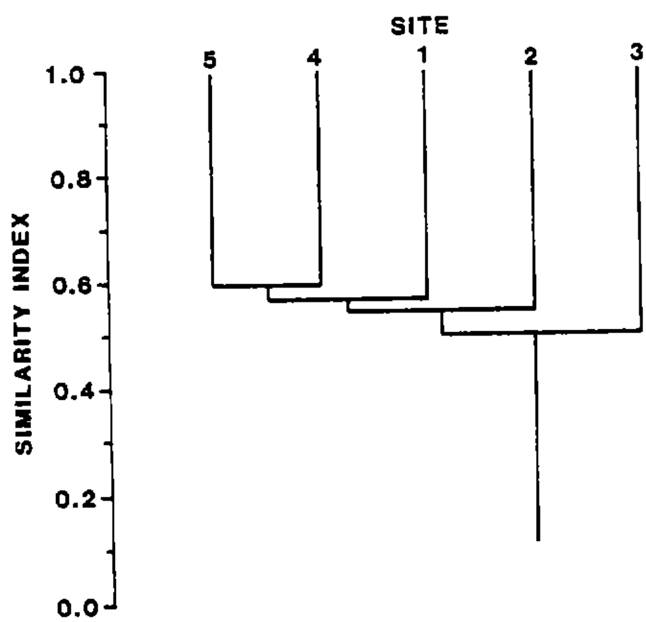

Figure 11: Similarity dendrograms for sites derived using Hummon's (1974) shared species diversity index for the arachnid data.

TABLE 9

THE TEN MOST ABUNDANT SPECIES OF ARACHNID, USED IN THE CALCULATION OF SHARED SPECIES DIVERSITY INDICIES.

Chenistonia tepperi	Ctenidae Genus 2 sp. 1
Eriophora biapicata	*Lampona* sp.
Chiracanthium sp.	*Lycosa* sp.
Supunna michaelsoni	*Latrodectus mactans hasselti*
Elassoctenus harpax	*Storena tricolor*

TABLE 10

MATRIX OF HUMMON'S SHARED SPECIES DIVERSITY SIMILARITIES (S_H') FOR THE SPECIES LISTED IN TABLE 9.

	SITE NO.				
	1	2	3	4	5
1		30.29	54.48	56.91	47.40
2			49.79	25.05	21.27
3				39.82	42.68
4					58.95

The proportions which the four guilds constitute within each community, is a feature of community structure which might be expected to vary according to the biology of the species concerned and changes in climate. Kendall's coefficient of concordance (Table 11) shows that the changes that occurred in guild composition during the study were not statistically significant (Table 11 and Appendix 4).

TABLE 11

ANALYSIS OF TEMPORAL VARIATION IN COMMUNITY GUILD COMPOSITION FOR EACH SITE, USING KENDALL'S COEFFICIENT OF CONCORDANCE (W).

Site No.	W	X^2	d.f.	Prob.
1	0.0878	2.8974	11	$p>0.99$
2	0.1076	3.5513	11	$p>0.98$
3	0.1092	3.6026	11	$p>0.98$
4	0.1107	3.6538	11	$p>0.95$
5	0.1014	3.3461	11	$p>0.98$

Correlations between arachnid species numbers or absolute abundance and habitat features such as leaf litter depth, percentage ground cover, and vegetation height profile provide evidence for the dependence of arachnid community structure on characteristics of the habitat.

Percentage ground cover correlates significantly with both the number of species and the absolute numbers of ground dwelling arachnids (Guilds B and G: Appendices 3 and 4, with $r^2 = 0.3014$, $p<0.05$; and $r^2 = 0.4872$, $p<0.005$ respectively: see Figures 12 and 13). Similarly, depth of leaf litter correlates significantly with both species numbers and absolute numbers for those same guilds ($r^2 = 0.2540$, $p<0.05$; and $r^2 = 0.4848$, $p<0.005$ respectively: see Figures 14 and 15).

The species of arachnids constituting the guilds of web weavers and ambushers or stalkers and pouncers (see Appendix 3) show a correlation with the number of plants 1.5 m or more in height, for both numbers of species and absolute numbers of individua's ($r^2 = 0.4251$, $p<0.01$; and $r^2 = 0.6642$, $p<0.001$ respectively; see Figures 16 and 17).

