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SOIL AND LITTER INVERTEBRATES OF SOME AUSTRALIAN MEDITERRANEAN-TYPE ECOSYSTEMS.

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PREFACE

Francesco di Castri

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When I attempted in 1973 and 1981 to compile a synthesis of our knowledge of soil zoology in the five regions of the world with a mediterranean type of climate (di Castri 1973, di Castri and di Castri 1981), admittedly an almost impossible task because of the great differences in approach, methods and objectives of the research, I stressed how essential but equally how scanty was the information available to me for the south- and western Australian ecosystems. This was in spite of the excellent and pioneering work carried out by a handful of research workers such as Wood, Lee, Marion Specht and Penelope Greenslade.

As a matter of fact, because of historical reasons, research on soil zoology developed first in the northern Mediterranean countries, then in Chile and South Africa, and only in more recent times in the southern Mediterranean Basin regions, Australia and California. In the last two regions there was no relation between their very advanced research on plant and animal ecology of the above-ground systems and the paucity of data on soil zoology.

Nevertheless, knowledge on the soil fauna of Australia is indispensable in order to place in focus our overall understanding of the structure and functioning of the mediterranean climate soil systems. Nowhere else more than in Australia is the influence of the soil conditions of such paramount importance in shaping the characteristics of the whole ecosystem; nowhere else do more drastic differences in soil patterns exist over very small topographic gradients; nowhere else is the weight of very old ecological factors so determinant in terms of soil genesis and biogeographical origin of the living components of soil. This is the main feature, if an evolutionary approach is adopted, of a "southern ecology" as compared with a "northern ecology" controlled by more recent factors.

I was therefore extremely pleased and stimulated when last August in Perth I discovered a blooming of interest and of research activity on soil zoology among my Australian colleagues. Their recent findings can conversely have a great influence on further development of this kind of research in countries with an older tradition in soil zoology, where comparison with Australian and South African soil systems should provide a basis to test a number of working hypotheses. The need for a more "comparative" ecology is something vital for upgrading ecology as a more predictive science.

In the light of the above considerations, I want to express to my colleagues and friends, Penelope Greenslade and Jonathan Majer, how honoured I feel having been asked by them to write a preface to this compendium of the results of research carried out mainly in Australian ecosystems. I am sure that this publication will provide a most useful insight for soil zoologists all around the world and particularly for those of the mediterranean climate regions. I have also no doubts that a number of joint intercontinental research efforts will emerge as a result of the dedicated work of the editors and the authors of this volume.

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EDITORS FOREWORD

These short papers arose out of a need to collect information on soil and litter invertebrates of mediterranean type ecosystems in Australia for a series of publications on the biota of mediterranean regions of the world. A large portion of south western and south-eastern Australia experiences this type of climate. Other mediterranean type regions are found in Chile, California, South Africa and of course Europe. The information sought fell into the following categories: composition, density, diversity or species richness, and phenology of the fauna and the affect of perturbations such as wild-fire or prescribed burning on this fauna. In this collection of supplementary papers a wide range of taxa are mentioned but, not surprisingly, coverage of these taxa has been uneven and dependent on what information was available from various specialists. We hoped that, if unifying features of mediterranean faunas exist, their characteristics might emerge on examination of the data that we have collected. We hoped as well that some indication of the origin of these relatively recently evolved ecosystems might emerge.

We have been particularly fortunate in Australia in the large number of invertebrate specialists here who have been enthusiastic about the project and who have supplied data and we would like to thank them for their contributions. It is planned that a synthesis of the information presented here, together with any other relevant data published earlier, will be prepared for Volume 1 of the series 'Mediterranean type and related ecosystems' to be edited by R. Specht and his colleagues.

We are also sincerely grateful to the five organisations listed below who supported this publication financially.

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PENELOPE GREENSLADE

JONATHAN MAJER

June, 1985

SOIL AND LITTER INVERTEBRATES OF THE SOUTH WEST BOTANICAL PROVINCE OF WESTERN AUSTRALIA

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Except where indicated, data for this chapter have been collected in the South-West Botanical Province of Beard (1980). This south-western extremity of the State has a winter rainfall ranging from 300-1500 mm and contains vegetation associations of heath, thicket, mallee, woodland and forests.

Collation of data on density, species richness, seasonality and succession of soil and litter invertebrates has been limited by the amount of available data. The data are therefore not uniformly drawn from across the taxa or the regions within this Province.

