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The Role of Invertebrates in Bauxite Mine Rehabilitation

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The Role of Invertebrates in Bauxite Mine Rehabilitation

by

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FRONT COVER

Del Park mine pit DP9 where unplanted and planted plots are situated.

Photograph: Les Harman

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Summary

The desirability of monitoring invertebrates during attempts at land reclamation following bauxite mining in the Darling Range is discussed. This is considered in relation to the sheer abundance of invertebrates, the paucity of ecological and taxonomic information on the group, their role in stabilising habitats, soil drainage, soil aeration, nutrient cycling, seed taking, limiting pest outbreaks and the fact that invertebrates comprise the diet of many vertebrates. The value of invertebrates as indicators of rehabilitation is also explored.

A continuous monitoring pitfall trap programme was performed over a two-year period in a forest control plot, and in mine pits which had been rehabilitated by planting marri (*Eucalyptus calophylla*), by direct seeding with native plants and in one which had not been subject to any form of revegetation. Ants were scored at the species level while other invertebrates were recorded at the level of Class, Order, Super-family, Family or Sub-family.

The study showed that a great variety of invertebrates occurred in the mine pits and that revegetation was not a pre-requisite for many taxa to be present. Of the mine plots, the unplanted plot supported the least variety, and lowest numbers of invertebrates. The variety of invertebrates was similar in the planted and seeded plots although invertebrate numbers were considerably higher in the latter.

There was an increase in total ants, ant biomass and ant species richness from the unplanted plot, through the planted plot to the seeded plot. Ant species richness did not attain the forest control plot values in any mine plots.

The inter-plot differences are discussed in relation to the different revegetation techniques and the implications of these findings are considered.

Introduction

Bauxite mining leases cover the following three sites in the south of Western Australia: Alcoa in the central and western Darling Plateau, Alwest in the eastern Darling Plateau and the Pacmine lease in the northern Darling Plateau (Hewett, 1975). Currently only Alcoa are mining bauxite from sites at Jarrahdale and near Dwellingup where the Del Park and Huntly mine sites are situated. There are currently plans by Alcoa and Alwest to commence mining operations in areas south of the existing mine sites.

It is desirable, for reasons such as water catchment protection, wildlife conservation and aesthetics, to revegetate the mined areas.

There is now a realisation that biological aspects should be considered when planning and carrying out mining operations. The influence of mining on flora and the importance of flora in mine site rehabilitation generally receive the most attention in biological components of mining studies. This is exhibited by the fact that a number of Western Australian mining companies employ botanists from time to time. Considerable research effort has been invested in the revegetation of bauxite mines (Tacey, 1974; Shea and Herbert, 1977).

Studies on fauna in relation to mining are less common. In cases where such studies have taken place, they have generally concentrated on the vertebrates. For instance Recher (1975) has looked at the succession of birds while Fox and Fox (1978) have investigated mammal incidence in sand mining areas at Myall Lakes, N.S.W. Although there are exceptions, such as the Alligator Rivers Region environmental fact-finding study (*Entomology*) (Anon., 1973), invertebrate studies have generally not been performed.

This paper is divided into two sections. In the first part the need for considering invertebrates in relation to mining operations is discussed, with particular reference to rehabilitation. In the second, data are presented on invertebrate succession in bauxite mine pits that have been subjected to two different types of rehabilitation to illustrate the foregoing discussion and to assess the ecological desirability of the different rehabilitation approaches.

SECTION 1

Importance of Studying Invertebrates

GENERAL

Invertebrates, the insects in particular, are among the most abundant and successful of terrestrial animals. It is known that insects often contribute a considerably greater diversity and biomass than vertebrates to forest faunae (Australian Entomological Society, 1976).

The amount of taxonomic and ecological information available on terrestrial invertebrates is not commensurate with their important role in ecosystems. Of the estimated 108 000 species of insects in Australia, only about 45 per cent have been described (Australian Entomological Society, 1976). Similarly, detailed information on the ecology and role of the majority of terrestrial invertebrates is virtually absent.

There is now a realisation that a consideration of invertebrates is of crucial importance in environmental decision-making studies. One recommendation of the recent Senate Standing Committee on Science and the Environment (Woodchips) stated that ". . . taxonomic studies on Australian flora and fauna, the invertebrates in particular, appear to be absolutely basic to research progress in many biological fields of importance to forestry" (Parliament of Australia, 1977).

One area where invertebrates are important is in bauxite mine rehabilitation.

Methods of revegetation vary and regrowth differs from that of the original unburnt forest by one or more of the following factors:

(1) A marked alteration of soil physical, nutrient and moisture regimes;
(2) An initial absence of the litter layer;
(3) A low plant structural and species diversity, at least in the initial stages;
(4) An uncertain stability as an ecosystem;
(5) The presence of non-indigenous plants;
(6) A period of high initial productivity with abundant new plant growth;
(7) A dissimilarity of plant age composition from that of the original forest.

The soil and epigaeic (surface active) invertebrates are partly responsible for litter breakdown and nutrient cycling (Neumann, 1973; Springett, 1978), and for drainage, aeration and turnover of forest soils (Lee and Wood, 1971). A knowledge of invertebrates succession in mined areas is clearly desirable to understand the effect of resulting regrowth-associated fauna on soil welfare. Table 1 reviews the studies performed on invertebrates in reclaimed lands. The trend in choice of taxa studied illustrates the importance most workers attribute to soil-invertebrate interactions.

A second concern of rehabilitation is that the initial low diversity of vegetation may lead to a decreased stability of the ecosystem and a vulnerability to pest outbreaks. This has certainly occurred in tropical tree crops, although May (1976), using theoretical models for his analysis, suggests that increasing complexity makes for dynamic fragility rather than robustness. May also suggests that the instability of many agricultural monocultures stems from a lack of history of co-evolution among the agro-ecosystem components rather than from the simplicity of the ecosystem.

There are no reports of serious pest outbreaks in the replanted or seeded bauxite mines at Jarrahdale, Del Park or Huntly. However, the author has noted an incidence of leaf galls, leaf miners and other damage on *Eucalyptus* spp. leaves and S. J. Curry* (personal communication) has recorded psyllids causing defoliation of *Albizia* sp. and the common longicorn *Phoracantha* sp. attacking drought-affected *Eucalyptus microcorys* in rehabilitated mine pits.

Rehabilitation attempts should be monitored for pest occurrences if successful long-term regeneration is to be assured.

A pest problem of a specialised nature relates to the direct seeding of bauxite mine pits with native or introduced plant species. Since seed taking by ants is widespread in Australia (Berg, 1975), concern has arisen that ants and other insects might reduce the success of these operations. Majer (1978*a*) has assessed the magnitude of seed theft by ants in reseeded bauxite mine pits and found that theft is significant only along the forest margins. It is necessary to maintain observations in seeded mine pits since seed theft might occur in mines in other parts of Western Australia. In addition, the regrowth will ultimately be subject to prescribed burns or wildfires. It is important to know whether seeds are deposited in ant nests beneath the soil surface and hence protected from the extreme heat of the fire—in effect, planted.

---

* Western Australian Department of Agriculture

Table 1

REVIEW OF INVERTEBRATE STUDIES PERFORMED ON RECLAIMED LANDS

Reclaimed substrate	*Locality*	*Taxonomic groups studied*	*Comments*	*Reference*
Heat sterilised soil	Rothamsted, England	Relevant soil inverts.	Field trial	Baweja (1939) Buahin & Edwards (1963)
Irradiated soil	Glamorgan, Wales	Acarina, Collembola	Field experiment	Coleman & MacFadyen (1966)
Ironstone open-cast quarry	Northants, England	Acarina, Collembola	Plots mostly reclaimed for pasture	Davis & Murphy (1961) Davis (1963)
Spoil heap of disused lead mine	Co. Durham, England	Relevant soil inverts.	Observations primarily to observe influence of lead	Williamson & Evans (1973)
Reclaimed polder	E. Flevoland, Holland	Annelida-Oligochaeta	Earthworms deliberately introduced into grassed areas	Van Rhee (1969)
Reclaimed polder	Lauwerszee, Holland	Coleoptera-Carabidae	Study primarily concerned with theory of migration	Meijer (1974)
Brown-coal spoil heaps	Bohlen & Berzdorf, Germany	Relevant soil and epigaeic inverts.	Compares fauna on reforested heaps and ones used for agriculture	Dunger (1964, 1967, 1968*a*) Brünning, Unger & Dunger (1965)
Brown-coal spoil heaps	Berzdorf, Germany	Collembola	Reforested land	Dunger (1968*b*)
Brown-coal spoil heaps	Bohlen & Berzdorf, Germany	Annelida-Oligochaeta	Reforested land	Dunger (1969)
Brown-coal spoil heaps	Helmstedt, Germany	Collembola	Reforested land	Bode (1975)
Brown-coal spoil heaps	Cologne District, Germany	Diplopoda, Isopoda, Coleoptera-Carabidae	Reforested land	Neumann (1971, 1973)
Brown-coal spoil heaps	Ville, Germany	Relevant soil inverts.	Reclaimed for agriculture	Hermosilla (1976)
Coal spoil heaps	Grangetown, England	Coleoptera	Natural regeneration	Walsh (1910)
Industrial waste pit heap	Co. Durham, England	Relevant soil and epigaeic inverts.	Sown with grass	Hutson (1972)
Coal surface mines	Tennessee Valley, U.S.A.	Relevant inverts.	Reforested land	Holland (1973)
Strip-mined spoil banks	Ohio, U.S.A.	Annelida-Oligochaeta	—	Vimmerstedt & Finney (1973)
Mineral sand mined area	Myall Lakes, N.S.W., Australia	Hymenoptera-Formicidae	Coastal heath revegetation	Fox (1978)
Bauxite mines	Jarrahdale, Western Australia	Relevant epigaeic inverts, particularly Formicidae	Forest plantings	Scott (1974)
Bauxite mines	Jarrahdale and Pinjarra, Western Australia	Hymenoptera-Formicidae	Planted and seeded reforested areas	Majer (1978*a*)

A further reason for studying invertebrates in relation to rehabilitation is that many reptiles, birds and mammals are partly or totally insectivorous, and their occurrence is dependent on the availability of suitable food. Recolonisation of rehabilitated mine pits by invertebrates is therefore important to encourage the return of certain native vertebrates.

One possible aim of mine pit rehabilitation is to produce an ecosystem which resembles the original one. To assess the success of such attempts the mine pit vegetation structure and species diversity may be compared with those of the original vegetation. Since many plants are ephemeral or seral, vegetation alone may not be an effective indicator of rehabilitation progress.

When monitoring the success of revegetation it may be possible to use invertebrates as indicators to augment the study of vegetation and soil characteristics. This is suggested because many invertebrates occupy specialised niches, and therefore provide information about the area according to their presence or absence. Furthermore, certain herbivores are influenced by the physiology and morphology of their host plant (Webb and Moran, 1978).

The possibility of using invertebrates as indicators of various factors has been explored by a number of workers. For instance Murphy (1953) used invertebrates as indicators of soil conditions, Franz (1949) related invertebrates to primary production, and Mahoney (1976) attempted to use the Collembola fauna as indicators of land recreation use. Majer (1977 and 1978*b*) has also explored the possibility of using ants as indicators of vegetation type and land use in Western Australia.

INVERTEBRATE BASE-LINE DATA IN THE JARRAH FOREST

It is necessary to have good base-line data on invertebrates if they are to be studied in relation to bauxite mining. The dominant vegetation in areas covered by the bauxite mining leases is jarrah (*Eucalyptus marginata*). Although generally referred to as jarrah forest, it comprises a variety of vegetation types (Havel, 1975*a* and *b*).

There have been a number of ecological studies on individual forest invertebrate species, or taxonomic groups, although few have been of synecological nature. McNamara (1955) compared the soil fauna of burnt and unburnt compartments of jarrah forest. Springett (1976*a*) compared litter and soil invertebrates in burnt and unburnt jarrah and karri (*Eucalyptus diversicolor*) forest and related the results to litter decomposition. The same author also compared soil microarthropods in jarrah forest and pine (*Pinus pinaster*) plantations and related these to differences in rates of decomposition (Springett, 1971 and 1976*b*). Springett (1977) also prepared a pictorial guide to the fauna of the forest floor.

Scott (1974) made a preliminary study of epigaeic invertebrate succession in planted bauxite mine pits at Jarrahdale. The samples from pit traps, which were used for this study, suggested that ants were the most prominent epigaeic group in the rehabilitated areas. Majer (1978*b*) used a similar sampling method to compare the ant fauna in a mine pit, which had been planted a year earlier, with the fauna in land subjected to other types of land use.

SECTION II

Epigaeic Invertebrate Monitoring in Rehabilitated Mine Pits

BAUXITE MINING AND REHABILITATION PROCEDURE*

Following the definition of ore bodies, forest is cleared from the required area. The top 10 to 30 cm of overburden soil is removed and is generally stockpiled. The cap rock is then blasted and the ore is removed down to the pallid zone of the laterite profile. The topsoil is then returned and the compacted pallid zone is ripped to a depth of approximately 2 m to enhance root penetration.

Methods of rehabilitation of bauxite mine pits are currently evolving so it is not possible to describe a single programme. The earlier attempts utilised nursery-reared, dieback disease (*Phythophthora cinnamomi*) resistant *Eucalyptus* spp. such as *E. microcorys, E. resinifera, E. saligna* and *E. maculata* from eastern Australia. However, there is currently an interest in promoting indigenous plants because the introduced species are not necessarily ideally suited to Western Australian conditions, and because certain indigenous legume species have an antagonistic effect on *P. cinnamomi* (Anon., 1978). Attempts are being made to direct-seed the mine pits. The methodology varies although it often follows the sequence of pit reshaping, topsoil return, ripping of subsoil, spreading of seed and fertiliser in the pit and then placing a layer of mulch over the surface to stabilise the soil. Additional trees may be planted then, or at a later date.

The results of these two rehabilitation approaches are quite different. The planted mine pits have the appearance of a plantation whereas direct seeding produces a regrowth of rich structural and species diversity looking much like coastal heath in the early stages.

INVERTEBRATE MONITORING PROGRAMME

Sample Sites

A single example of each rehabilitation approach was selected for study. Replication of plots was decided against so that greater attention could be paid to successional and seasonal trends within the study areas. Most work was performed in the Del Park mine site in the region shown in Plate 1.

An area which was planted with marri (*Eucalyptus calophylla*) in June 1976 was selected as an example of the planting approach. This is referred to as the "planted plot". A 100 × 100 m plot situated 55 m north-east of the planted plot was also marked out. With the exception of topsoil replacement and ripping, no rehabilitation was performed in this experimental area. The centre of this area, referred to as the "unplanted plot", was used for invertebrate monitoring. It was not possible to select a seeded area at the Del Park operation so one was chosen in the Jarrahdale mine site. This is referred to as the "seeded plot". The species used here are listed in Table 2.

Simultaneous samples were obtained from a forest control plot situated approximately 1 km east of the Del Park mine pit plots.

The original vegetation of the three mine pit sampling areas corresponded to Havel's (1975*a*) group S. The tree strata were predominantly *E. marginata* with some *E. calophylla* and the understorey comprised *Banksia grandis, Persoonia longifolia* and *Casuarina fraserana.*

A description of the four invertebrate monitoring plots is given in Table 3. A general view of each plot is shown in Plates 2 to 5. It should be noted that it was not possible to standardise the mine pit study plots for conditions of topsoil replacement, use of stockpiled topsoil, and distance from forest border.

Monthly climatic data were obtained from the Forests Department, Dwellingup. Jarrahdale recordings have not been considered since they follow similar seasonal trends.

Sampling Methods

A single grid of 6 × 6 pitfall traps spaced at 3-m intervals was established in a representative region of each plot. Traps consisted of 18 mm internal diameter pyrex test tubes set in the ground in plastic tubes to facilitate changing. Traps contained 3 ml of alcohol-glycerol preservative. Greenslade and Greenslade (1971) investigated the performance of this preservative in pitfall traps and concluded that although ants were not attracted to the alcohol, certain other taxonomic groups were.