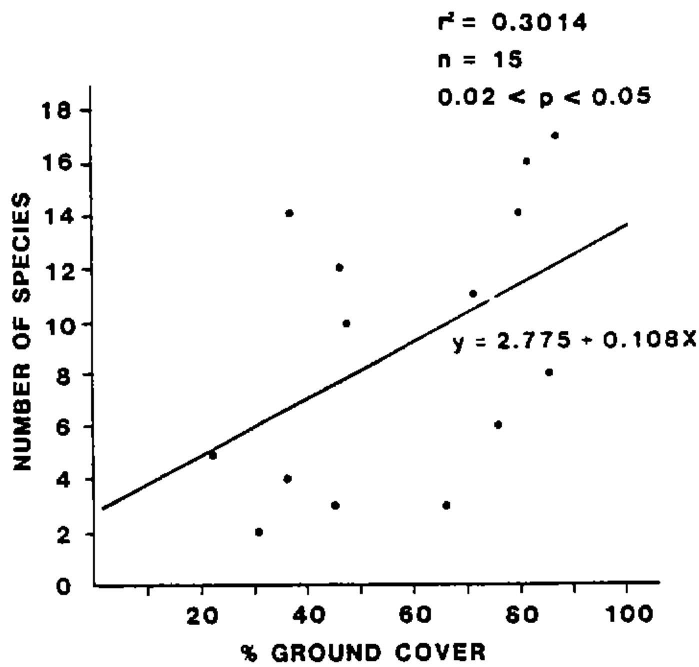

Figure 12: Number of species of ground dwelling arachnids

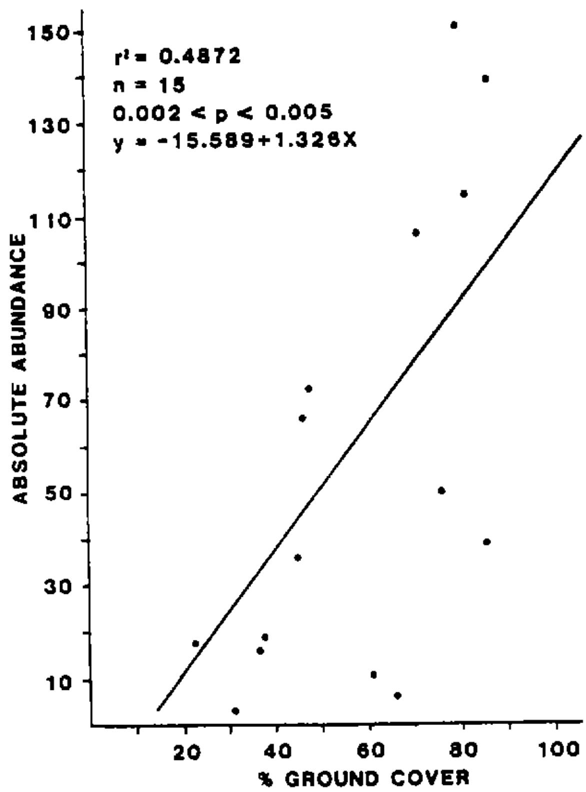

Figure 13: Absolute abundance of ground dwelling arachnids versus percentage ground cover.

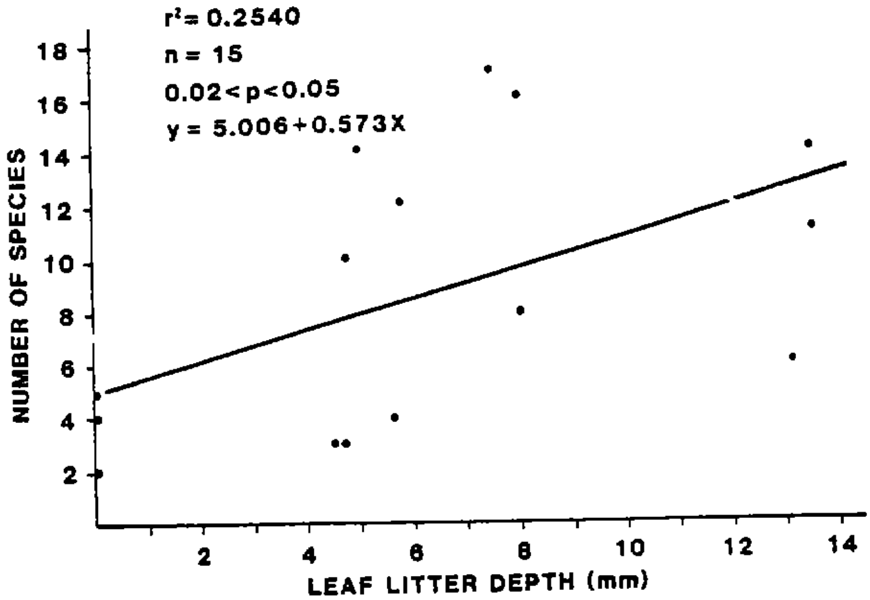

Figure 14: Number of species of ground dwelling arachnids versus leaf litter depth.

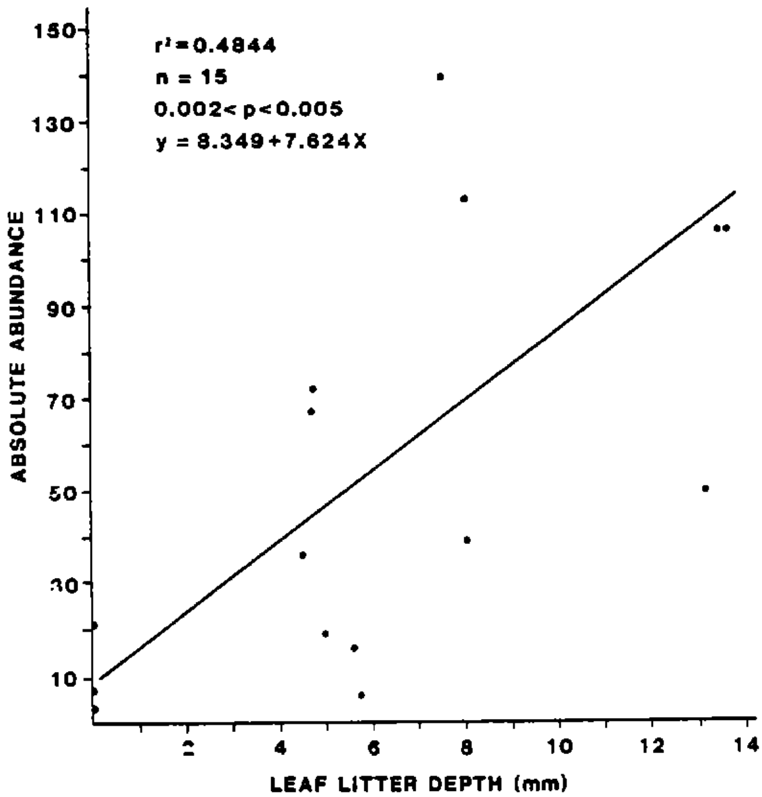

Figure 15: Absolute abundance of ground dwelling arachnids versus leaf litter depth.