Interpretation of the data has been kept to a minimum. However, for readers who require more information on a particular subject, key references are given at the end of each section.

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SPECIES RICHNESS OF SCORPIONS (Scorpionida) AND SCOLOPENDRID (Scolopendridae) CENTIPEDES IN SOUTH-WESTERN AUSTRALIA

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These two groups are predators (carnivores) with mainly nocturnal feeding activity. The data are from specimens obtained mostly by opportunistic collecting; nevertheless this collecting has been relatively thorough. The species richness values for Australia, Western Australia and the South-West Botanical Province are shown below.

Table 1. Numbers of species of scorpions and scolopendrid centipedes.

	Australia	W.A.	Southwest Botanical Province
Scorpions	29	19	7
Centipedes (family Scolopendridae only)	33	21	9

The numbers of species collected within each Australian National 1:250,000 map boundary is shown for the South-West Botanical Province in Figure 1.

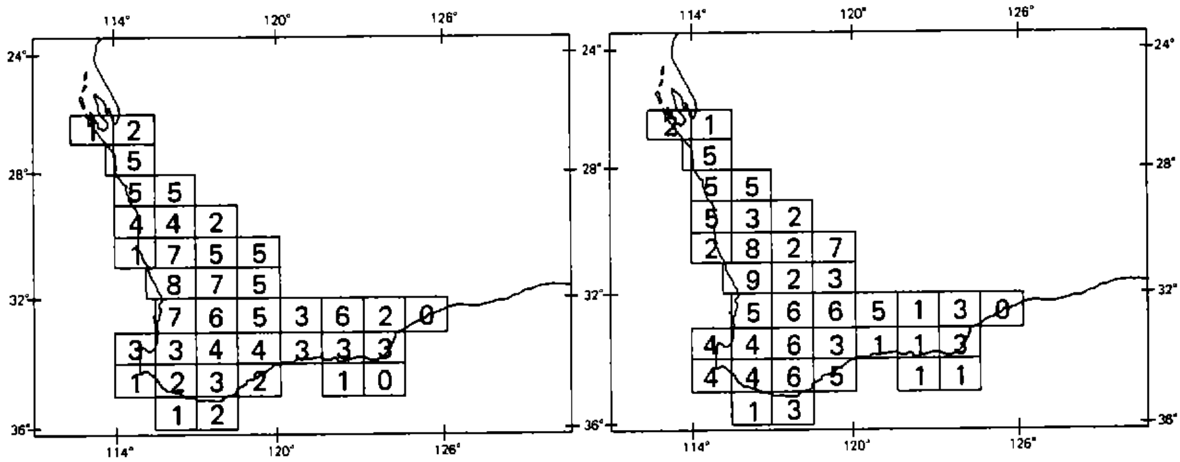

Figure 1. Number of species of (a) scorpions and (b) scolopendrid centipedes in 1° x 1.5° grids overlying the South-West Botanical Province.

These maps reveal no obvious trends in species richness of either group. It is interesting to note that there appears to be as many species in the wheatbelt area as in those areas less disturbed by man.

Soil and litter invertebrates of Australian mediterranean-type ecosystems (Ed. Penelope Greenslade and J.D. Majer). WAIT School of Biology Bulletin, No. 12.

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RICHNESS OF SPIDERS (Araneae) IN SOUTH-WESTERN AUSTRALIA

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The spider fauna of Australia, compared to that of Europe, is still poorly known taxonomically at the generic and species levels. It has been estimated from surveys in eastern Australia that 60 to 80% of species collected are undescribed (Gray 1976). Most females also require taxonomic revision. Because of such inadequacies it is difficult to make meaningful numerical comparisons at the generic and species levels between south-western W.A. and other regions of Australia. Therefore comparative figures are given here for (a) families and (b) genera of Mygalomorphae. Even these figures can expect to be modified when several current studies are completed.

Although this section ostensibly deals with only soil and litter invertebrates, all families of spiders are considered. While some families are exclusively terrestrial, many have both terrestrial and arboreal (corticolous and foliage-dwelling) representatives. Even those which are predominantly "space-dwelling" i.e. aerial web-builders e.g. Araneidae, have some representatives which attach their webs to the ground or are small and live within the litter. Very few families, e.g. perhaps the Oxyopidae and Thomisidae, could be considered almost exclusively non-terrestrial.