---

* The method of rehabilitation has altered since this paper was written.

Plate 1

Del Park mine pit DP9 where unplanted and planted plots are situated. (*Photography by Les Harman.*)

Plate 2

General view of forest control plot.

Table 2
REHABILITATION PROCEDURE USED IN THE JARRAHDALE SEEDED PLOT

Species used	*Seeding rate* $kg.ha^{-1}$	*Seeds per* m^2
(i) Broadcast native shrubs		
Acacia extensa	2·5	20
A. saligna	0·75	5
A. strigosa	0·5	10
A. decurrens	2·0	10
Albizia lophantha	1·0	2
Bossiaea aquifolium	0·5	3
(ii) Broadcast trees (northern end)		
Eucalyptus patens	1·3	—
E. megacarpa	1·3	—
E. marginata	0·3	—
E. calophylla	2·7	—
E. accedens	0·7	—
E. wandoo	0·7	—
E. laeliae	0·1	—
E. robusta	1·3	—
(iii) Planted tree seedlings—understorey		
E. cornuta	—	—
E. megacornuta	—	—
E. erythronema	—	—
E. nutans	—	—
E. transcontinentalis	—	—
E. sargentii	—	—
E. brachycorys	—	—
(iv) Planted tree seedlings—overstorey		
E. resinifera (two-thirds)	—	—
E. calophylla (one-third)	—	—

A mixture of native tree and shrub seed was hand broadcast at 7·75 $kg.ha^{-1}$ on 10 July 1976. A broadcast dressing of 250 $kg.ha^{-1}$ of No. 1 mix superphosphate was applied in late winter. Further spot dressings will later be applied to encourage maximum development. Tree seedlings were planted randomly at approximately 550 trees per hectare of overstorey and 60 trees per hectare of understorey species. These trees were spot fertilised with a dressing of 100 g Agras 12:52 at three and nine weeks after planting.

After leaving the traps in the ground for one week to minimise digging-in effects, the traps were uncorked for seven days commencing on the dates shown in Table 3. The seven-day samples were repeated at monthly intervals until June 1977, after which sampling intensity was gradually reduced to four times per year. Traps were returned to the laboratory for hand sorting of the contents. Invertebrates were recorded at the level of Class, Order, Super-family, Family or Sub-family depending on taxonomic expertise and which level was adequate to describe a particular feeding habit. Ants were recorded at the level of species.

The vegetation structure and density were recorded using a 2 m rod divided into 25 cm intervals. The immediate sample area plus a 2 m surround was gridded out and fifty systematic rod placings were made. The number of contacts of vegetation touching the rod at each 25 cm interval was counted and the species identified. The tree canopy situated vertically above the rod was also recorded (Levy and Madden, 1933). Two parameters were calculated from the resulting data. Percentage area cover of vegetation was obtained by calculating the percentage of the fifty recordings which touched any plant, regardless of species. Plant cover density (a measure of the thickness of vegetation where it occurred) was obtained by dividing the total number of plant contacts by the number of rods which touched any vegetation. This calculation was performed for the total length of the rod to give an overall cover density value and also for each 25 cm interval to construct a vertical profile of cover density. Surveys were performed in October 1975, January 1977 and September 1977. No forest recordings were made on the first date.

Data Analysis

It should be noted that pitfall traps provide a measure of the activity of an organism in addition to its abundance. Southwood (1966) reviews the limitations of pit trapping and points out that caution should

Table 3
DESCRIPTION OF FOUR PLOTS USED FOR INVERTEBRATE SUCCESSION STUDY

Plot description	*Location*	*Date area cleared*	*Date topsoil replaced*	*Topsoil stockpiled*	*Date planted or seeded*	*Distance from forest border (m)*	*First invertebrate sampling date*
Forest control	Del Park	N.A.[1]	N.A.[1]	N.A.[1]	N.A.[1]	N.A.[1]	March 1976
Unplanted	Del Park (DP9)	Early 1972	October 1975	Yes	N.A.[1]	225	March 1976
Planted with marri (*Eucalyptus calophylla*) only	Del Park (DP9)	Early 1972	October 1975	Yes	June 1976	170	June 1976
Seeded with mixed native species	Jarrahdale (JW 402/406)	Early 1974	April 1976	No	July 1976	35	June 1976

[1] N.A. = Not applicable.

Plate 3

General view of seeded plot showing remaining forest in background.

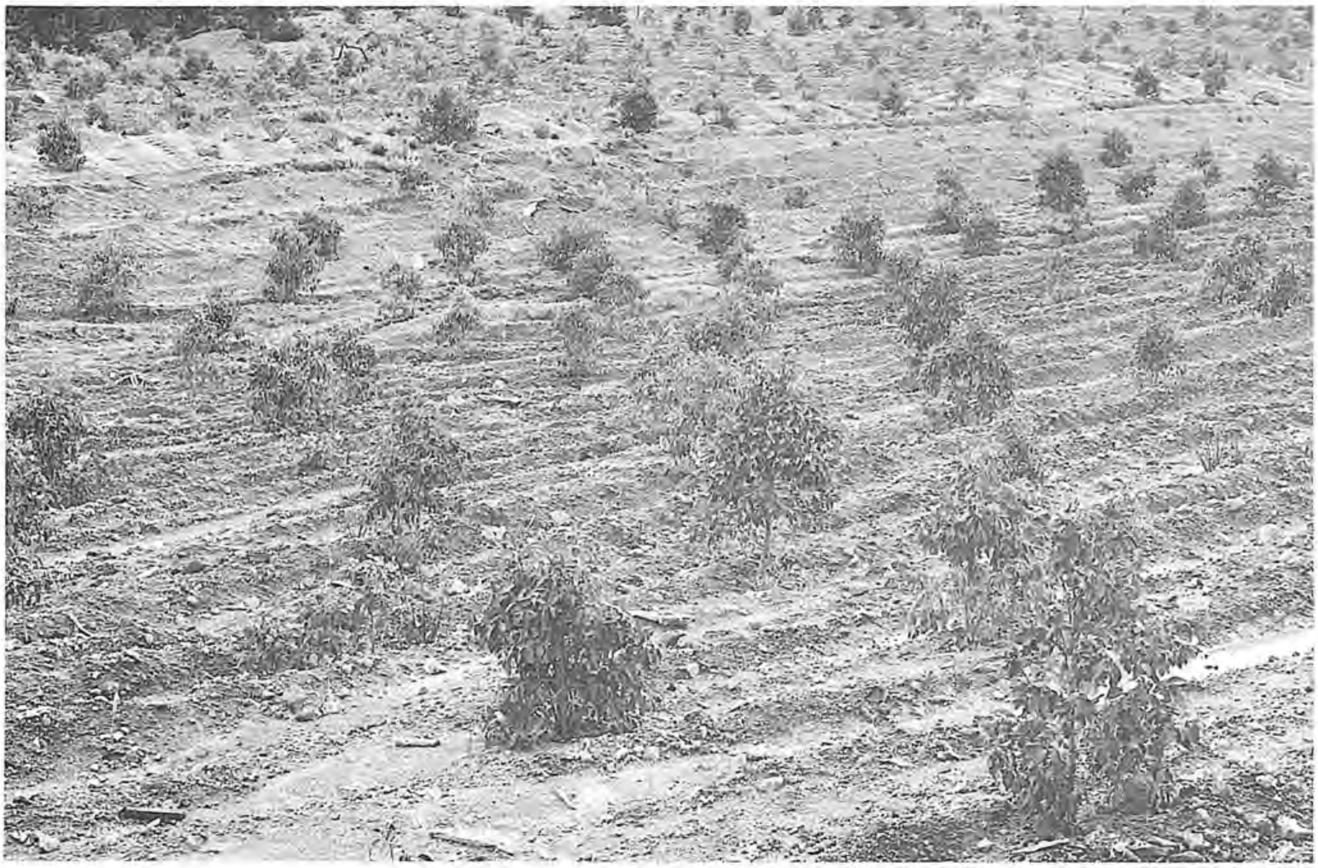


Plate 4

General view of planted plot.

Plate 5

General view of unplanted plot showing areas planted two years earlier in the background.

be exercised when using the method to compare the fauna in different habitats. These limitations largely result from different trapping efficiencies arising from variations in the nature of the litter and vegetation. For this reason the trap data from the forest control plot are not directly compared with those from the mine pits although inter-mine pit sample comparison is considered to be valid in view of the relative similarity of ground conditions during the sampling period. Non-parametric statistical tests using ranked data rather than actual sample values were employed.

A comparison was made of each taxonomic group within each of the three mine pit samples for the periods July 1976 to February 1977 and March 1977 to April 1978. Wilcoxon's matched-pairs signed-ranks test (Siegel, 1956) was used for the comparison since it compares samples from each particular month and hence allows for the seasonal trends of the data. For statistical reasons it was only possible to use the test when a taxonomic group occurred in at least six monthly samples.

The ant data will be discussed in more detail in a subsequent paper although some general characteristics of this group are also presented here. The total ants value was obtained by summing individuals of all species for the two eight-sample periods. An index of ant biomass was obtained by multiplying species totals by size weightings (1, $<2{\cdot}5$ mm; 2, 2·5 to 6·0 mm; 3, >6 mm) as described by Greenslade (1976). The diversity of a community comprises two characteristics: the total number of species (richness) and the relative abundance of individuals of each species (evenness). Ant species richness (S) is obtained by summing the number of species collected in a particular time and plot. The diversity of ants is further investigated using Shannon's (1948) H' index which attempts to give a combined measure of richness and evenness. This is calculated by the following formula:

$$H' \text{ (decits)} = \frac{N \log N - \sum_i n_i \log n_i}{N}$$

where N = total number of individuals, and n_i the importance value of the ith species. Room (1975) has found this to be of only limited value for describing the diversity of ant faunae. However, it is useful for deriving the evenness index (J'). This is obtained by the following formula:

$$J' = \frac{H' \text{ (decits)}}{\log S}$$

The greater the value of J', the more even is the relative abundance of individuals of each species.

Similarity of the ant fauna in terms of species composition was compared for the four sample sites for certain sample periods using Mountford's (1962) index of similarity (I). This is calculated by the following formula:

$$I = \frac{2j}{2\,ab - (a + b)\,j}$$

where a is the number of species in site A, b is the same for site B and j is the number of species in common with both sites. A comparison of mine pits with the forest plot by this method is considered to be acceptable as species presence/absence is used rather than quantitative data. A direct comparison of total ants and biomass index between forest and mine plots should be viewed with more caution.

RESULTS

Climatic and Plant Data

Figure 1 shows the monthly means for minimum and maximum temperature, relative humidity at 0900 hours and the monthly rainfall totals.

Figure 2 shows the plant cover density profiles of the four study plots on the three survey dates. The percentage plant area cover and plant cover density values are given in Table 4. No colonisation of vegetation in the unplanted plot was detected using the point quadrat method although a few small *Kennedia prostrata* have been noted in the plot. Both planted and seeded plots showed increases in plant percentage area cover and cover density following revegetation. The seeded plot values always exceeded those of the planted plot, and, by September 1977, both seeded plot variables exceeded those of the original forest. The cover density profiles (Figure 2) reveal that, with the exception of the last recording from the seeded plot, vegetation was confined to the 0 to 75 cm height range. A small amount of vegetation exceeded 2 m in the last seeded plot recording. The point quadrat recording method generally underestimates the number of species present in an area (Majer, unpublished data) although the number of species touched by the rod can serve as an index of plant species richness. The figures are zero, three, seven and fifteen for the unplanted, planted, seeded and forest plots respectively.

Figure 1
Monthly means for minimum and maximum temperature (*a*), relative humidity at 0900 hours (*b*), and monthly rainfall totals (*c*) at Dwellingup

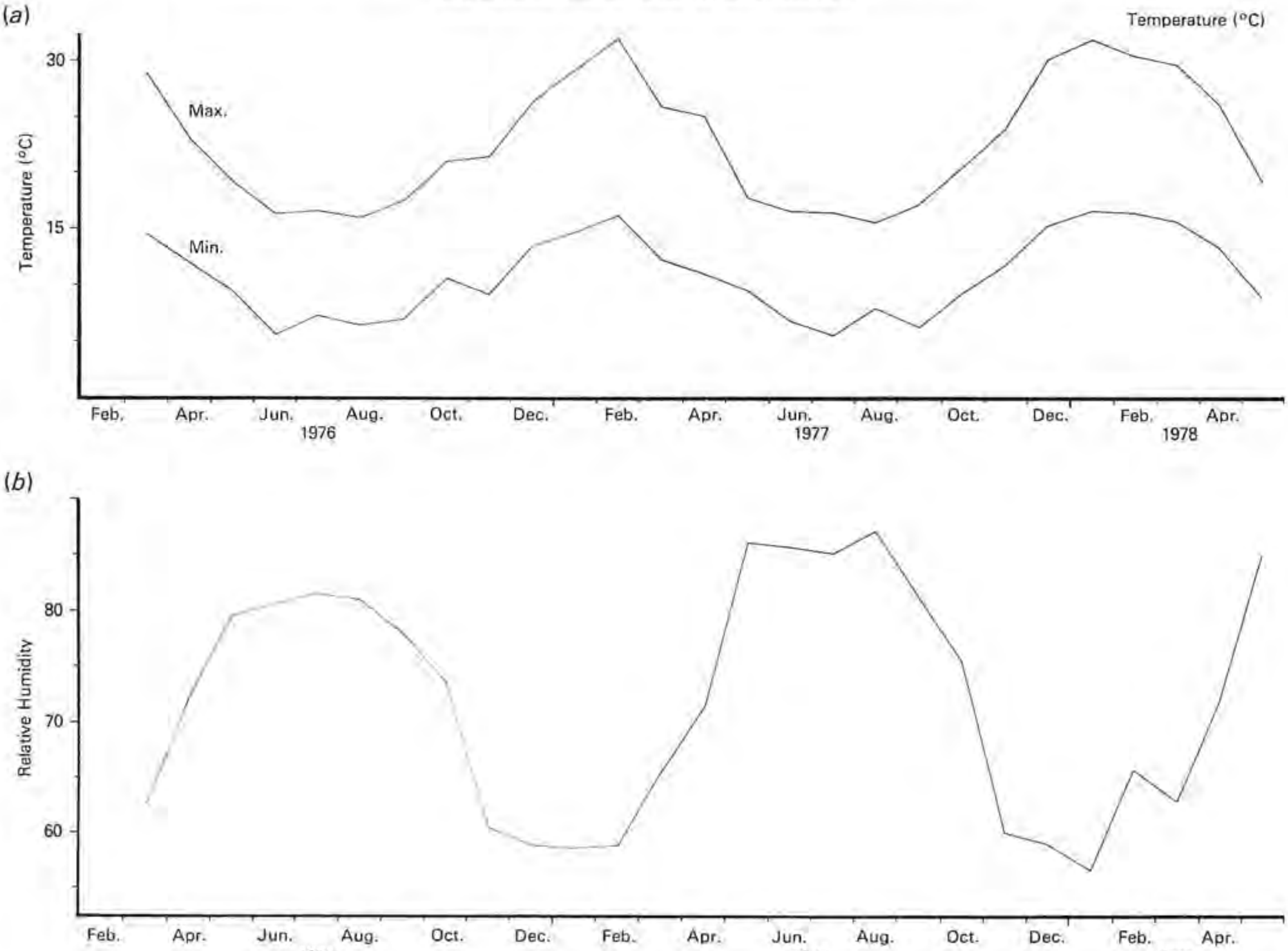


Figure 1—continued

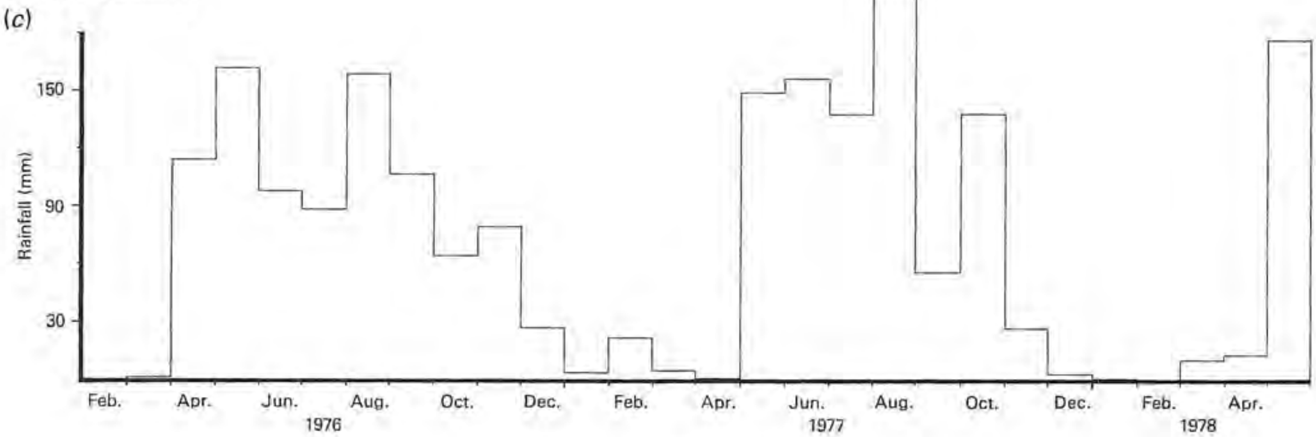


Table 4

PERCENTAGE AREA COVER AND PLANT COVER DENSITY OF THE FOUR STUDY PLOTS

Study plot	*October 1975*		*January 1977*		*September 1977*	
	Percentage area cover	*Plant cover density*	*Percentage area cover*	*Plant cover density*	*Percentage area cover*	*Plant cover density*
Forest control	N.D.[1]	N.D.[1]	82	2·5	70	2·6
Unplanted	0	0	0	0	0	0
Planted	0	0	6	1·3	14	4
Seeded	0	0	16	2·5	73	14

[1] N.D. = Data not available.