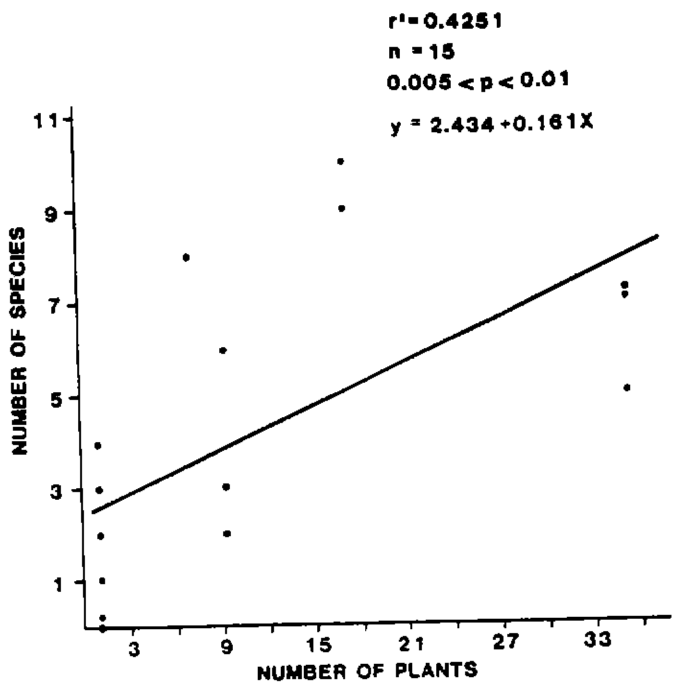

Figure 16: Number of species of web builders and ambushers versus number of plants greater than 1.5 m tall.

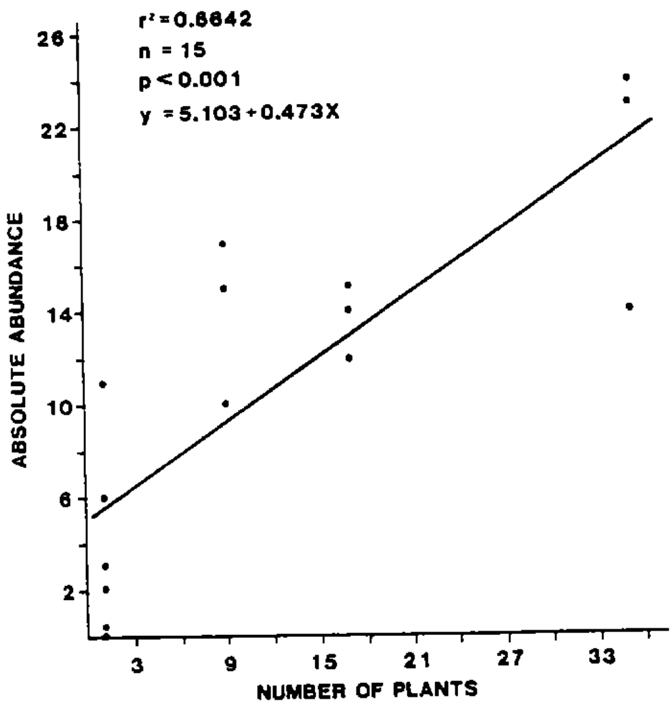

Figure 17: Absolute abundance of web builders and ambushers versus number of plants greater than 1.5 m tall.

DISCUSSION

Typically plant succession refers to the changes observed in an ecological community following a perturbation that opens up a relatively large space. Space can result from both by natural or man-made perturbations, such as fire, or as in this study, mining operations.

The process of succession has often been described as a plant by plant replacement system, as reflected by the earliest studies conducted on succession (see Clements, 1916). More recently, studies have described changes in other characteristics such as biomass, productivity, diversity, and niche breadth.

Connell and Slatyer (1977) examined succession in terms of its direction of progress following initial perturbation. The method which best describes the processes which have occurred in bauxite mine rehabilitation sites would come under the heading of the 'tolerance' model.

In this model, modifications wrought on the environment by the earlier colonists neither increase nor decrease the rates of recruitment and growth to maturity by later colonists. The processes of applying fertilizer, sowing a predetermined seed mix, and planting out tree seedlings at a specific rate, attempt to ensure that no particular species dominate the environment or inhibit the growth of other species to any degree.

By planting tree seedlings at the same time as the seed mix is sown, the time span over which the normal successional sequence would occur has been contracted into only a few years. This can be seen by the similarity between Site No.3, an 8 year old rehabilitated mine pit, and jarrah forest found in Site No.5. The normal sequence of successional changes appears to be taking place in Site No.4, with the small shrubs and herbaceous plants dominating the site since the removal of most of the large trees.

The results of the floristic survey show that there is some form of successional development occurring in the rehabilitated sites with diversity, evenness, and species richness increasing with the age of the site. The apparent anomaly in the case of Site No.3 is probably due to the dominance of the early vegetation by _A. extensa_. This is perhaps because of the limited range of species seeded in this plot, and the inhibitory effect which _A. extensa_ had on the development of other understorey plants. As such the diversity and species richness of the site have not increased, and will probably not do so until fire or natural senescence remove the now predominantly dead canopy of this species.

If all successions led to a similar species composition at equilibrium, as postulated by Clements (1916), there would be global stability. If quite different species compositions were reached the system would have multiple stable points. The evaluation of diversity, evenness, and species richness at each of the sites indicates that the three rehabilitation sites and Site No.4 are all moving towards a climax community of some form. The convergence of the Site No.4 plant community with that of Site No.5 would be expected since there have been no additions of exotic species into the area. However, it is unlikely that communities in the rehabilitated sites will be very similar to those of Site No.4 and No.5 in the medium term, simply because of the different suite of species chosen in the rehabilitation programme.

The fact that the species composition of the various plant communities will be different does not necessarily mean that the arthropod communities will also be different. Large variations in plant species composition occur naturally throughout forest communities. The presence of most plants ameliorate climatic conditions to a marked degree. Not only the height of plants but also the quality and density of herbage affect temperature and humidity of the microclimate (Cloudsley-Thompson, 1962). Other features of the environment such as timber, logs, rocks, soil cover and litter all play important roles in providing insulated microenvironments in which many cryptozoic animals can exist, despite the apparent extremity of the macroclimate of the area. It is the nature of the environment which is important, rather than the specific types of plants which contribute to the composition of that environment.

It is well known that the effects of temperature and humidity are interrelated. It is generally difficult, however, to distinguish between the effects of these two variables in the field. Temperature, humidity, and their seasonality can directly affect the quality, quantity, and spatial and temporal distribution of arthropods-predator and prey alike (Landres and MacMahon, 1983). Both insects and arachnids such as scorpions have been shown to possess water relations that are associated with the humidity of their environments and with their activity times (Williams, 1962; Warburg and Ben-Horin, 1978).