Families and genera of spiders

Table 1. Family classification based on Levi (1982) plus seven families accepted by various authors. The table extends the family names presented in Main (1981). Mygalomorphae families and genera based on Main (in press).

	Australia	W.A.	South-west Botanical Province	
			(including karri, Stirling/Porongorup Ranges, south coast)	(excluding karri, etc.)
Total families	63	45	45	37
Mygalomorphae				
Families	7	5	5	5
Genera	41	20	18	15

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SPECIES RICHNESS OF DUNG BEETLES (Scarabaeidae) IN SOUTH-WESTERN AUSTRALIA

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Most dung beetles (Scarabaeidae: Scarabaeinae and Aphodiinae) of south-western Australia are endemic to this region and are active during the winter. The abundance and species richness of dung beetles was investigated in natural heath and forest habitats in June and July 1980 and again in 1982.

Dung beetles were collected in pitfall traps baited with 5-6 ml human dung placed on a thin wood strip over a waxed paper cup (80 mm diam), sunk so that the top was level with the soil surface, and containing 20 mm of ethylene glycol as an odourless preservative. A rain shield was placed over each container. In 1980 ten traps were set and left for 5 days at each of 40 sites throughout the region south of Busselton (33° 39'S) and west of the Stirling Range (118° 31'E). From vegetation data all sites were classified into three habitat types based on those of Specht (1970);

1) Tall open forest (mostly karri **Eucalyptus diversicolor**)
2) Open forest (mostly jarrah E. **marginata**) and
3) Heath (including E. **wandoo** woodland).

In 1982 traps were set for 7 days at each of 16 sites in national parks at Badgingarra (30° 24'S, 115° 27'E) and Watheroo (30° 12'S, 115° 50'E).

In the southern areas species richness was greatest in heath (Table 1). Numbers of beetles/site of the tribes Onthophagini and Aphodiini were greater in heath and open forest than in tall open forest ($P < 0.01$), and numbers of species/site were greater in heath than in tall open forest ($P < 0.01$). In contrast numbers of beetles of the tribe Scarabaeini did not differ significantly between sites and numbers of species of Scarabaeini/site were greater in open forest than in other habitats. In the northern sites some different species were involved but the same relative abundance and numbers of species of Onthophagini and Aphodiini were evident (Table 1). There was a significant positive correlation between the quantity of dung, estimated from quadrats at each trap, and numbers of Onthophagini ($r^2 = 0.55$). Aphodiini were more abundant at Badgingarra where their abundance was also positively correlated with quantity of dung ($r^2 = 0.60$).

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Table 1 Abundance and species richness of dung beetles

TRIBE	SOUTHERN AREAS*			NORTHERN AREAS**
	Tall open forest	Open forest	Heath	Heath
	n=12	n=14	n=11	n=16
	Mean no. beetles/site			
Onthophagini	3.7	45.6	124.7	35.7
Scarabaeini	12.1	53.0	59.9	2.5
Aphodiini	20.9	823.0	443.5	987.7
	Mean no. species/site			
Onthophagini	0.7	1.8	2.8	2.3
Scarabaeini	0.4	1.1	0.5	0.3
Aphodiini	0.8	1.8	2.2	2.9
Total no. species	10	10	16	11

n = number of sites

Onthophagini and Aphodiini have a strong preference for dung baits over carrion baits (Ridsdill Smith *et al.* 1983), and the relative success of these tribes in heath is probably due in part to the observed abundance of macropod dung in this habitat.

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SPECIES RICHNESS OF GEOTRUPINE BEETLES (Scarabaeidae: Geotrupinae) IN SOUTH-WESTERN AUSTRALIA

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The Geotrupinae are a subfamily of scarab beetles that are well represented in Australia by approximately 150 species belonging to 10 genera, all in the tribe Bolboceratini (see Howden, 1981). All species make vertical or sinuous burrows, forming their brood cells at some depth and provisioning the cell with surface humus. The distribution of various species seems to be most strongly influenced by soil type (sand, sandy loam, clay) and by the amount of moisture. The type of ground cover and temperature appear to be of secondary importance. Surface activity of the adults is related to the presence and abundance of underground (just below the surface) fungi which the beetles utilize as food, hence activity is greatest in late winter and spring in southwest Western Australia. Occasional bush fires apparently have little effect on populations, but clearing and cultivation, which destroy both the humus layer and fungi, eliminate the Bolboceratini fauna. Survival is possible in small "reserves" and along roadside nature strips.