General Invertebrate Data

Figures 3 to 30 show the seven-day totals for each invertebrate taxon in the four plots. The forest results have been drawn on a separate graph for greater clarity although graphs are combined when a taxonomic group is not sampled in one or more plots.

Table 5 lists the taxa sampled during the study and also a description of the feeding habits of the members of each group sampled and their main period of occurrence in the pit traps (a measure of their activity and, to a lesser extent, seasonal abundance). The taxa which are thought to be attracted to the trap preservative, and therefore not necessarily active in the area, are also indicated.

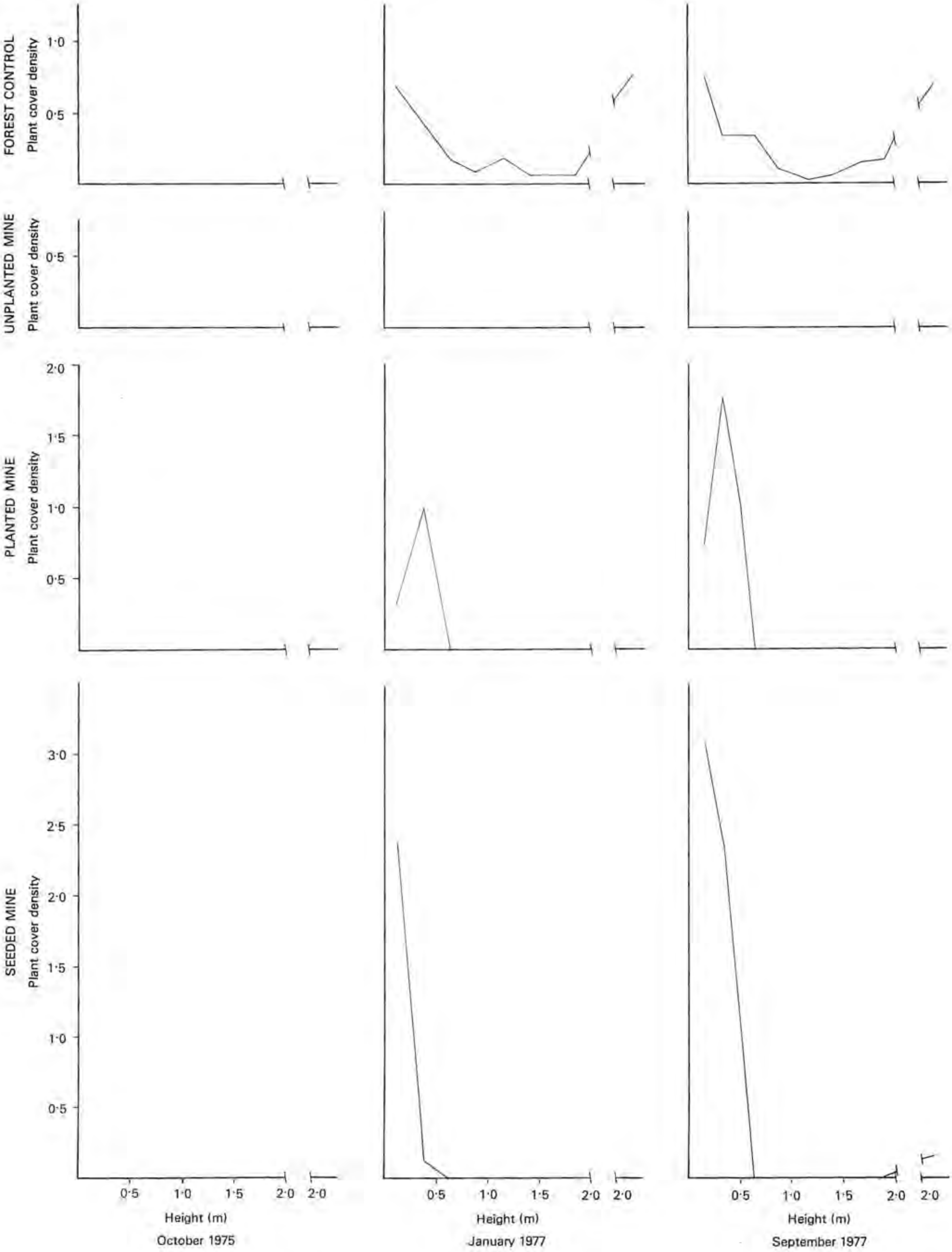
Table 6 compares the presence/absence and mine plot ranks of total abundance of each taxon for the periods July 1976 to February 1977 and March 1977 to April 1978. The forest plot numerical ranges of each taxon and its frequency out of sixteen sequential samples are given as a guide to its abundance in the forest. It should be noted that infrequently occurring taxa have a greater chance of being missed in the mine pit sampling programme than in the forest sampling.

The pairs of plots in which significantly different quantities of particular taxa are found are labelled. For statistical reasons it was not possible to compare certain taxa between plots and in such cases no statement is made on the significance of inter-plot differences. Table 6 is summarised in three ways. The ranks in each column are summed and the best rank obtained for the early and later sampling periods. The individual ranks showed a significant degree of concordance ($W = 0{\cdot}15$, $p = 0{\cdot}05$ for the early sample period; $W = 0{\cdot}26$, $p = 0{\cdot}02$ for the later sampling period using Kendall's coefficient of concordance [Siegel, 1956]). The data suggest that the seeded plot supports the most invertebrates while the unplanted plot supports the least in the initial sampling period. The situation is slightly different in the later sampling period in that the unplanted plot exceeds the planted plot. If only taxa which show significant differences between plots are compared, the same rank as the early sampling period is obtained.

The number of taxa present in each plot for the two sampling periods is also shown in Table 6. The mine totals were always lower than those of the forest although there was an increase between the two sampling periods. This may result partly from the longer and different time-span of the second sampling period. In each period the unplanted plot supported fewer taxa than the other two mine plots.

Forest epigaeic invertebrates which were initially absent from the mine plots include Scorpionida, Pseudoscorpionida, Opiliones, Isopoda, Isoptera and Acrididae. Scorpionida, Isoptera and Acrididae were found in certain mine plots in the second sampling period. Dermaptera were absent in the seeded plot.

Figure 2
Plant cover density profiles for the four study plots in October 1975, January 1977 and September 1977



LEGEND
Figures 3 to 30

x———x Forest control (Del Park)
+———+ Planted mine site
●- - - - - -● Non-revegetated mine site (Del Park)
○———○ Seeded mine site (Jarrahdale)
↓ First sampling date for planted and seeded plot

The forest control and non-revegetated mine site first sampled in March 1976.

Figure 3
Seven-day totals for *Scorpionida* taxon sampled in the four study plots.

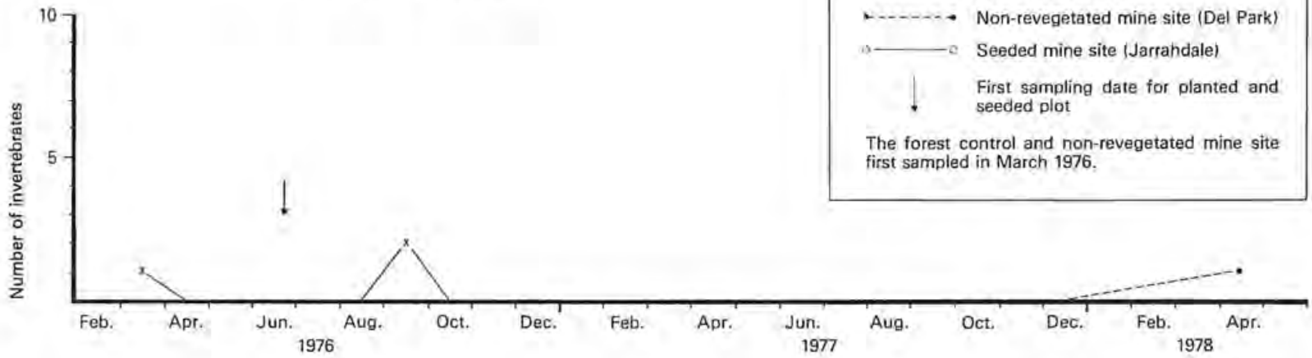


Figure 4
Seven-day totals for *Pseudoscorpionida* taxon sampled in the four study plots.

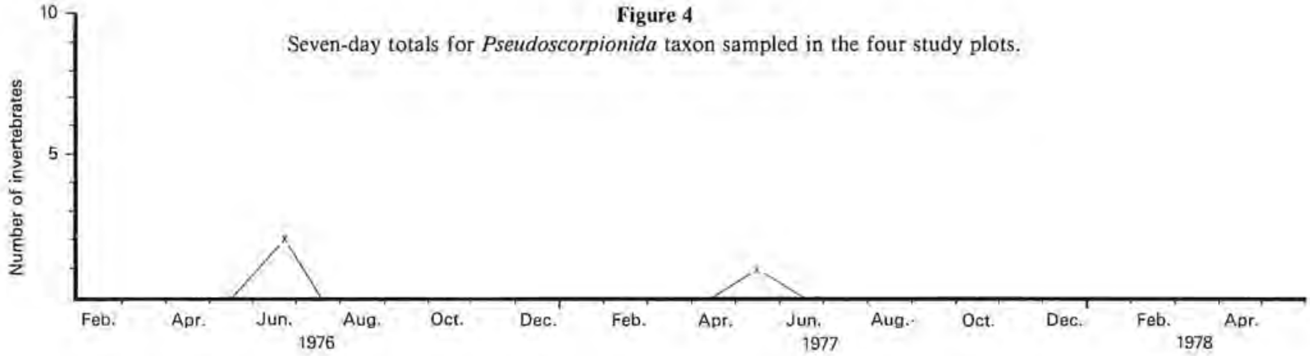


Figure 5
Seven-day totals for *Opiliones* taxon sampled in the four study plots.

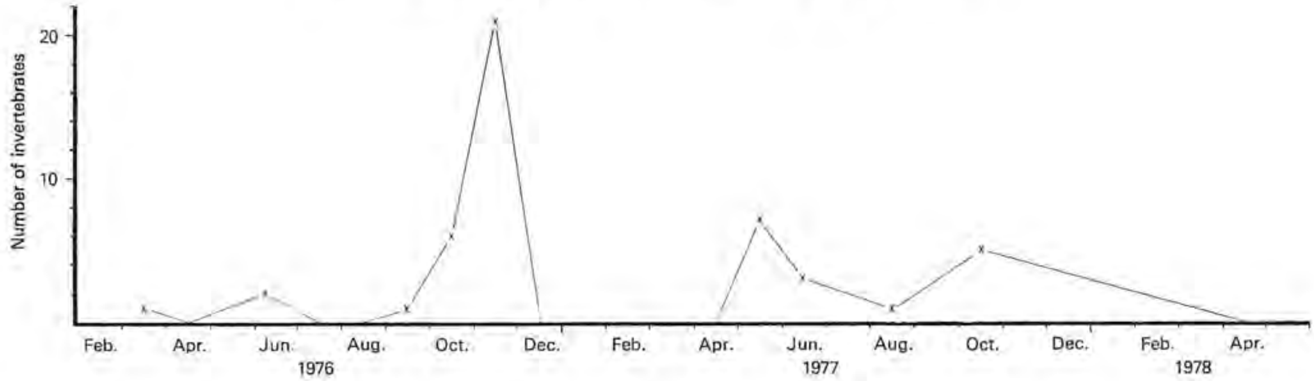


Figure 6
Seven-day totals for *Araneae* taxon sampled in the four study plots.
The forest data are presented as a separate graph for clarity.

(*a*)