Wind is also important in determining the species composition of communities. In established communities wind has a strong influence over relative humidity while in unstable early successional communities wind has the additional influence on aerial recruitment by juveniles (Richter, 1970; Cloudsley-Thompson, 1962).

Alterations to leaf litter and soil surface micro-habitats create environments subject to wider fluctuations in temperature and moisture (Bell and Sipp, 1975), and eliminate microhabitats and refuges for some species. This situation is clearly evident from the variation in species richness and diversity of the ground dwelling arachnids of the five study sites. The significant factors determining community structure at ground level in the study sites are leaf litter depth, which involves the component of litter complexity, and the percentage ground cover. These correlations may be due to the quantity and quality of niches or refuges which the leaf litter and ground cover provide, or they may be due to the primary production of the sites which determines the quality of the detritivore arthropod community, a community which constitutes a large proportion of arachnid prey.

Uetz (1976, 1979) recorded similar results in streamside forest communities, with more species being added to the community as the litter became deeper and more complex. He attributed this to the greater variety of microhabitats and prey items which were provided, with the added possibility that habitat heterogeneity reduced interspecific predation.

Bultman and Uetz (1982) took the study of habitat structure a step further, concluding that litter depth was more influential in organizing forest floor spider communities than structural complexity or nutritional content. Bristowe (1939) and Duffey (1974) have drawn attention to the observation that many spider species are associated with markedly varying environments. The same observation can be made in this study, particularly amongst the ground dwelling species, with Chiracanthium sp. Elassoctenus harpax, Ctenidae Genus 2 spp. 1, Lampona sp. and Lycosa sp. being recorded in all five study sites. All the above species were prominent in at least one site, and each species was associated in lower abundances with one or more other habitats .

Temporal patterns in diversity, species richness, and abundance are directly related to the biology of the species concerned. The change in community structure and population size (as shown in Appendix 4) suggest that the majority of these arachnid species are short-lived (i.e. they complete their life cycle in only 1 - 2 years) and that they may be correlated with seasonal prey abundance. Such a correlation would support Pianka's (1974) 'productivity hypothesis', in that the more productive time periods support more species of foraging predators because each species may then specialise and utilise less of the total standing crop.

Generally, spiders are not known to specialise on prey species. However, some evidence has been presented that they do specialise on prey size groups (Moulder and Reichle., 1971; Turnball, 1966). Nentwig (1982) found a positive correlation between the abundance of spiders and of their potential prey. He also found a significant correlation between the body size of spiders and of their potential prey.

Probably the single most important factor affecting the diversity and abundance of web building spiders at the study sites is the availability of suitable sites for attachment of webs. Riechert (1974) observed a regular spacing of webs in a population of spiders in an area of desert in southern U.S.A.

In the present study a significant relation was found to exist between the species richness and abundance of web builders and the number of plants greater than 1.5 m in height. Brown (1981) found that for three species of Argiope (Araneidae), the height of the web in a bush was associated with both the web size and body size of the spider. Such web spacing has only been observed for adults, not for immature specimens.

This behaviour may explain why adults of the araneid, Eriophora biapicata were only found at Site No.2, while juvenile specimens were collected from all five sites. The failure of juvenile E. biapicata to reach maturity at the other four sites may be due to their inability to cope with the macroclimatic conditions of those sites, or that juveniles can utilize any available space for web sites but, maturing adults find these web sites increasingly unsuitable.

The mean spacing of individuals is governed by the availability of an adequate food supply. Within the different areas which spiders inhabit, the types of prey and their proportions in the diet change (Nentwig, 1983). This characteristic may permit small species to survive, but not large specimens such as E. biapicata. Wise (1983) has found direct evidence that prey scarcity limits the growth of some juvenile spiders, while the density of individuals does not affect growth.

A noticeable feature of the distribution of salticids was their preference for the more openly vegetated sites, with only one species being recorded from Site 3. Hately (1978) recorded similar trends among hunting guilds (equivalent to guild A of this study). Such spiders used sage brush in a manner which depended on the foliage density of the bush. Salticids were more abundant in open bushes, while web builders were present in denser bushes.

The fauna which colonise early successional habitats, such as the one provided by Site No.1, is typically generalist and restricted to one major guild, that of ground dwellers. These ground dwellers are all highly mobile, and almost all do not use permanent retreats. Recruitment into such areas is predominantly by dispersal along the ground, as with spiders of the Family Lycosidae, Ctenidae, Gnaphosidae, Clubionidae and Zodariidae. However, Richter (1970) reports that least eight species of Pardosa (Lycosidae) use aerial dispersal to varying extents, and Main (1976) says that Lycosa pullastra, common in Perth suburbs, disperses by air both as juvenile and as adult.

In the absence of other invertebrate predators and high levels of arachnid interspecific competition, early successional communities can invariably establish themselves. Apparent scarcity of food in early successional sites need not necessarily be a limiting factor since behavioural and physiological adaptations exist including possession of very low maintenance energy requirements, a highly distensible abdomen, permitting gorging during times of prey abundance, the ability to store large amounts of fat, and the ability to lower metabolic rate during transient periods of starvation (Greenstone, 1978).

Once a population has become established its methods of recruitment and the competitive relations within the population determine its level of development and the length of time it will remain as a part of the community. Site No.1 has only just been colonised by a few of the more robust ground dweller, and two species of web builder. One of these web builders (Latrodectus mactans hasselti) was probably introduced through human activity. The moderate species richness and low abundance of arachnids indicates that competitive interactions are probably not regulating the community. More likely, factors such as food availability and microhabitat instability, associated with habitat development, are the limiting factors.

Site No.2 represents a habitat which has developed sufficiently to support a large, reasonably diverse, ground fauna and an arboreal fauna consisting primarily of those species which have the largest range of habitat preference. The ground fauna is dominated by one Lycosid species, which is present in several stages of its development at any one time, indicates that it lives for more than one year. Hence this species probably fills several niches, according to body size, and competitively excludes some species that would otherwise be present.