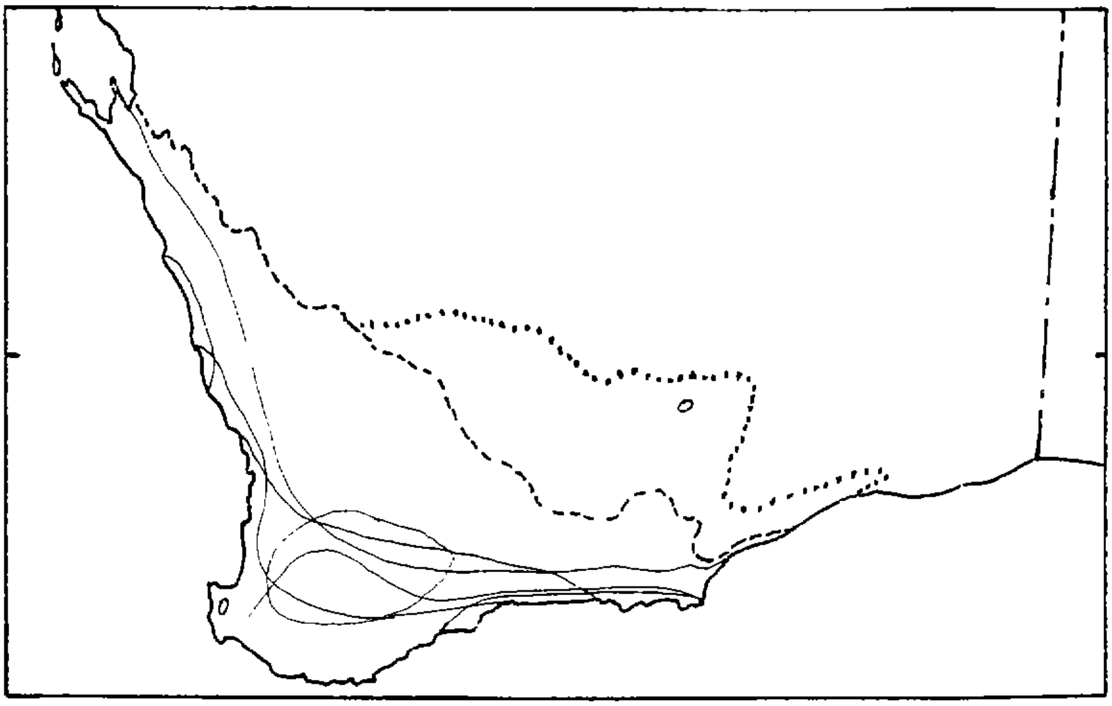

Figure 1. The approximate ranges of the three species of Stenaspidius and six of Bolborhachium occurring in south-west Western Australia. Other species in both genera occur both to the north and in the eastern half of the continent.