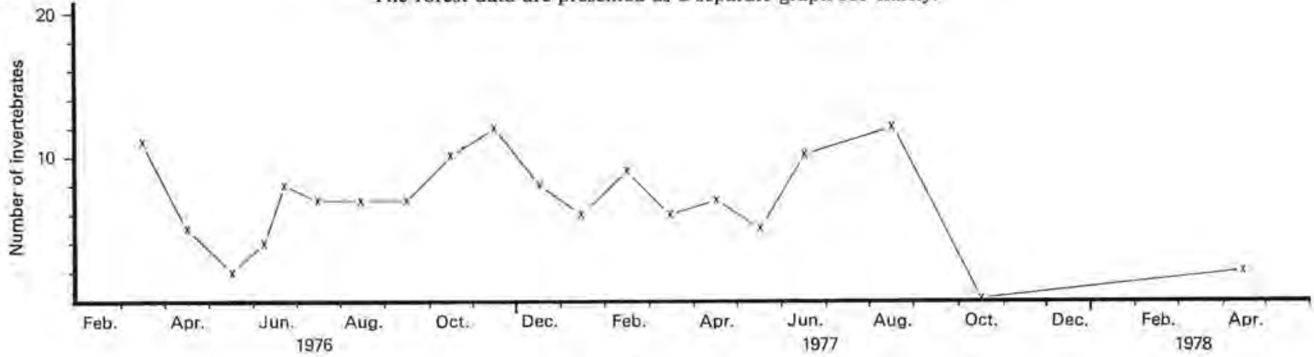


Figure 6—continued

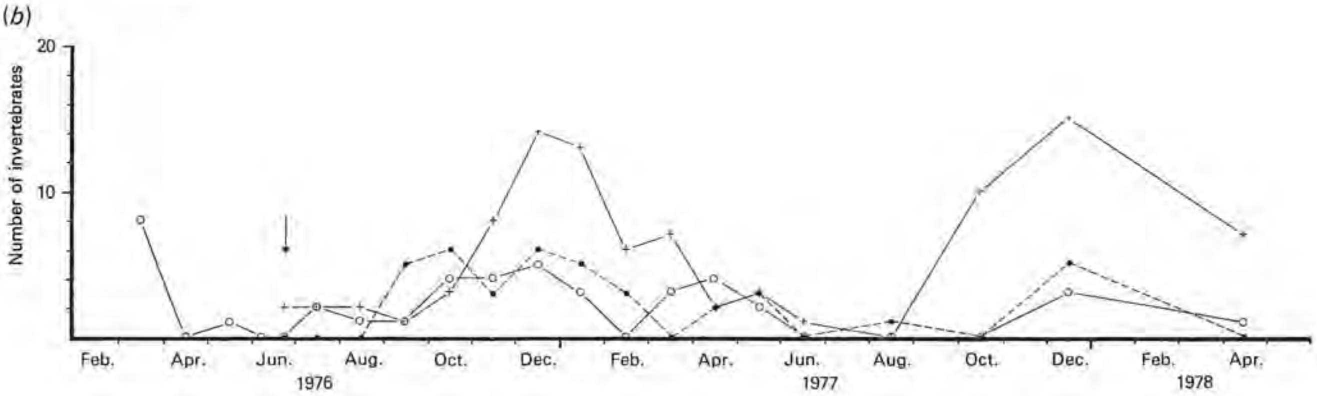
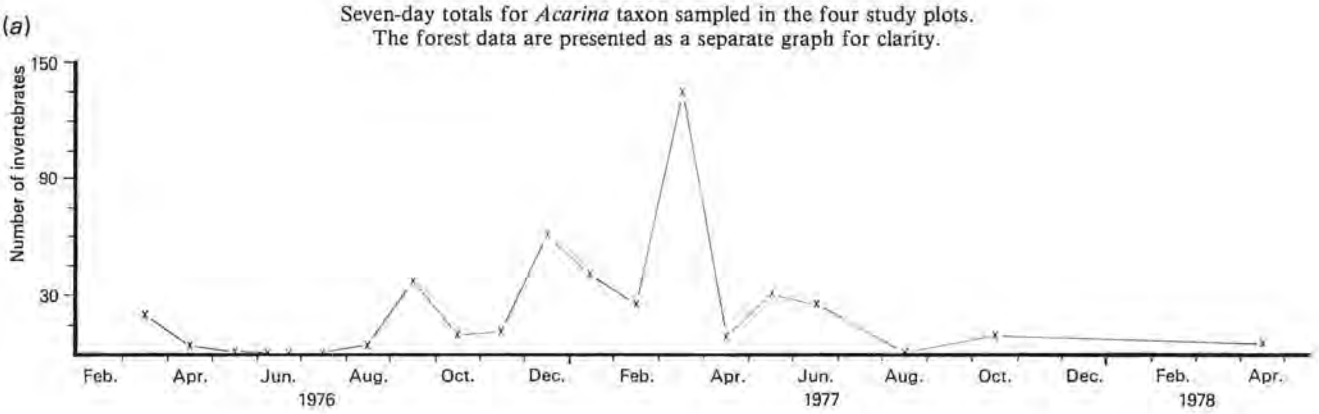
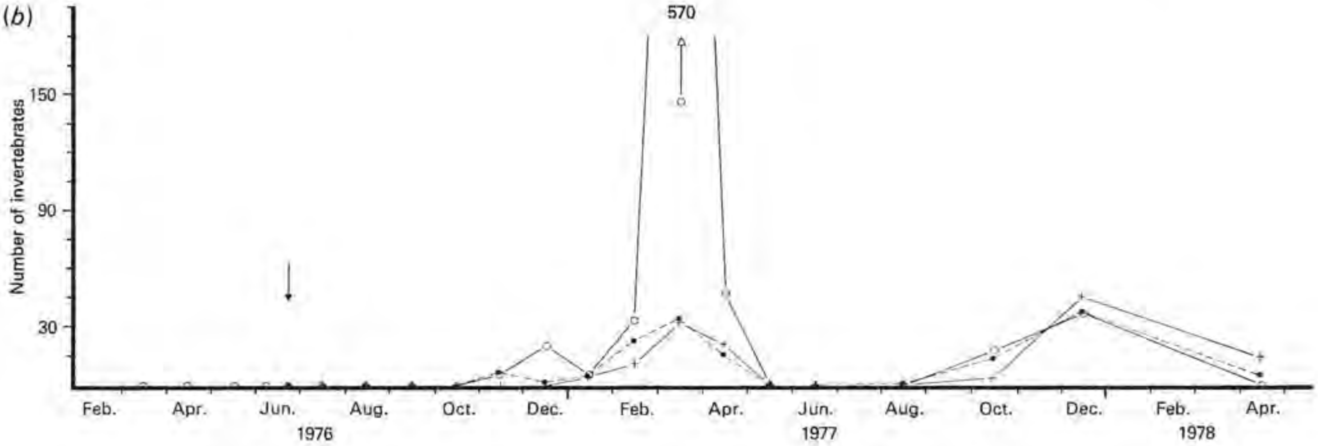


Figure 7
Seven-day totals for *Acarina* taxon sampled in the four study plots.
The forest data are presented as a separate graph for clarity.





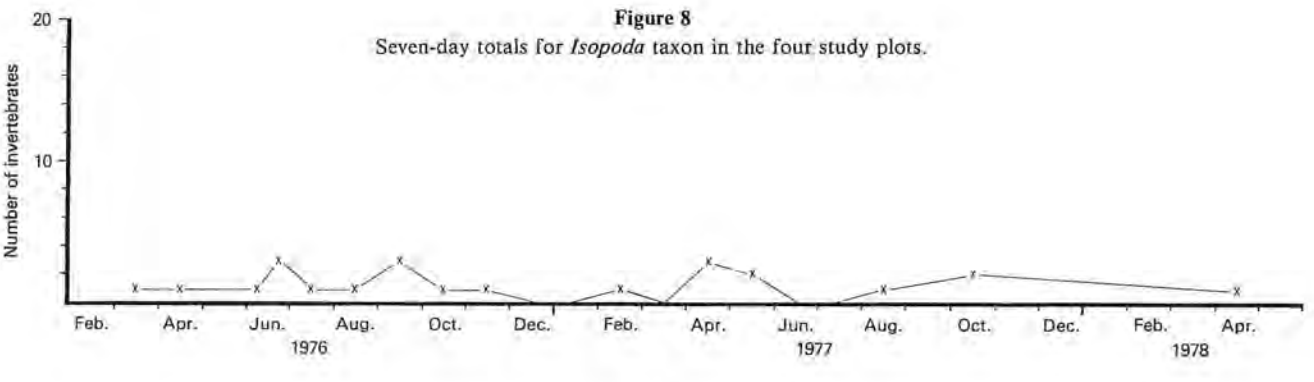


Figure 8
Seven-day totals for *Isopoda* taxon in the four study plots.

Figure 9

Seven-day totals for *Diplopoda* taxon sampled in the four study plots.

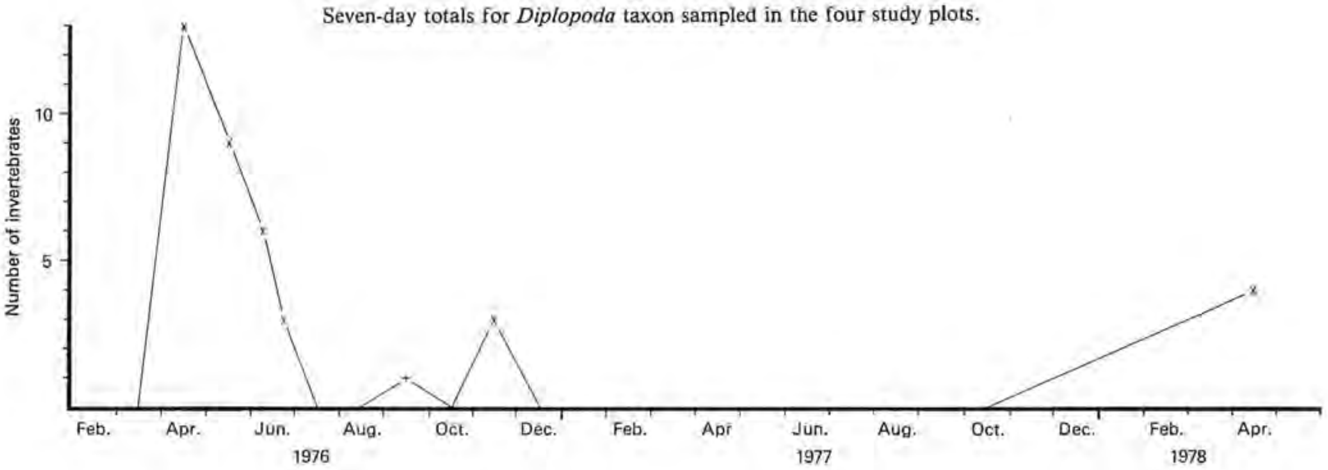


Figure 10

Seven-day totals for *Chilopoda* taxon sampled in the four study plots.

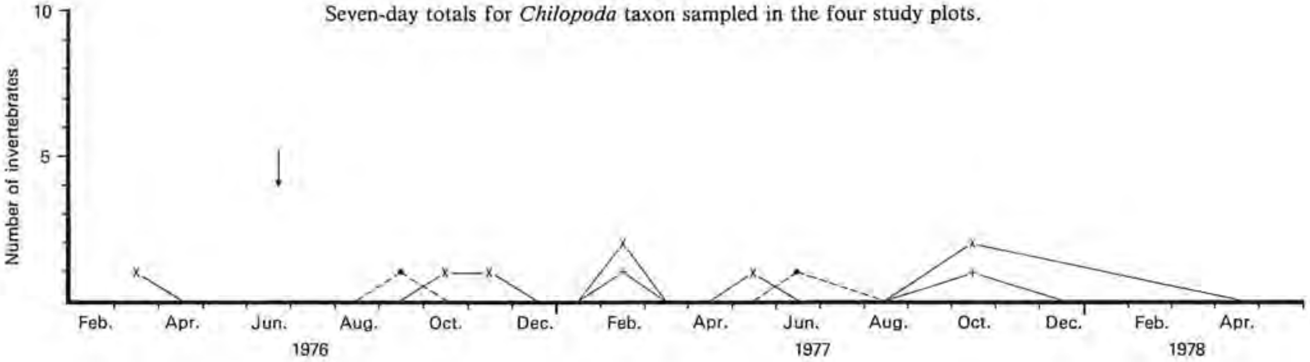


Figure 11

Seven-day totals for *Collembola* taxon sampled in the four study plots.
The forest data are presented as a separate graph for clarity.

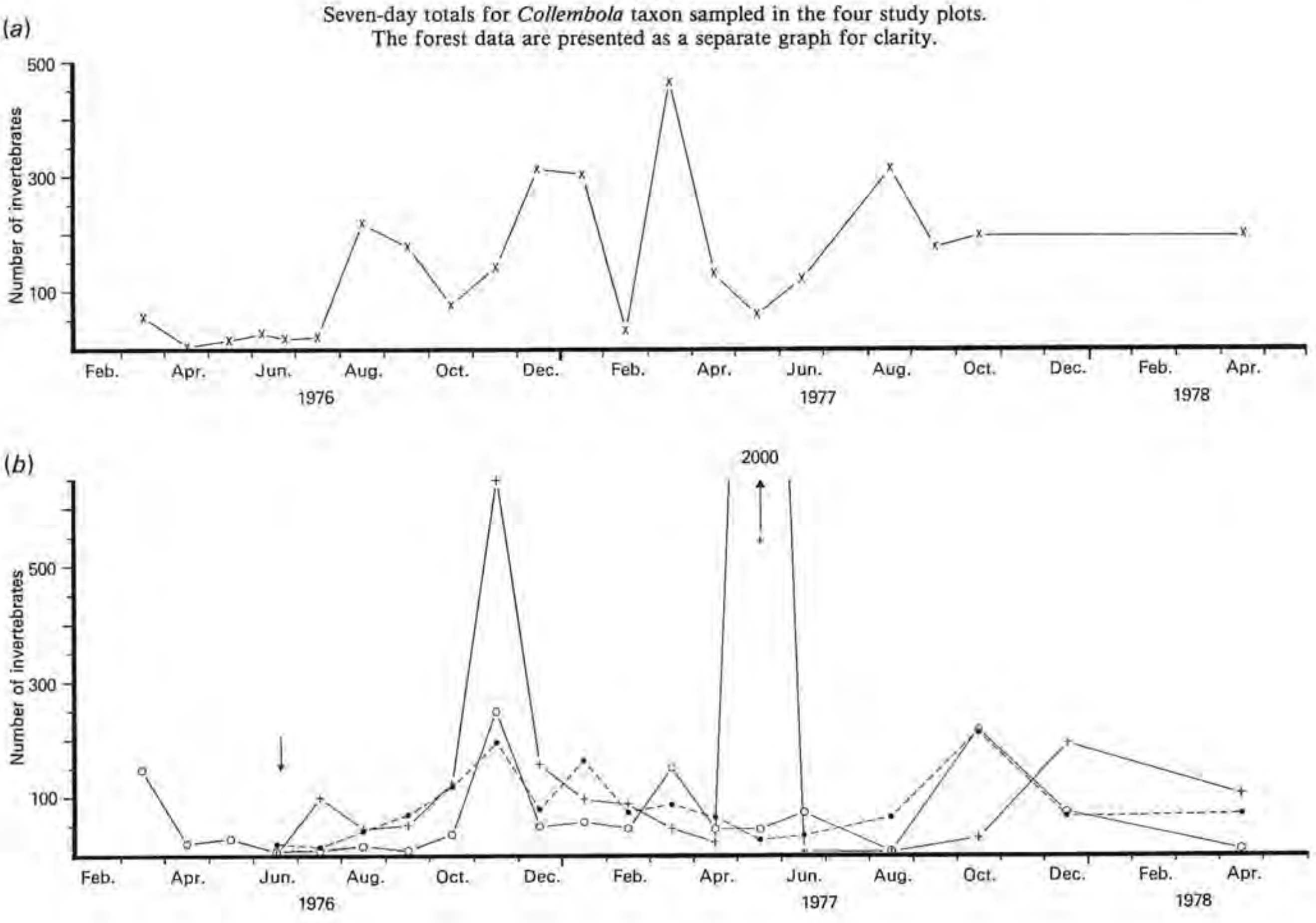


Figure 12

Seven-day totals for *Blattodea* taxon sampled in the four study plots.

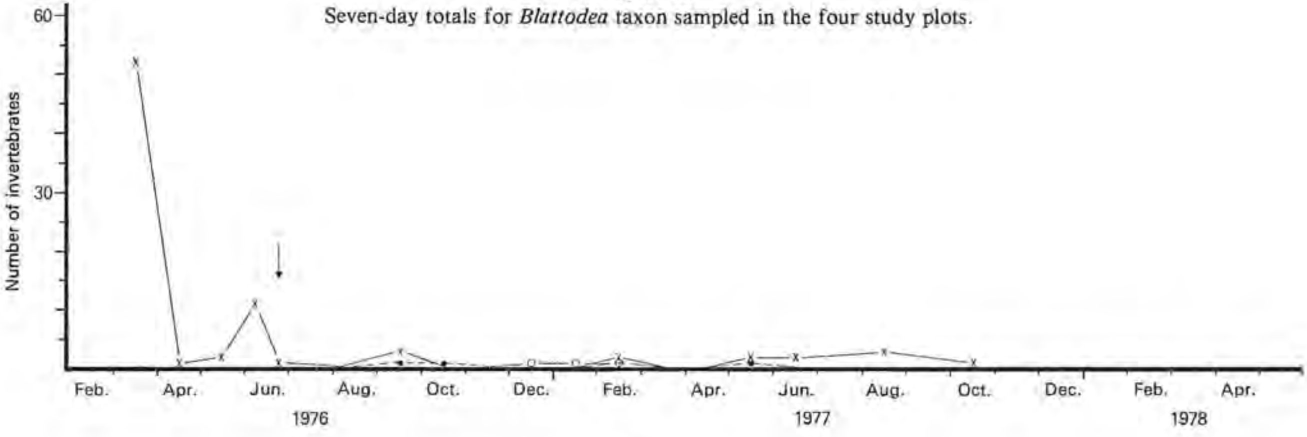


Figure 13

Seven-day totals for *Isoptera* taxon sampled in the four study plots.