Site No.3 provides a habitat approaching that of a climax community, with a humid stable microclimate, luxuriant litter and ground cover and a multitude of sites for web attachment. This is the only rehabilitated site in which opiliones and scorpions were found, suggesting that these species require a more complex environment, and that their methods of recruitment do not lend to rapid recolonisation of new sites. Conditions in this later successional site have become modified in such a way that, as a result of changes in the plant and general habitat community structure, spider species which were dominant in environments like those of Site 1 and 2, can no longer maintain such roles in the community.

The fauna of Site No.4 shows aspects of both recolonisation and remnants of its pre-fire community. Riechert and Reeder (1972) observed that changes in species composition following fires were due to the elimination of species active on the surface at the time of the burning. Those species occupying sub-surface burrows or sacs under rocks or clumps of dense vegetation escaped burning. That observation is supported here by the presence of five species of mygalomorph, of which only two species were recorded in any of the rehabilitated sites. It is very probable that those mygalomorphs captured in the rehabilitated sites were immigrant males from the surrounding jarrah forest, and not resident animals.

In addition to the mygalomorphs, the other ground dwellers present are vagrant species which have begun to recolonise the area from surrounding bush. All the web builders have entered the area by aerial dispersal from their nursery sites.

The fauna of Site No.5 represents that of a climax community, with all guilds well represented. Many of the species present are specialist feeders, or at least specialised in their methods of prey capture (e.g. Arcys sp., and the Thomisidae). Added to this are the general low abundances of many of the species which contribute to an overall moderate evenness value, but a high evenness value for the ground dwelling species.

Both species of opilione and three of the four species of scorpion are found at Site No.5. The restriction of Urodacus novaehollandiae, U.planimanus, and Cercophonius squama to Site No.4 and No.5 may be due to the soil condition of those two sites, in comparison to the softer, high clay content soils of the three rehabilitated sites. Lamoral (1978) studied 19 species of scorpion of the genus Opisthophthalmus, in south-west Africa, with the most significant finding to emerge from the data collected on soil hardness being that the habitat selection, distribution, and range of each species was directly correlated to a particular range of soil hardness.

The soils of Site No.4 and No.5 are predominantly laterite gravel with an underlying clay bed (see Tacey and Glossop, 1980), while those of the rehabilitated sites consist of a shallow topsoil under which is the overburden and clay bed. Soil condition may also influence the choice of burrow site of the mygalomorphs, some of the Lycosidae, and some of the Zodariidae.

The recolonization of the rehabilitated bauxite mines is an entirely natural process (ie. no animals are physically relocated), and results from the present study show that it takes a minimum of 8 years for populations of arachnids in rehabilitated mine sites to reach a level of complexity comparable with that of the surrounding undisturbed jarrah forest. If the primary objective of the rehabilitation programme is to create an environment similar to that of surrounding jarrah forest, then it is desirable to achieve this objective as soon as possible. To this end it is felt that the arachnid recolonisation of the rehabilitated bauxite mines could be hastened if the following practices are incorporated into the existing rehabilitation programme.

Recommendations for future management

1. Several features of the habitat of the ground dwelling fauna could be improved upon, principally in the early stages of rehabilitation. These include the addition of more suitably sized rocks and logs, to provide immediate alternative refuges, and the provision of a leaf litter layer or suitable substitute, to increase microclimate stability and to encourage the development of arthropod communities.

2. With regards to Site No.3 and its dense closed canopy of A. extensa, a mild intensity fire should be put through the site, either for the whole site or in a mosaic pattern. This would open up the tree canopy, providing better sites for web building, and reduce the dense mat or leaf litter to a less compacted, more complex form.

3. Further variation in the types of plants used in the composition of the seed mix and seedling trees could be introduced to provide a more continuous array of flowering plants, rather than the present situation in which many of the species flower concurrently for a

limited period. Increasing the length of effective flowering time during the year would promote insect diversity and provide a more continuous supply of potential prey items for the invertebrate predators of the rehabilitation sites. The more extensive seed mix used since 1982 (about 70 species) should help achieve this aim.

4. Increasing the productivity of rehabilitation sites in their early stages of development by planting a variety of native annuals would greatly enhance the arthropod community structure of the sites, and provide ground cover and litter when the annuals die off.

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References

Balogh, J. and Loksa, J. (1948). Quantitative-biosoziologische Untersuchung der Arthropodenwelt ungarische Sandgebiete. Arch. biol. Hung. 18, 65-100.

Bell, D.T. and Sipp, S.K. (1975). The litter stratum in the streamside forest ecosystem. Oikos, 26, 391-97.

Bristow, W.S. (1939). The community of spiders. London : The Ray Society.

Brown, K.M. (1981). Foraging ecology and niche partitioning in orb-weaving spiders. Oecologia, 50, 380-85.

Bultman, T.L. and Uetz, G.W. (1982). Abundance and community structure of forest floor spiders following litter manipulation. Oecologia, 55, 34-41.

Clements, F.E. (1916). Plant Succession. Washington : Carnegie Inst.

Cloudsley-Thompson J.L. (1962). Microclimates and the distribution of terrestrial arthropods. Ann. Rev. Entomol. 7, 199-222.

Connell, J.H. and Slatyer, R.O. (1977). Mechanisms of succession in natural communities and their role in community stability and organization. Am. Nat. 111, 1119-144.

Coyle, F.A. (1981). Effects of clearcutting on the spider community of a southern Appalachian forest. J. Arachnol. 9, 285-98.

Duffey, E. (1972). Ecological survey and the ecologist. Bull. British Arachnol. Soc. 2, 69-82.

Duffey, E. (1974). Nature reserves and wildlife. London : Heinmann Education Books.

Duffey, E. (1978). Ecological strategies in spiders including some characteristics of species in pioneer and mature habitats. Symp. zool. Soc. Lond. 42, 109-23.