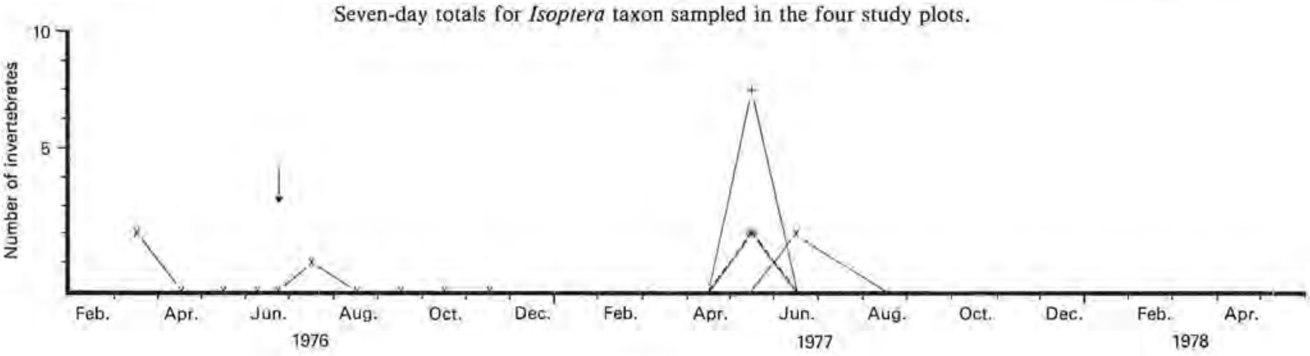


Figure 14

Seven-day totals for *Dermaptera* taxon sampled in the four study plots.

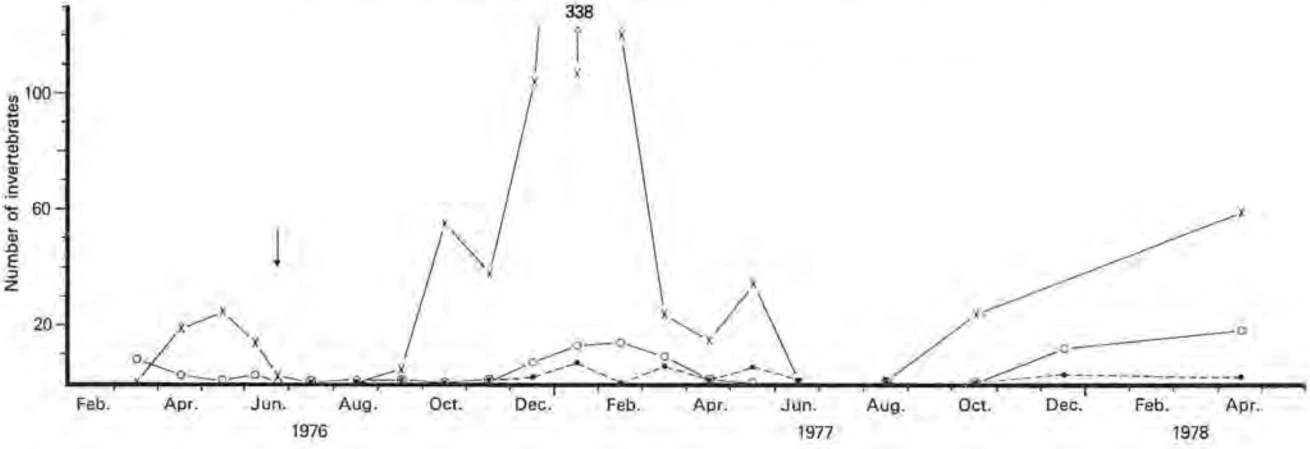


Figure 15

Seven-day totals for *Gryllacridoidea* taxon sampled in the four study plots.

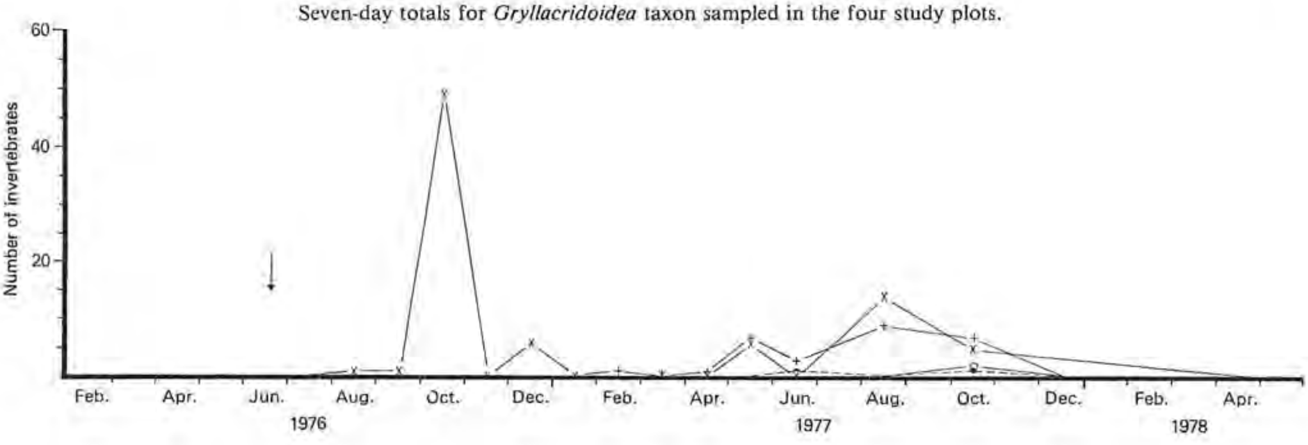


Figure 16

Seven-day totals for *Gryllidae* taxon sampled in the four study plots.
The forest data are presented as a separate graph for clarity.

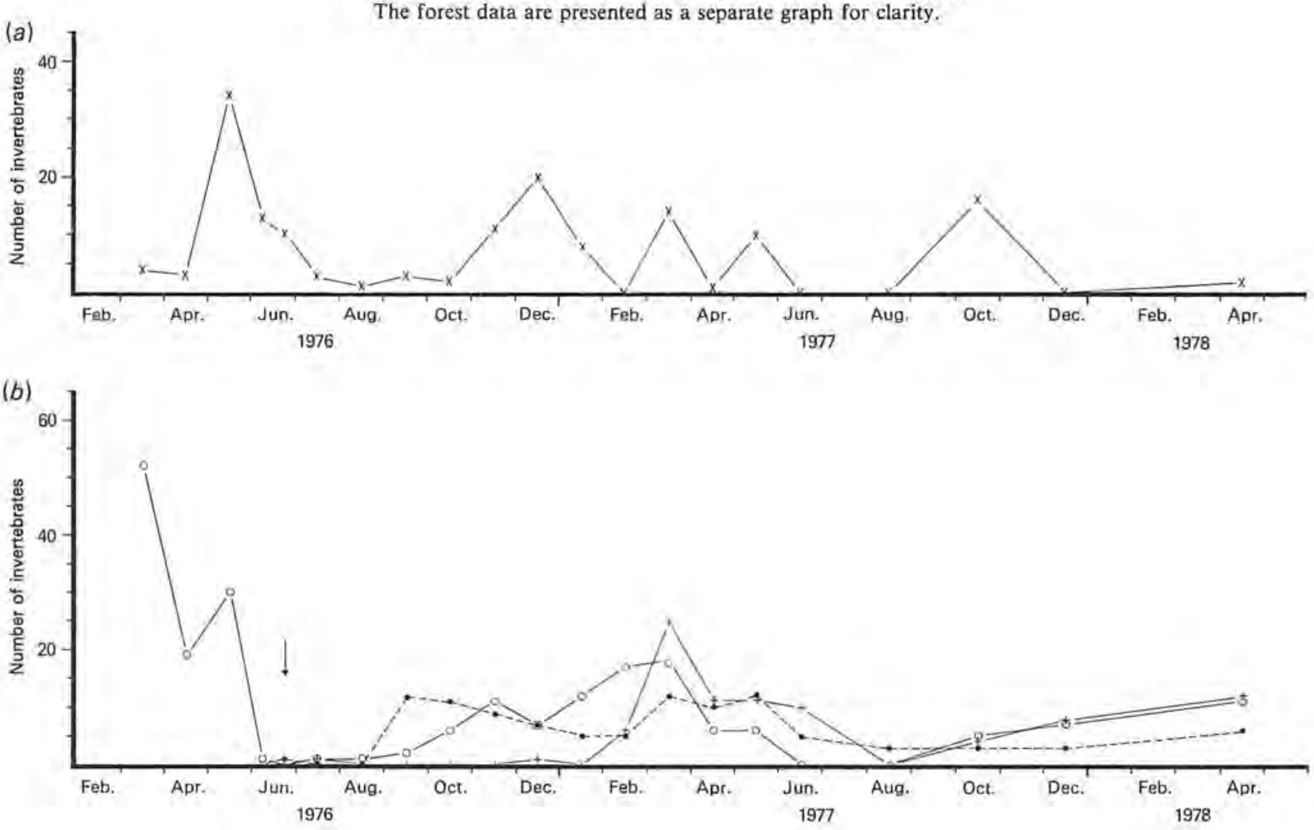


Figure 17

Seven-day totals for *Acrididae* taxon sampled in the four study plots.

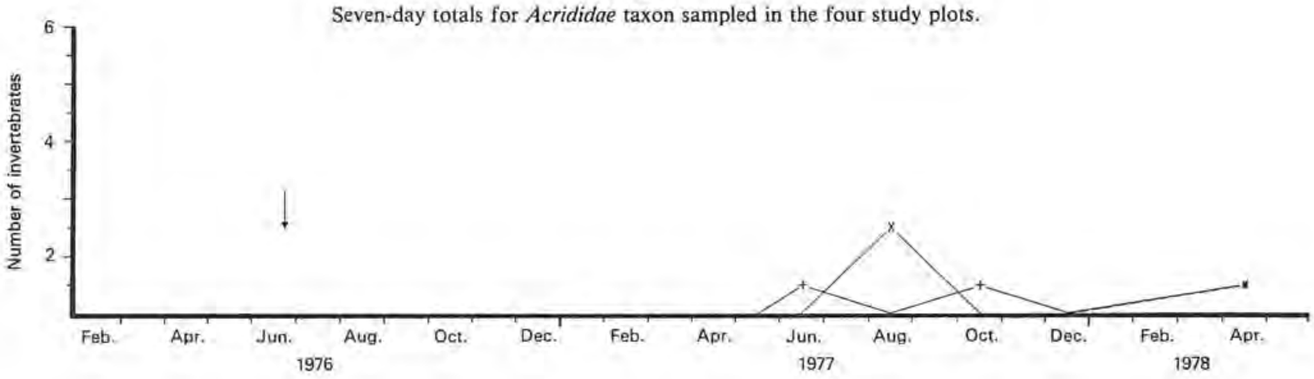


Figure 18

Seven-day totals for *Hemiptera* (*Homoptera*) taxon sampled in the four study plots.

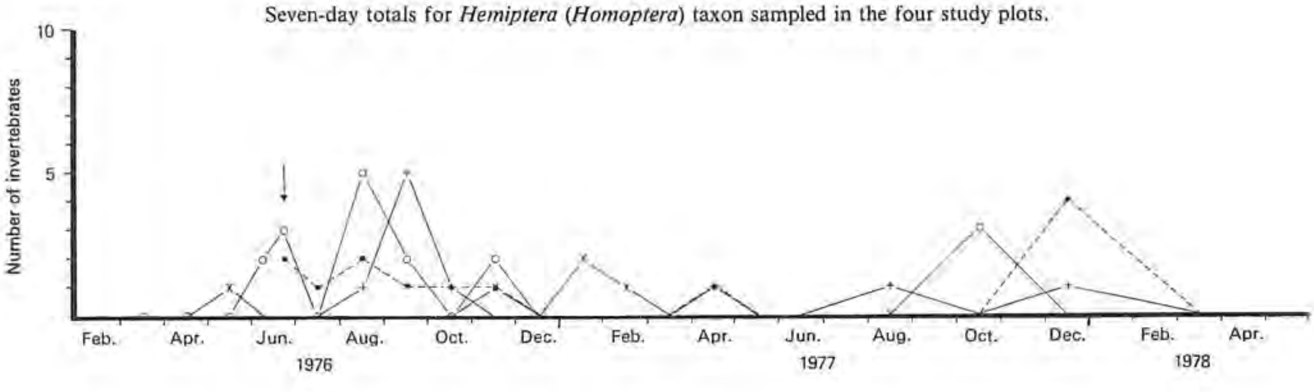


Figure 19

Seven-day totals for *Hemiptera* (*Heteroptera*) taxon sampled in the four study plots.

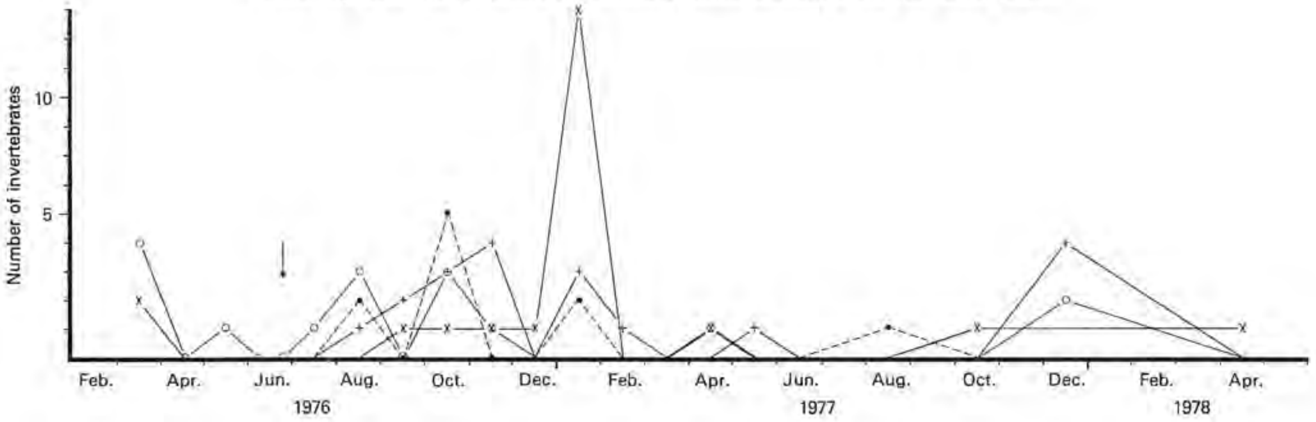


Figure 20

Seven-day totals for *Carabidae* taxon sampled in the four study plots.

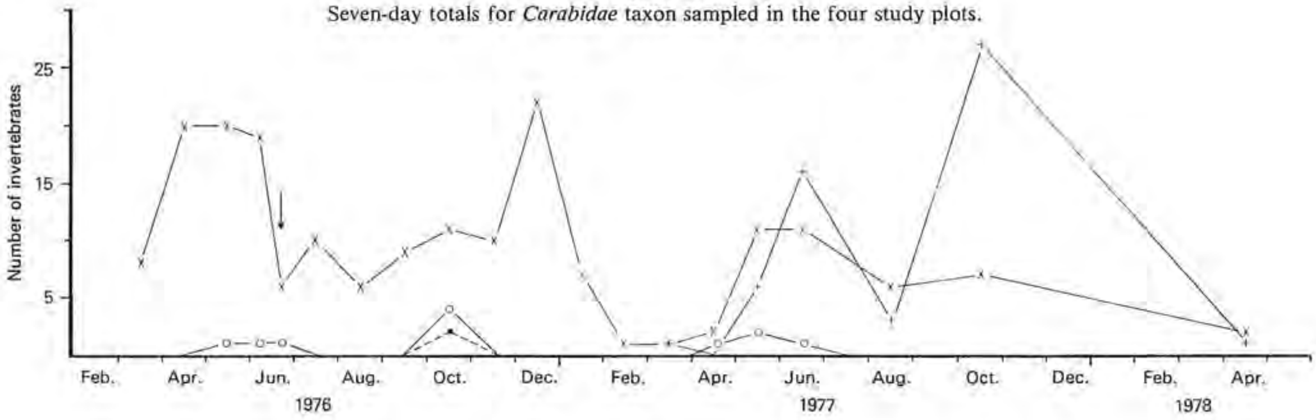


Figure 21

Seven-day totals for *Staphylinidae* taxon sampled in the four study plots.
The forest data are presented as a separate graph for clarity.

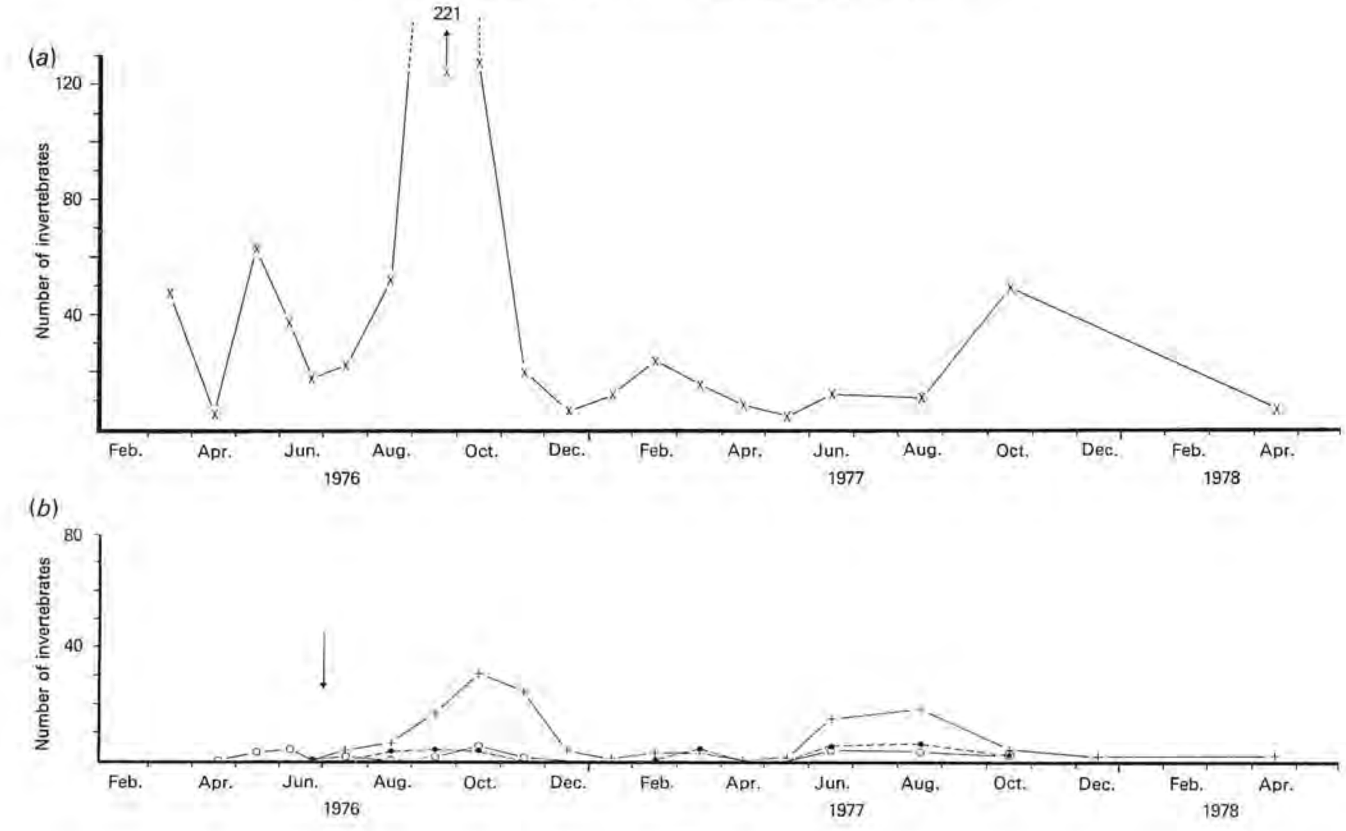


Figure 22
Seven-day totals for *Scarabaeidae* taxon sampled in the four study plots.

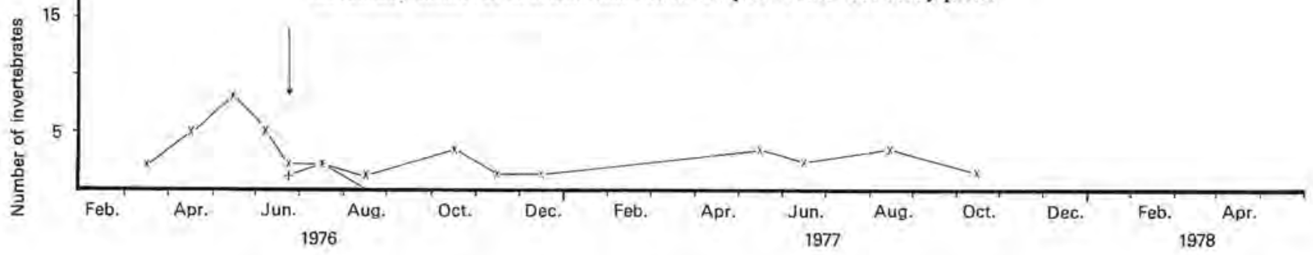


Figure 23
Seven-day totals for *Curculionidae* taxon sampled in the four study plots.

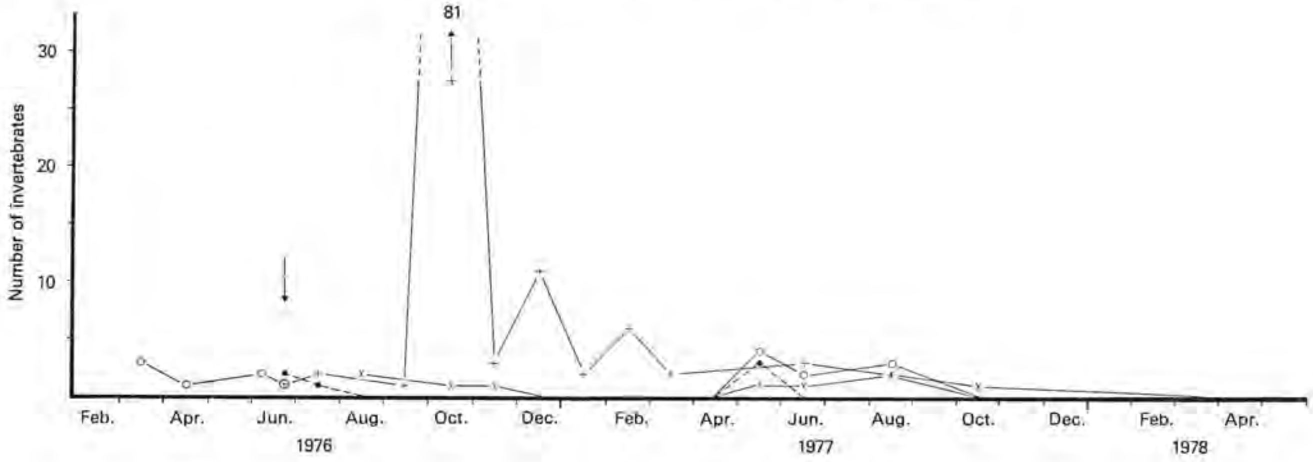


Figure 24
Seven-day totals for *Scolytinae* taxon sampled in the four study plots.

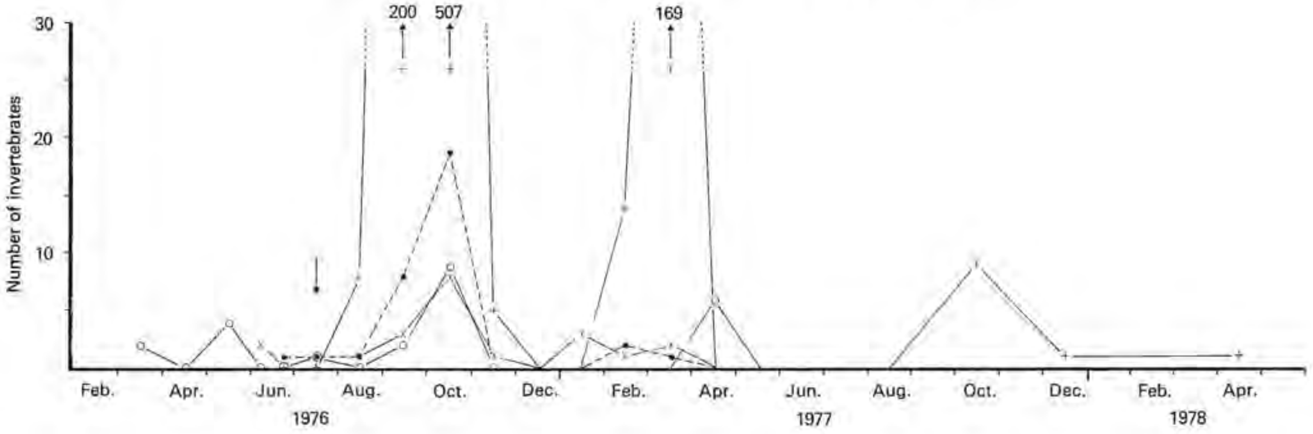


Figure 25
Seven-day totals for *Coleoptera* (others) taxon sampled in the four study plots.
The forest data are presented as a separate graph for clarity.

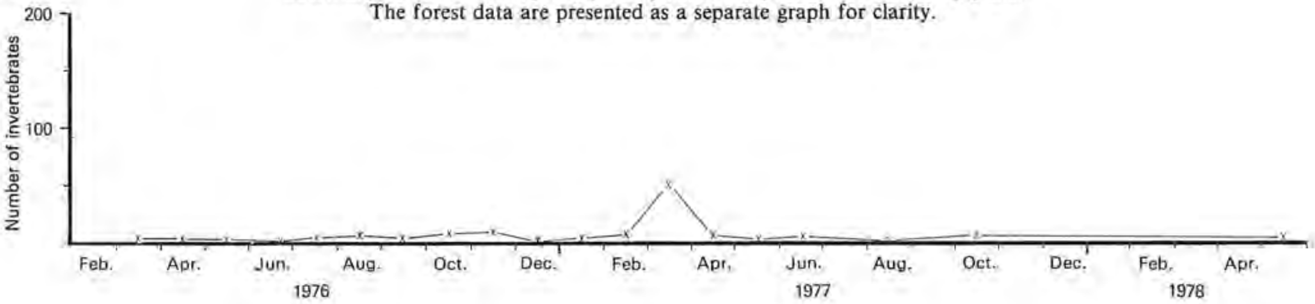


Figure 25—continued

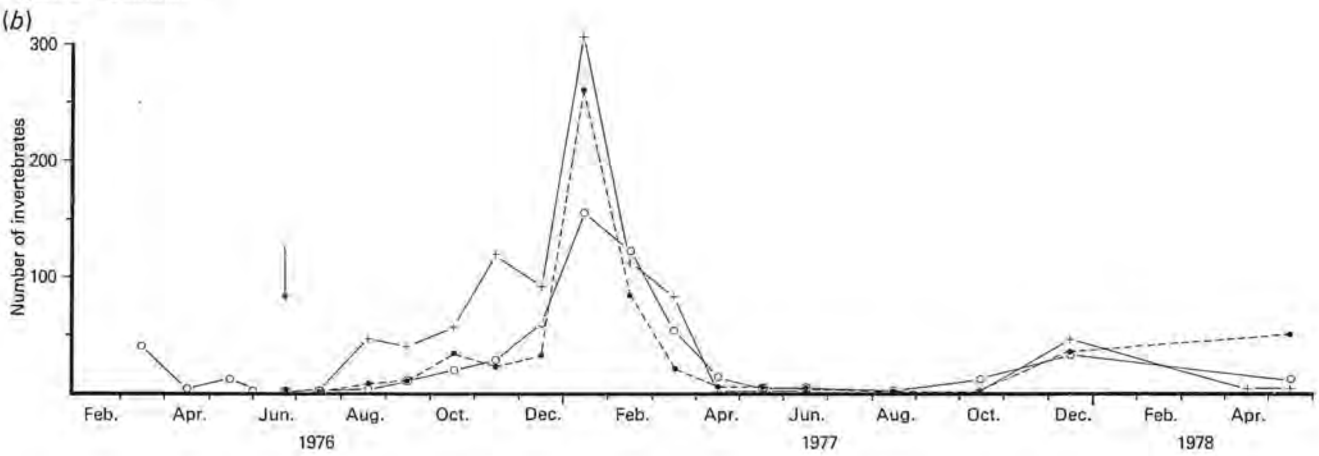


Figure 26

Seven-day totals for *Diptera* taxon sampled in the four study plots. The forest data are presented as a separate graph for clarity.

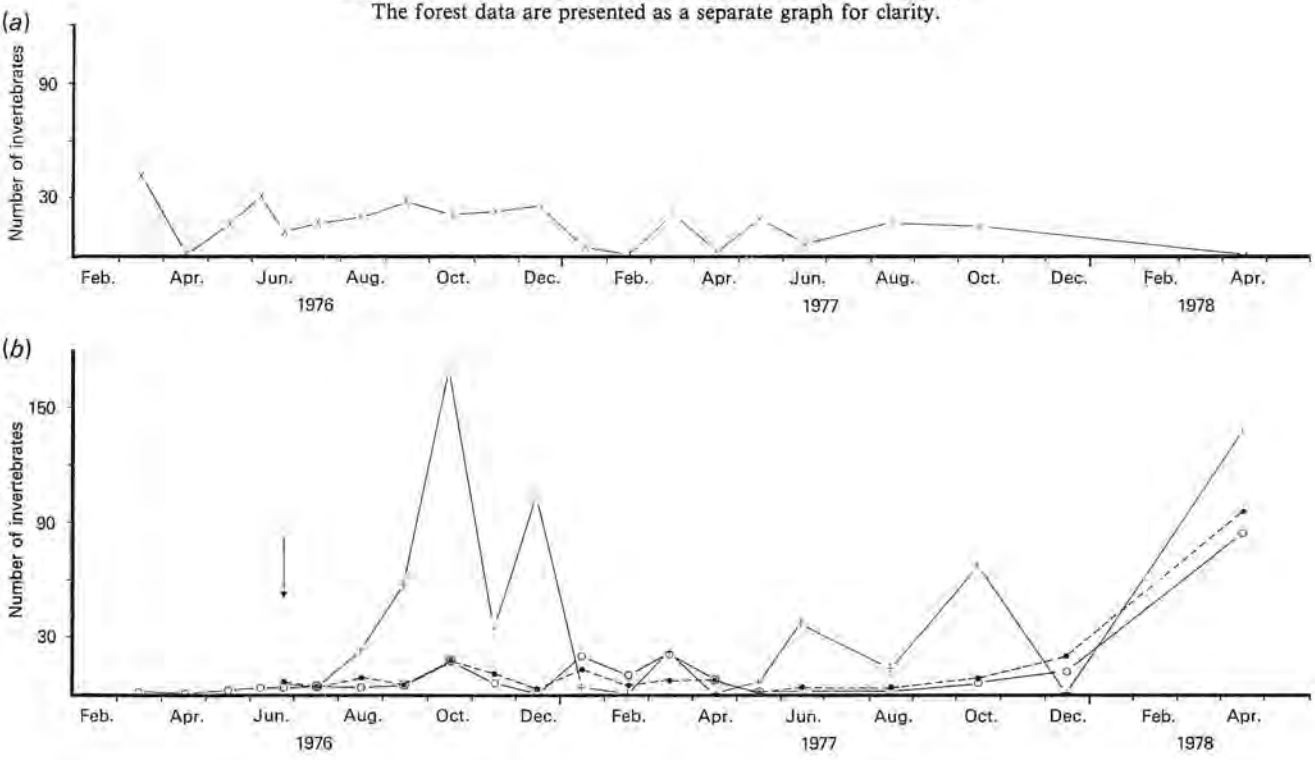


Figure 27

Seven-day totals for *Lepidoptera* (Larvae) taxon sampled in the four study plots.