Green, J.W. (1981). Census of the vascular plants of Western Australia. Dept. Agric., W.A. Herbarium publication.

Greenstone, M. (1978). The numerical response to prey availability of Pardosa ramulosa (Araneae: Lycosidae) and its relationship to the role of spiders in the balance of nature. Symp. zool. Soc. Lond. 42, 183-93.

Hatley, C. (1978). The role of vegetation architecture in determining spider community organization. Thesis, Utah State Uni. Logan, Utah, U.S.A.

Huhta, V. (1979). Evaluation of different similarity indices as measures of succession in arthropod communities of the forest floor after clear-cutting. Oecologia, 41, 11-23.

Hummon, W.D. (1974) S_H : A similarity index based on shared species diversity, used to assess temporal and spatial relations among intertidal marine gastrotricha. Oecologia, 17, 203-20.

Koch, L.E. and Majer, J.D. (1981). A phenological investigation of various invertebrates in forest and woodland in the south-west of Western Australia. J. Roy. Soc. W.A. 63, 21-8.

Lamoral, B.H. (1978). Soil hardness, an important and limiting factor in burrowing scorpions of the genus Opisthophthalmus C.L.Koch, 1837 (Scorpionidae, Scorpionida). Symp. Zool. Soc. Lond. 42, 171-81.

Landres, P.B. and MacMahon, J.A. (1983). Community organization in some oak forests of western North America. Ecol. Monogr. 53, 183-208.

Main, B.Y. (1976). Spiders. Sydney : Collins.

Mawson, P.R. (1983). A comparative study of arachnid community structure in rehabilitated bauxite mines. Unpublished Honours thesis, University of Western Australia.

Moulder, B.C. and Reichle, D.E. (1971). Significance of spider predation in the energy dynamics of forest arthropod communities. Ecol. Manager. 42, 473-98.

Nentwig, W. (1982). Epigeic spiders, their potential prey and competitors: Relationship between size and frequency. Oecologia, 55, 130-36.

Nentwig, W. (1983). The prey of web-building spiders compared with feeding experiments. (Araneae: Araneidae, Linyphiidae, Pholcidae, Agelenidae). Oecologia, 56, 132-39.

Neumann, U. (1973). Succession of soil fauna in afforested spoil banks of the brown coal mining district of Cologne. In Ecology and Reclamation of Devastated Land, Vol. 1, ed R.J. Hutnik and G.Davis, pp 335-48 New York : Gordon and Breach, .

Nichols, O.G. and Bunn, S. (1980). Termite utilisation of rehabilitated bauxite mined areas. Alcoa of Australia Limited. Environ. Res. Bull. No. 9

Nichols, O.G. and Burrows, R. (1981). Recolonisation of revegetated bauxite minesites by predatory invertebrates. For. Ecol. and Manage. 10, 49-64.

Peet, R.K. (1975). Relative diversity indicies. Ecology, 56, 496-8.

Pianka, E.R. (1974). Niche overload and diffuse competition. Proc. Natl. Acad. Sci. U.S. 71, 2141-5.

Pielou, E.C. (1966). The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13, 131-44.

Richter, C.J.J. (1970). Aerial dispersal in relation to habitat in eight wolf spider species. (Pardosa, Araneae, Lycosidae). Oecologia, 16, 200-14.

Riechert, S.E. (1974). The pattern of local web distribution in a desert spider: mechanisms and seasonal variation. J. Animal. Ecol. 43, 733-46.

Riechert, S.E. and Reeder, W.G. (1972). Effects of fire on spider distribution in southwestern Wisconsin prairies. Proc. Second Midwest Prairie Conf. pp 73-90.

Root, R.B. (1967). The niche exploitation pattern of the Blue-grey gnatcatcher. Ecol. Monogr. 37, 317-50.

Siegal, S. (1956). Nonparametric Statistics: For the behavioural sciences. New York:McGraw-Hill.

Southwood, T.R.E. (1966). Ecological Methods. London : Methuen and Co. Ltd.

Tacey, W.A. and Glossop, B.L. (1980). Assessment of topsoil handling techniques for rehabilitation of site mined for bauxite within the jarrah forest of Western Australia. J. Appl. Ecol. 17, 195-201.

Turnball, A.L. (1966). A population of spiders and their potential prey in an overgrazed pasture in Eastern Ontario. Canad. J. Zool. 44, 557-83.

Uetz, G.W. (1976). Gradient analysis of spider communities in a streamside forest. Oecologia, 22, 373-85.

Uetz, G.W. (1979). The influence of variation in litter habitats on spider communities. Oecologia, 40, 29-42.

Uetz, G.W. and Unzicker, J.D. (1976). Pitfall trapping in ecological studies of wandering spiders. J. Arachnol. 3, 101-11.

Warburg, M.R. and Ben-Horin, A. (1978). Temperature and humidity effects on scorpion distribution in Northern Israel. Symp. zool. Soc. Lond. 42, 161-69.

Whittaker, R.H. (1965). Dominance and diversity in land plant communities. Science, 147, 250-60.

Williams, G. (1962). Seasonal and diurnal activity of harvestmen (Phalangida) and spiders (Araneida) in contrasted habitats. J. Animal. Ecol. 31, 23-42.

Wise, D.H. (1983). Competitive mechanisms in a food-limited species: Relative importance of interference and exploitative interactions among labyrinth spiders (Araneae:Araneidae). Oecologia, 58, 1-9.

APPENDIX 1 : Species of plants recorded in the study sites.