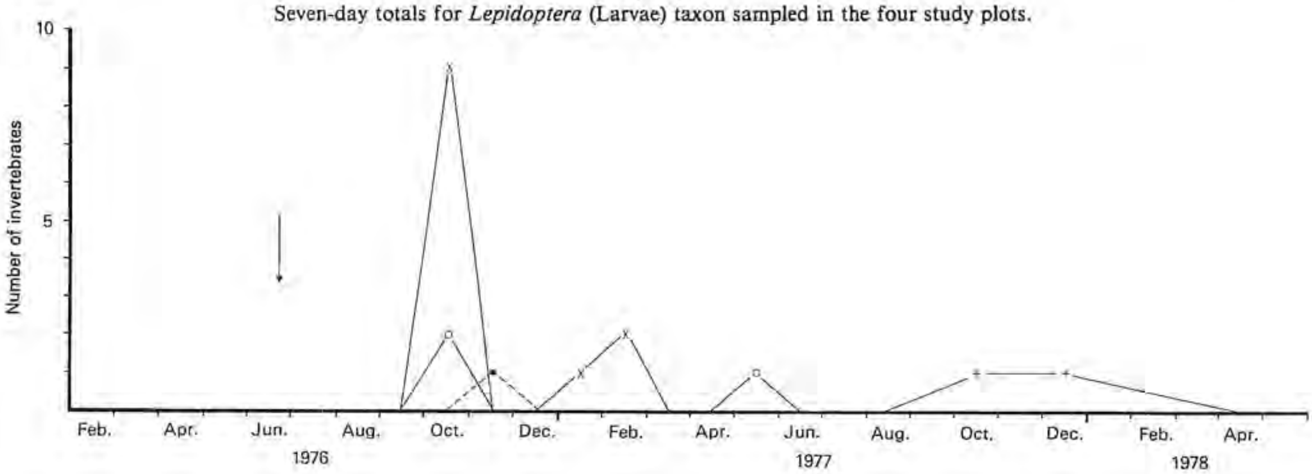


Figure 28

Seven-day totals for *Hymenoptera* (excluding *Formicidae*) taxon sampled in the four study plots.

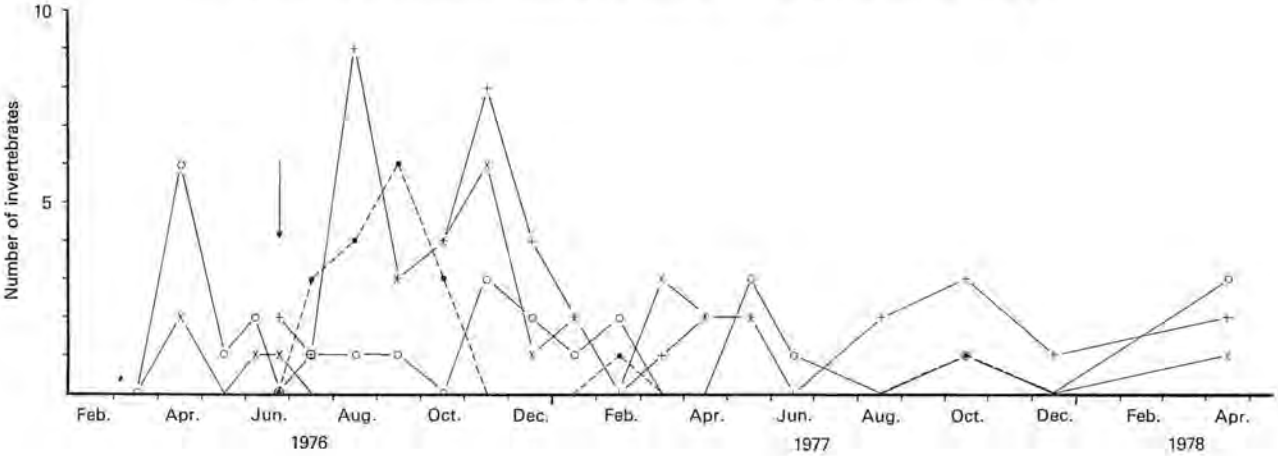


Figure 29

Seven-day totals for *Formicidae* (log. number of individuals) taxon sampled in the four study plots. The forest data are presented as a separate graph for clarity.

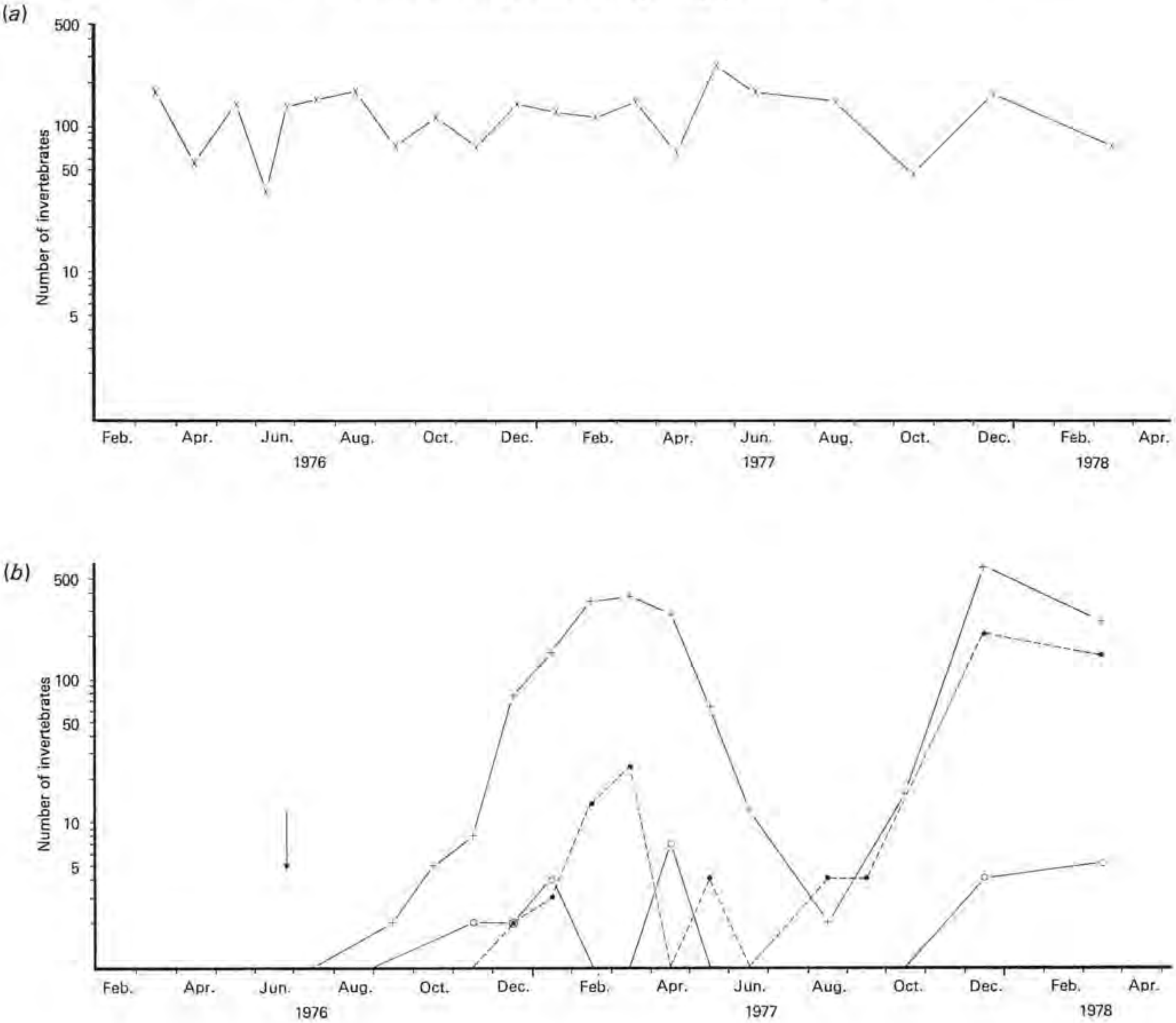
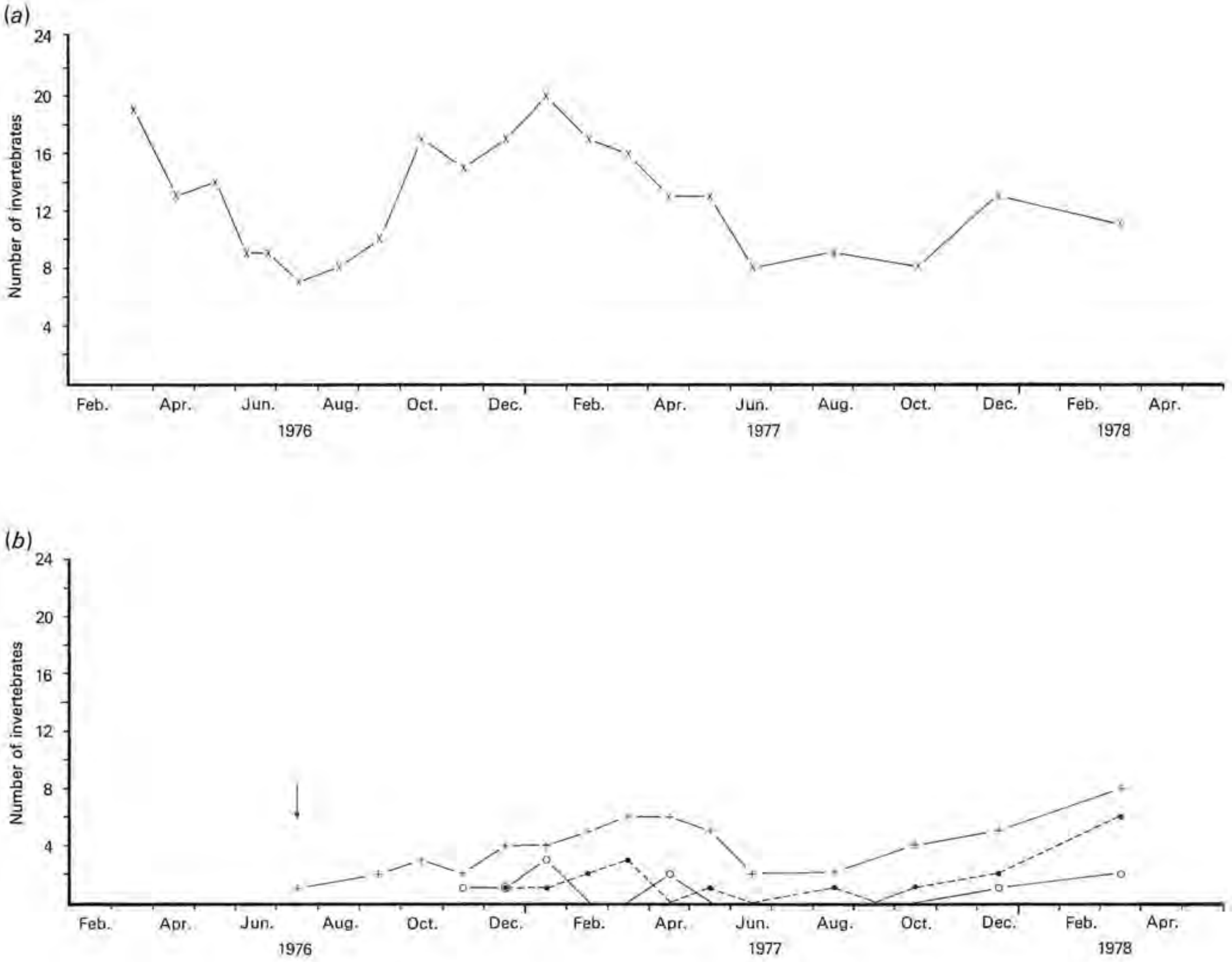


Figure 30

Seven-day totals for *Formicidae* (species richness) taxon sampled in the four study plots.
The forest data are presented as a separate graph for clarity.



Ant Data

The ant faunae of the four plots are compared in Table 7. As already indicated, ant totals and biomass indices are not necessarily directly comparable between forest and mine plots. However, some useful information may result from a comparison of species presence/absence, richness, diversity and evenness values between all four plots.

There is an increase in total ants, ant biomass index and species richness from the unplanted, through the planted and to the seeded plot. Species richness does not attain the forest control values in any mine plots. The diversity index values are not discussed here since its two components, species richness and evenness, are here considered separately. The forest evenness values for the two sample periods correspond with values found in other little-disturbed areas (Majer, 1977). The high evenness values in the unplanted plot and earlier planted plot sampling period indicate that the various species present have similar densities. The later planted plot and both seeded plot records show low evenness values, indicating that some species, particularly *Iridomyrmex* spp., have attained high densities.

The forest-mine plot similarity index values are all low when compared with values obtained by comparing more mature ecosystems (Majer, 1978*b*). This is partly due to the low species richness in the mine plots although it is noteworthy that, in each sampling period, the seeded plot possesses the fauna most similar to that of the forest.

Table 5

PRINCIPAL GROUPS OF INVERTEBRATES COLLECTED IN THE SAMPLING PROGRAMME SHOWING MAIN PERIODS OF ACTIVITY, FEEDING HABITS AND FIGURE NUMBER IN TEXT

Class	*Taxon*[1]	*Main period of occurrence in pitfall traps in forest control plot*	*Feeding habits*	*Other comments*	*Figure number in text*
Arachnida	O. Scorpionida	Autumn and spring	Predators		3
Arachnida	O. Pseudoscorpionida	Autumn and winter	Predators		4
Arachnida	O. Opiliones	High in spring and autumn	Predators		5
Arachnida	O. Araneae	All year	Predators		6
Arachnida	O. Acarina	Summer and autumn	Predator families only		7
Crustacea	O. Isopoda	Autumn, winter and spring	Dead plant material and other detritus		8
Diplopoda		Autumn, winter and spring	Dead plant material and other detritus		9
Chilopoda		Spring and summer	Predators of other invertebrates		10
Collembola		Autumn, winter and spring	Micro-organisms associated with decaying plant material	Decomposition of bodies in traps obscures trend	11
Insecta	O. Blattodea	Autumn and winter	Probably omnivorous scavengers		12
Insecta	O. Isoptera	Autumn and winter	Decaying wood		13
Insecta	O. Dermaptera	Spring, summer and autumn	Omnivores	Probably attracted to alcohol	14
Insecta	O. Orthoptera, S.F. Gryllacridoidea	Autumn, winter and spring	Probably omnivorous scavengers		15
Insecta	O. Orthoptera, F. Gryllidae	Autumn, spring and early summer	Omnivores		16
Insecta	O. Orthoptera, F. Acrididae	Late winter and spring	Herbivores		17
Insecta	O. Hemiptera, S.O. Homoptera	Autumn, winter and spring	Plant sap suckers		18
Insecta	O. Hemiptera, S.O. Heteroptera	Spring and summer	Mainly seed or fungus feeders or predators		19
Insecta	O. Coleoptera, F. Carabidae	All year	Predators		20
Insecta	O. Coleoptera, F. Staphylinidae	Spring, summer and autumn	Predators	Probably attracted to alcohol	21
Insecta	O. Coleoptera, F. Scarabaeidae	Autumn, winter and spring	Dead plant material and root feeders		22
Insecta	O. Coleoptera, F. Curculionidae	Winter and spring	Herbivores, mostly seed feeders	Scolytinae excluded	23
Insecta	O. Coleoptera, S. Scolytinae	Autumn and spring	Wood borers	Probably attracted to alcohol	24
Insecta	O. Coleoptera (other families)	All year but low in winter	Various	Some attracted to alcohol	25
Insecta	O. Diptera	All year	Various	Some attracted to alcohol	26
Insecta	O. Lepidoptera (larvae)	Spring	Live and decaying plant material		27
Insecta	O. Hymenoptera	Spring, summer and autumn		1. Some attracted to alcohol 2. Formicidae excluded	28
Insecta	F. Formicidae (number of individuals)	All year with summer peak	Predators, nectar and seed feeders		29
Insecta	F. Formicidae (species richness)	All year with summer peak	Predators, nectar and seed feeders		30

[1] O. = Order; S.O. = Sub-order; S.F. = Super-family; F. = Family; S. = Sub-family.