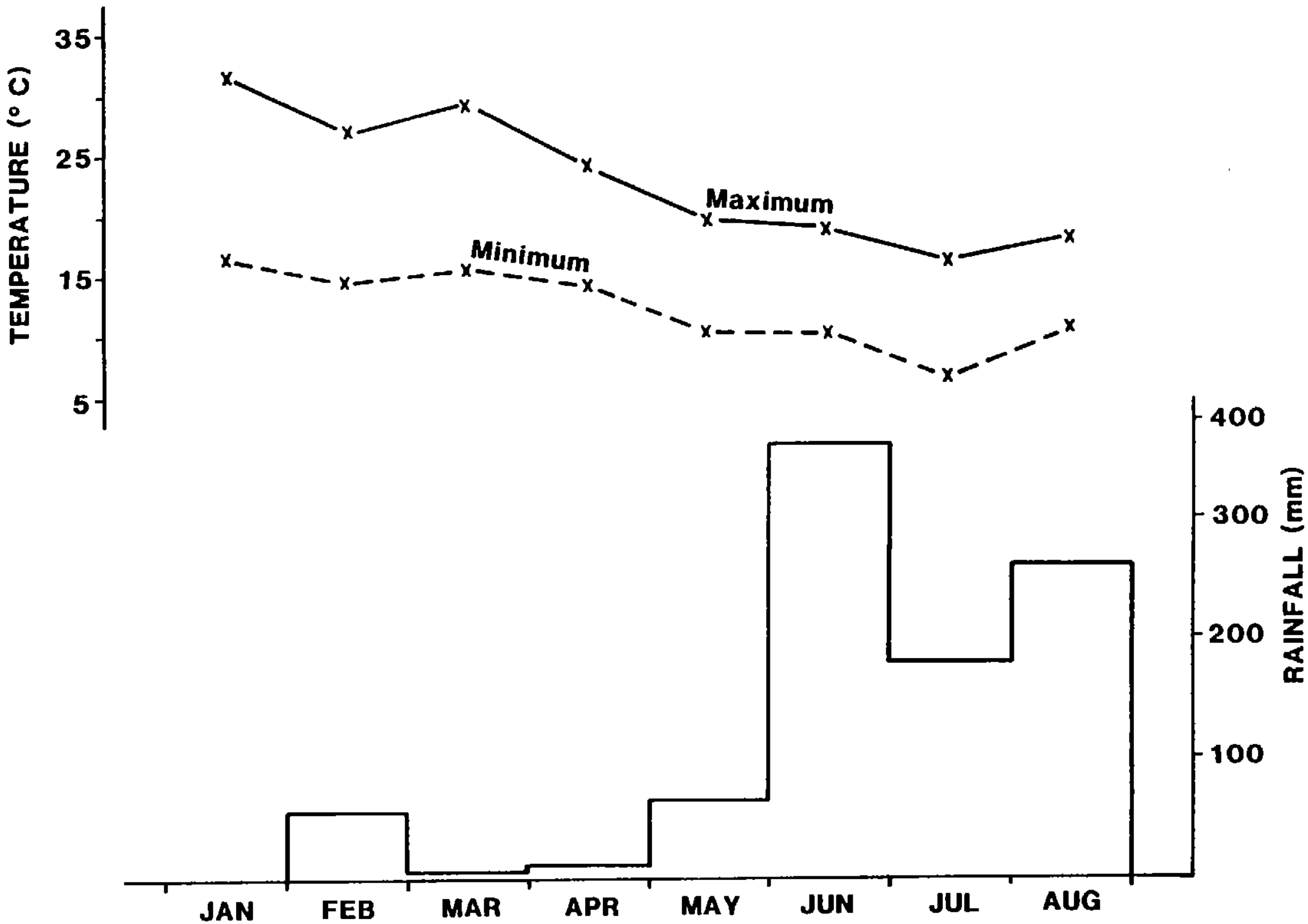
Species	Site No. 1	2	3	4	5
APIACEAE					
Pentapeltis peltigera				*	
Platysace compressa	*				
Xanthosia candida					*
CASUARINACEAE					
Casuarina fraserana					*
DROSERACEAE					
Drosera spp.				*	*
DILLENIACEAE					
Hibbertia montana				*	*
EPACRIDACEAE					
Leucopogon capitellatus				*	*
Styphelia spp.					*
EUPHORBIACEAE					
Phyllanthus calycinus				*	
GOODENIACEAE					
Leschenaultia biloba					*
HAEMODORACEAE					
Conostylis setosa				*	*
IRADACEAE					
Patersonia occidentalis					*
LEGUMINOSAE					
Acacia angustifolia		*	*		
A. drummondii	*	*	*		
A. extensa		*	*		
A. lateriticola	*	*	*		
A. pulchella	*	*	*		
A. salasifolia		*			
A. saligna		*	*		

APPENDIX 1 cont'd

Species	Site No. 1	2	3	4	5
Albizia lophantha			*		
Bossiaea aquifolium			*		
B. ornata					*
Daviesia pectinata	*		*	*	*
Hardenbergia comptoniana	*				
Hovea chorezemifolia				*	*
Kennedia coccinea	*	*		*	
K. prostrata	*	*	*		
Mirbelia dilatata		*	*		
LILIACEAE					
Lomandra sp.				*	
Thysanotus sp.					*
Xanthorrhoea gracilis					*
X. preissii				*	*
MYRTACEAE					
Calothamnus quadrifidus	*				
Eucalyptus calophylla	*	*	*	*	*
E. maculata	*				
E. marginata				*	*
E. resinifera	*	*			
E. wandoo		*	*		
Eucalyptus spp.	*	*			
PITTOSPORACEAE					
Sollya heterophylla				*	
PROTEACEAE					
Adenanthos barbigerus		*		*	*
Banksia grandis				*	*
Dryandra nivea				*	*
Persoonia longifolia				*	*
Synaphea petiolaris				*	
RANUNCULACEAE					
Clematis aristata					*
RESTIONACEAE					
Loxocarya sp.				*	

APPENDIX 1 cont'd

Species	Site No. 1	2	3	4	5
RHAMNACEAE					
Trymalium ledifolium		*	*	*	*
RUBIACEAE					
Opercularia sp.	*			*	
RUTACEAE					
Boronia fastigiata				*	*
SOLANACEAE					
Solanum nigrum			*		
STERCULIACEAE					
Lasiopetalum floribundum		*		*	*
STYLIDIACEAE					
Stylidium pilosum				*	
THYMELAEACEAE					
Pimelia suaveolens					*
TREMANDRACEAE					
Tetratheca viminea				*	*
ZAMIACEAE					
Macrozamia riedlei				*	*



APPENDIX 2 : Monthly rainfall and average maximum and minimum temperatures recorded for 1983 at the Karnet weather station.