Table 6

COMPARISON OF INVERTEBRATE DATA BETWEEN MINE PIT PLOTS FOR THE FIRST EIGHT AND THE LAST FOURTEEN MONTHS OF THE STUDY PERIOD

Class	*Taxon*[1]	*Abundance in forest control plot traps*		*Months for which collections compared*					
		Range of individuals caught per plot per month	*Frequency out of 16 sample dates*	*July 1976 to February 1977 (N = 8)*			*March 1977 to April 1978 (N = 8)*		
				Unplanted plot (U)	*Planted plot* (P)	*Seeded plot* (S)	*Unplanted plot* (U)	*Planted plot* (P)	*Seeded plot* (S)
Arachnida	O. Scorpionida	0-2	1	—	—	—	—	1	—
Arachnida	O. Pseudoscorpionida	0-2	1	—	—	—	—	—	—
Arachnida	O. Opiliones	0-21	7	—	—	—	—	—	—
Arachnida	O. Araneae	0-12	14	1^{NS}	2^{NS}	3^{NS}	2^{NS}	1^{NS}	3^{NS}
Arachnida	O. Acarina	0-135	13	3^{NS}	2^{NS}	1^{NS}	3^{NS}	1^{NS}	2^{NS}
Crustacea	O. Isopoda	0-3	11	—	—	—	—	—	—
Diplopoda		0-4	2	—	—	1	—	—	—
Chilopoda		0-2	5	—	2	1	—	1·5	1·5
Collembola		13-465	16	1^{*S}	2^{*S}	3^{*UP}	1^{NS}	2^{NS}	3^{NS}
Insecta	O. Blattodea	0-3	6	1	2	3	—	1	—
Insecta	O. Isoptera	0-2	2	—	—	—	1·5	1·5	3
Insecta	O. Dermaptera	0-338	12	2^{NS}	1^{NS}	—	2^{NS}	1^{NS}	—
Insecta	O. Orthoptera, S.F. Gryllacridoidea	0-49	7	—	—	1	$1{\cdot}5^{NS}$	$1{\cdot}5^{NS}$	3^{NS}
Insecta	O. Orthoptera, F. Gryllidae	0-20	12	3^{*S}	2^{NS}	1^{*U}	1^{*S}	2^{NS}	3^{*U}
Insecta	O. Orthoptera, F. Acrididae	0-3	2	—	—	—	—	1	2
Insecta	O. Hemiptera, S.O. Homoptera	0-2	3	3^{NS}	1^{NS}	2^{NS}	1·5	3	1·5
Insecta	O. Hemiptera, S.O. Heteroptera	0-13	8	1^{NS}	2^{NS}	3^{NS}	2	1	3
Insecta	O. Coleoptera, F. Carabidae	0-22	15	2	1	—	1^{*S}	—	2^{*U}
Insecta	O. Coleoptera, F. Staphylinidae	0-221	15	1^{*S}	2^{*S}	3^{*UP}	1^{*S}	2^{NS}	3^{*U}
Insecta	O. Coleoptera, F. Scarbaeidae	0-3	9	—	—	1	—	—	—
Insecta	O. Coleoptera, F. Curculionidae	0-2	7	1^{*S}	2^{*S}	3^{*UP}	2^{NS}	1^{NS}	3^{NS}
Insecta	O. Coleoptera, S. Scolytinae	0-8	7	1^{NS}	2^{NS}	3^{NS}	2	1	3
Insecta	O. Coleoptera (other families)	0-52	14	1^{*S}	2^{*S}	3^{*UP}	3^{NS}	1^{NS}	2^{NS}
Insecta	O. Diptera	0-28	13	$1{\cdot}5^{NS}$	$1{\cdot}5^{NS}$	3^{NS}	$1{\cdot}5^{NS}$	$1{\cdot}5^{NS}$	3^{NS}
Insecta	O. Lepiodoptera (larvae)	0-9	3	2	1	—	1	—	2
Insecta	O. Hymenoptera	0-6	9	1^{NS}	2^{NS}	3^{NS}	2^{NS}	1^{*S}	3^{*P}
Insecta	F. Formicidae (number of individuals)	36-274	16	1^{*S}	2^{*S}	3^{*UP}	1^{*S}	2^{*S}	3^{*UP}
Insecta	F. Formicidae (species richness)	7-20	16	2^{*S}	1^{*S}	3^{*UP}	1^{*S}	2^{*S}	3^{*UP}
Best rank of all taxonomic groups		—	—	1	2	3	2	1	3
Best rank of taxonomic groups in rows where some significant difference		—	—	1	2	3	1	2	3
Total taxa present		27	—	17	18	18	18	20	19

The highest rank number corresponds to the plot where most invertebrate numbers have been found. The numerical range and frequency of occurrence of each group in the forest plot is also shown. An asterisk means that the plots are significantly different from the stated plot. U, P or S at least at the 0·05 level, NS means that differences are not significant, and unlabelled ranks have not been tested owing to statistical limitations

[1] O. = Order; S.O. = Sub-order; S.F. = Super-family; F. = Family; S. = Sub-family.

Table 7

COMPARISON OF ANT FAUNA PARAMETERS DERIVED FROM BULKED SAMPLE DATA FOR THE FIRST EIGHT-MONTH, AND THE LAST FOURTEEN-MONTH, PERIOD OF SAMPLING IN THE FOUR STUDY PLOTS

Parameter	*July 1976 to February 1977*				*March 1977 to April 1978*			
	F[1]	U	P	S	F	U	P	S
Total ants	954	8	18	586	1056	16	382	1586
Biomass estimate	1797	11	27	995	1610	28	528	2109
Species richness	32	4	3	10	27	2	6	11
Shannon index of diversity	1·048	0·526	0·391	0·381	0·931	0·287	0·255	0·416
Equitability index	0·696	0·875	0·820	0·381	0·656	0·954	0·327	0·399
Similarity to forest fauna index	N.C.[2]	0·040	0·030	0·050	N.C.[2]	0·010	0·026	0·027

[1] Plots as follows: F = forest plot; U = unplanted plot; P = planted plot; S = seeded plot.
[2] N.C. = Not calculated.

DISCUSSION

Scope of Study

It should be stressed that these findings are the result of a preliminary study on mine pit invertebrate fauna succession. The pit traps sample epigaeic invertebrates only. The census of this faunal component is also incomplete since the traps tend to sample the more mobile taxa. A more complete evaluation of mine pit fauna succession should include samples of litter fauna and invertebrates directly associated with the vegetation, and should utilise a number of complementary sampling methods. Such a study is about to be performed at the time of writing. Nevertheless, the findings of the present study may also be indicative of trends in the soil fauna since Hutson's (1972) study on epigaeic and soil fauna of an English reclaimed pit heap showed that taxa sampled by pit traps were generally also found in the soil samples from the same site.

Inter-plot Differences

The present study has revealed that a great variety of invertebrates is present in the mine pits and that artificial revegetation is not a pre-requisite in the short term for the presence of many taxa. The unplanted plot supports the lowest variety of taxa, most of which are sampled in lower numbers than in the revegetated plots. Both seeded and planted plots support a similar variety of taxa although most taxa are sampled in greater quantities in the seeded plot. Inspection of the raw data in Figures 3 to 30 shows that although the catches of most groups in the seeded plot exceed those of the other mine plots, the differential between planted and unplanted plots is usually much less (see Figures 6, 11, 13, 15, 20, 21, 26, 28 and 29).

This observation is further supported by the values for total ants, ant biomass and ant species richness (see Table 7) which all increase in the plot order unplanted, planted, seeded and which are all considerably greater in the seeded plot. Two questions arise from these observations. Why does seeding of pits encourage a more diverse and abundant fauna when compared with the planting approach and what is the food for invertebrates in the unplanted plot?

Before attempting to relate these questions to the revegetation approach, the environmental conditions associated with each plot should be considered. The planted and unplanted plots differ only in that trees have been planted in the former (see Table 3). The seeded plot differs from the other plots in its close proximity to the forest edge and in that topsoil was not stockpiled before return. The author has noted no base-line difference in invertebrate diversity and abundance between the Del Park and Jarrahdale plots.

The invertebrate trends (see Figures 3 to 30) indicate that build-up of invertebrates occurred after a similar period in both seeded and planted plots, suggesting that time since revegetation is a more important determinant of succession than is time since topsoil replacement. The effects of stockpiling cause a deterioration in soil physical condition (Hunter and Currie, 1956) and microbial activity (Miller and Cameron, 1976), and a reduction in subsequent colonising vegetation (W. Tacey*, personal communication). It is also likely that stockpiling reduces the numbers of most invertebrates in the soil. Thus the omission of stockpiling in the seeded plot soil could be partly responsible for the high numbers of certain invertebrates, at least during the early part of the monitoring period.

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* Alcoa Australia, Pinjarra.

Dunger's (1969) work on earthworms and Neumann's (1973) invertebrate monitoring programme, both performed in revegetated coal spoil heaps, emphasise the importance of nearby vegetation as a reservoir for colonising invertebrates. Majer (1978*a*) ran ten transects of pit traps, oriented from 50 m into the forest to the same distance into the mine, in unplanted mine pits. The results for ants suggest that the proximity of forest is responsible for mine pit fauna enrichment to a distance of 20 m, beyond which species richness and abundance varies independently of the proximity of the forest edge. The transects revealed similar trends with the other invertebrates collected in the traps. It therefore appears that, although invertebrate richness and abundance in the seeded plot may be accounted for partly by the lack of stockpiling, the type of revegetation is probably largely responsible for the observed results.

Influence of Vegetation

The discussion will now focus on the influence of vegetation on invertebrates in the two revegetated plots. These plots support a similar range of taxa, although greater numbers of individuals were collected in the seeded plot. The data also suggest that ant species richness is higher in the seeded plot (see Table 7). The choice of ants for study at species level is appropriate since many are predators or occupants of specialised niches and their species richness may reflect the diversity of other invertebrate food sources, nesting sites and foraging areas. There are no comparable studies which compare invertebrates in replanted and reseeded reclaimed lands although a number of workers have compared land converted to agricultural and forestry use. Dunger (1964) and Bruning *et al.* (1965) both investigated invertebrate recolonisation of coal spoil heaps converted to forestry and agriculture use. Dunger (1964) found that the diversity of most groups was greatest in the afforested areas although Bruning *et al.* (1965) observed a higher invertebrate biomass in the agricultural land.

In order to relate the fauna to rehabilitation method the resulting differences in vegetation should be considered. The seeded plot has the higher plant species richness, plant cover density, percentage area of ground cover (see Table 4) and also has the more structurally complex vegetation. The greater density and cover of vegetation produces a more humid and cool soil surface and soil environment. Significant litter build-up has been noted in the seeded plot although none has been observed in the planted area.

Murdoch *et al.* (1972) noted a positive correlation between plant and invertebrate species richness in abandoned fields in Michigan, although they were unable to resolve whether plant structure or species diversity was the important factor. Fox (1978) has attempted to relate the ant community in coastal heath, replanted after sand mining, to structural and floristic characteristics. Her data suggest that certain plant structural characteristics have a major influence on the nature of the ant community.

Hutson and Luff (1978) have discussed the importance of micro-climate in determining the species of Collembola on reclaimed industrial sites. Most members of this taxon require a relative humidity of at least 90 per cent in order to survive for any extended period. Many of the taxa sampled in the bauxite mine plots are poorly adapted to dessication of body tissue so the more harsh micro-climate of the open planted areas may be a limiting influence. This would in turn limit the abundance of insect predators.

The final influence of vegetation which will be discussed is litter accumulation. Neumann (1971), working on rehabilitated spoil banks of coal mines, concluded that areas planted with trees producing high amounts of readily decomposable litter support more decomposer organisms than do other plots. It may be that the greater litter production in the seeded plot of this study has also contributed to the greater diversity and abundance of certain taxa.

This discussion has not resolved what the relative contributions each of these factors make in determining the type of invertebrate community, nor was elucidation of this the aim of the study. It may be concluded, however, that to enhance the rapid build-up of a diverse and abundant invertebrate fauna, seeding of mine pits seems preferable to planting.

Time-scale of Succession

The time-scale of succession in the rehabilitated mine pits may vary the revegetation method. Scott (1974) located eleven to nineteen species of ants in Jarrahdale bauxite mine pits supporting eight-year-old plantations of *Eucalyptus* spp. or *Pinus pinaster*. In the present study, where revegetation was less than two years old, six ant species were located in the planted plot and eleven in the seeded plot. The combined data from this study and those of Scott (1974) suggest that species richness may increase with the age of the planted trees, and that the increase is more rapid in the seeded plot.

However, Scott's plots were larger than those used in this study and the comparability of the data is open to question. More work is planned to investigate the time-scale of succession for the various revegetation methods.

Food Source of Invertebrates

A question to consider is: on what do invertebrates in the unplanted plot feed? Many are winged forms and, in the case of certain Dermaptera, Coleoptera, Diptera and Hymenoptera, are probably attracted to the trap preservative. Collections of these groups do not necessarily indicate residence in the unvegetated pits although they certainly reflect the capacity of these groups to establish themselves once food becomes available. The Araneae, Acarina, Collembola and Formicidae are wingless and are certainly inhabiting the plot.

Dunger (1964) and Bruning *et al.* (1965) have monitored the soil surface fauna and soil fauna of unplanted coal spoil heaps while Davis and Murphy (1961) have investigated the soil Acarina and Collembola in unplanted land, reclaimed after open-cast iron-stone mining. All sites described contained more pioneer plants than did the unplanted bauxite mine plot. The coal spoil heaps supported a high density of Dermaptera, Carabidae, Staphylinidae and Araneae. It is suggested that winged Diptera are an important food source for these predators since the activity of small arthropods was low. Davis and Murphy (1961) found a similar density and diversity of Acarina and Collembola in the levelled quarry, which had been colonised by colts foot (*Tussilago farfara*), to that of nearby revegetated areas.

This study has not examined the soil biota, on which many epigaeic animals may feed. The moderate Collembola density in the unplanted plot suggests that other decomposer taxa may also be present in the soil. Their principal food source is probably old roots, wood or other organic matter and also the accompanying microbial flora. These small arthropods probably provide a major food source for the predator groups. Other prey may comprise herbivores which feed on the few plants which have established, or winged insects alighting in the area.

Implications of the Study

This study has revealed differences in the range and abundance of various taxa and of species richness of at least one group, the ants, in mine pits revegetated by different approaches. It is now possible to discuss the implications of the findings to some of the points raised in Section I of this paper.

It is essential that efficient decomposition, and hence nutrient cycling mechanisms, are established in rehabilitated areas. Springett's (1976*a* and *b*) comparison of soil microarthropods in pine plantations and jarrah forest suggested that both ecosystems had similar densities of animals, although species richness was lower in the pines. Her parallel investigation of litter decomposition suggested that the impoverished pine fauna decomposed litter at a slower rate than fauna in the native vegetation. Prescribed burning of pines reduced microarthropod richness and abundance and resulted in a further reduction in decomposition rate. No data are yet available on litter decomposition in the mine pits although Springett's work suggests that it would be slower in the planted plot than in the seeded area.

Efficient soil turnover and aeration mechanisms are also desirable for successful rehabilitation. Termites and ants are of major importance in this regard. Termites have not yet established large colonies in any of the mine plots studied although ants have reached high densities in the seeded plot. Most species are soil nesters. The greater abundance and diversity of ants in the seeded plot suggest that pedological activity would be greater here than in the planted plot.

It was mentioned earlier that the presence of invertebrates is necessary for the return of certain insectivorous vertebrates. The relative abundance and diversity of invertebrates in the revegetated plots indicates that the seeding of mines is more likely to encourage such vertebrates than is the planting approach.

Finally, it should be mentioned that, at least in the case of the ant fauna, the seeded plot shows the greatest similarity to the forest control plot in terms of the species present, species diversity and ant density. This suggests that this rehabilitation approach is producing a regrowth which, of the two types investigated, is most similar to that of the forest in terms of its invertebrate fauna.

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