APPENDIX 3: Species of arachnids recorded in the study sites.

Species	Guild	Site No. 1	2	3	4	5
MYGALOMORPHAE						
ACTINOPODIDAE						
Missulena hoggi	B				*	*
BARACHELIDAE						
Synothele michaelsoni	B				*	
CTENIZIDAE						
Aganippe raphiduca	B				*	
Idiosoma sp.	B			*	*	*
DIPLURIDAE						
Chenistonia tepperi	B	*		*	*	*
Genus 1 sp. 1	B	*				*
ARANEOMORPHAE						
AGELENIDAE						
Corassoides sp.	W					*
Genus 1 sp. 1	W					*
ARANEIDAE						
Araneus pustulosus	W			*		*
Arcys sp.	W					*
Eriophora biapicata	W	*	*	*	*	*
Gasteracantha minax	W		*	*	*	
Phonognatha sp.	W					*
Poltys salebrosus	W			*		
Genus 1 sp. 1	W			*		*
Genus 2 sp. 1	W					*
Genus 3 sp. 1	W			*		
CLUBIONIDAE						
Chiracanthium sp.	G	*	*	*	*	*
Clubiona sp.	G			*		
Molycria sp.	G			*		
Supunna michaelsoni	G		*	*	*	*
Genus 1 sp. 1	G			*		*
Genus 2 sp. 1	G				*	

APPENDIX 3 cont'd

Species	Guild	Site No. 1	2	3	4	5
CTENIDAE						
Argoctenus sp.	G	*		*		*
Elassoctenis harpax	G	*	*	*	*	*
Genus 1 sp. 1	G		*	*	*	
Genus 2 sp. 1	G	*	*	*	*	*
Genus 3 sp. 1	G					*
DICTYNIDAE						
Baiami volucripes	W					*
DINOPIDAE						
Dinopis sp.	W		*			
GNAPHOSIDAE						
Hemicloea sp.	G					*
Lampona sp.	G	*	*	*	*	*
Genus 1 sp. 1	G			*		
Genus 2 sp. 1	G			*		
Genus 3 sp. 1	G		*		*	*
HERSILIIDAE						
Tama brachyura	A			*		*
LINYPHIIDAE						
Laetesia mollita	W			*		*
Genus 1 sp. 1	W			*		*
LYCOSIDAE						
Artoria sp.	G				*	
Geolycosa serrata?	G				*	
Lycosa sp.	G	*	*	*	*	*
MITURGIDAE						
Miturga sp.	G					*
OXYOPIDAE						
Oxyopes sp.	G		*	*		*

APPENDIX 3 cont'd

Species	Guild	Site No. 1	2	3	4	5
SALTICIDAE						
Genus 1 sp. 1	A			*		*
Genus 2 sp. 1	A				*	*
Genus 3 sp. 1	A	*				
Genus 4 sp. 1	A				*	*
Genus 5 sp. 1	A	*				
Genus 6 sp. 1	A	*	*		*	
Genus 7 sp. 1	A				*	
Genus 8 sp. 1	A		*			*
Genus 9 sp. 1	A					*
Genus 10 sp. 1	A					*
Genus 11 ap. 1	A					*
SEGESTRIIDAE						
Ariadna sp.	G				*	
SPARASSIDAE						
Olios sp.	G				*	
SYMPHYTOGNATHOIDEA						
Genus 1 sp. 1	W			*		
THERIDIIDAE						
Achaearanea sp.	W					*
Argyrodes sp.	W			*		*
Coleosoma sp.	W			*		
Latrodectus mactans hasselti	W	*	*	*	*	*
Icodamus sp.	W					*
Phoroncidea sp.	W				*	
Genus 1 sp. 1	W			*		*
Genus 2 sp. 1	W				*	
Genus 3 sp. 1	W		*	*		
Genus 4 sp. 1	W			*		
Genus 5 sp. 1	W					*
THOMISIDAE						
Hedana sp.?	A			*		
Sidymella sp.	A			*		
Stephanopis sp. 1	A				*	
Stephanopis sp. 2	A					*
Genus 1 sp. 1	A		*			

APPENDIX 3 cont'd

Species	Guild	Site No. 1	2	3	4	5
ZODARIIDAE						
Storena tricolor	G	*	*	*	*	*
S. variegata?	G		*			
Storena sp. 3	G		*	*		*
Storena sp. 4	G					*
Storena sp. 5	G					*
Storena sp. 6	G					*
OPILIONIDA						
TRIAENONYCHIDAE						
Nunciella aspersa	G			*	*	*
PALPATORES						
Spinicrus minimus?	G			*		*
SCORPIONIDA						
BOTHRIURIDAE						
Cercophonius squama	G					*
BUTHIDAE						
Ulychas Marmoreus	G					*
SCORPIONIDAE						
Urodacus novaehollandiae	G				*	*
U. planimanus	G					*

KEY TO GUILDS

B = Permanent burrow dweller
G = Vagrant ground dweller
W = Web builder
A = Ambusher, or stalker and pouncer

APPENDIX 4: Distribution of arachnid abundances within guilds during the study period (1983).

Site No.	Guild	Time of Sampling Feb.	May	Aug.
1	B	0	0	3
	G	7	18	0
	W	0	2	0
	A	0	4	0
2	B	0	0	0
	G	36	72	6
	W	14	16	10
	A	1	1	0
3	B	0	4	3
	G	106	146	47
	W	16	23	11
	A	7	1	3
4	B	3	16	6
	G	16	49	10
	W	2	7	1
	A	1	5	1
5	B	6	9	4
	G	133	104	35
	W	6	8	11
	A	6	8	3

KEY TO GUILDS

B = Permanent burrow dwellers.
G = Vagrant ground dwellers.
W = Web builders.
A = Ambushers or stalkers and pouncers.