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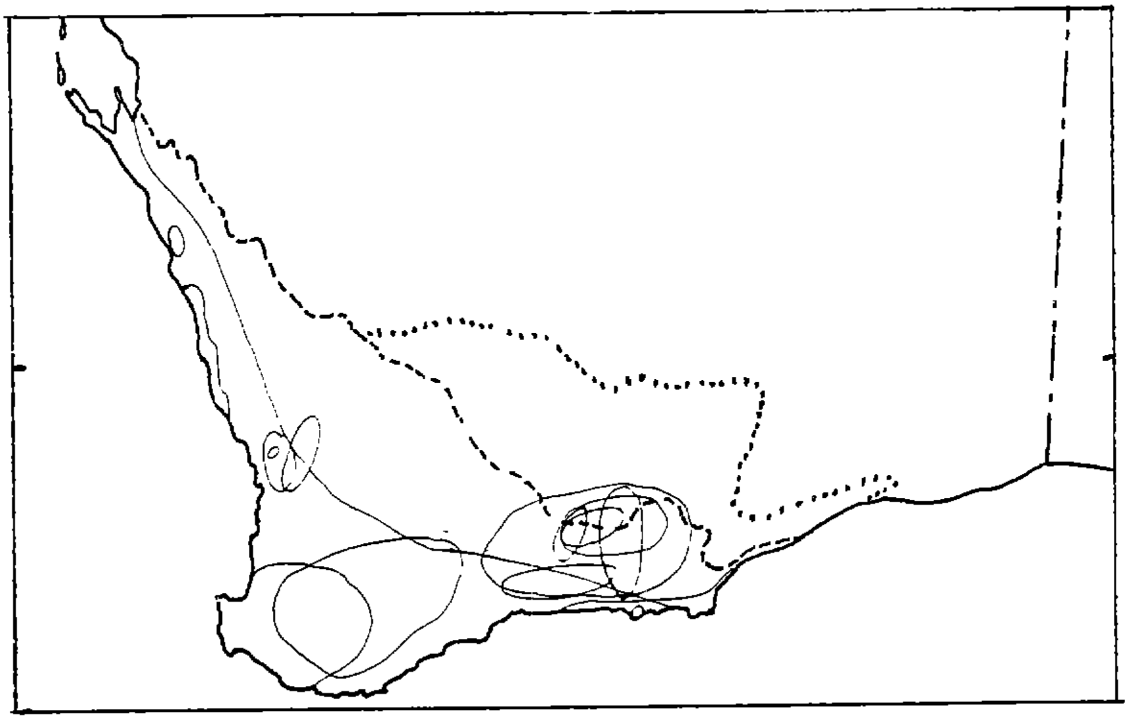

Figure 2. The approximate ranges of the 16 species of Blackbolbus occurring in south-west Western Australia. Most of the remaining 12 species in the genus are concentrated in South Australia and New South Wales. The numerous restricted ranges indicate a relict group. Some species could easily be eliminated by clearing for agriculture.

Of the ten genera, seven have at least one species ranging into the South-West Botanical Province, while three genera have one or more species restricted to the Province. Of the latter, **Stenaspidius** has three of six species; **Bolborhachium** six of 25; and **Blackbolbus** 16 of 28. Thus 16% of the species of Australian Geotrupinae are restricted to the south-west corner of Australia.

Reference

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SPECIES RICHNESS OF ANTS (Formicidae) IN SOUTH-WESTERN AUSTRALIA

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Ants, in terms of their abundance, species richness, activity and energy consumption, are one of the most important components of Australian ecosystems. They generally occupy the higher trophic levels and many species have specialised feeding, nesting or foraging habits.

A number of ant surveys have been performed in heath, forest and woodland in the South-West Botanical Province (Majer 1983). All surveys utilised a combination of pitfall trapping and hand collection. Traps consisted of Pyrex test tubes of 18 mm internal diameter. These contained an alcohol/glycerol preservative which is not attractive to ants. Hand collections were performed for a minimum time of 1 person-hour during the day and were repeated, whenever possible, at night. Two basic trap configurations were utilised: grids, in which permanently established traps were installed as a 6 by 6 grid with 3m between each trap, and transects, in which 20 or 40 traps were installed in a given habitat. Traps were either placed at regular intervals along a straight-transect or at various sites along a meandering-transect so that they drew samples from the major habitats of the area. In the case of both grids and transects the traps were left open for 7 days following a 1 week settling-in period designed to minimise digging-in effects.

In addition to these surveys, the Western Australian Museum sampled ants in the semi-arid Eastern Goldfields using large diameter pitfall traps located beneath 50 m drift fences. Eleven sites, each with from 6 to 9 sub-sites, were sampled in each of three seasons between 1978 and 1981. The sampling regime, methods and site characteristics have been described elsewhere (Biological Surveys Committee, in press). Although outside the area of interest, the results of this survey are presented here since they show trends in ant species richess immediately outside the South-West Botanical Province.

The total number of ant species collected at each of the sites studied is shown in Figure 1.

Interpretation of the data should take into account the fact that sampling regimes were not standardised. All values were under-estimates of the true count as litter or subterranean species, or those which were only active during certain seasons, were not well sampled. The variation in values over small distances (e.g. south of Perth) reflects variations in sampling intensity. However, when this is accounted for there appears to be no trend in species richness in the heath, forest or woodland of the South-West Botanical Province. The generally lower species richness values in the Eastern Goldfields is probably due to the reduced sampling intensity used here. Three of the most westerly Goldfields sites had more than 40 species, the two northern most sites had less than 29 and the rest had intermediate species richness values. This north or north-west trend of decreasing

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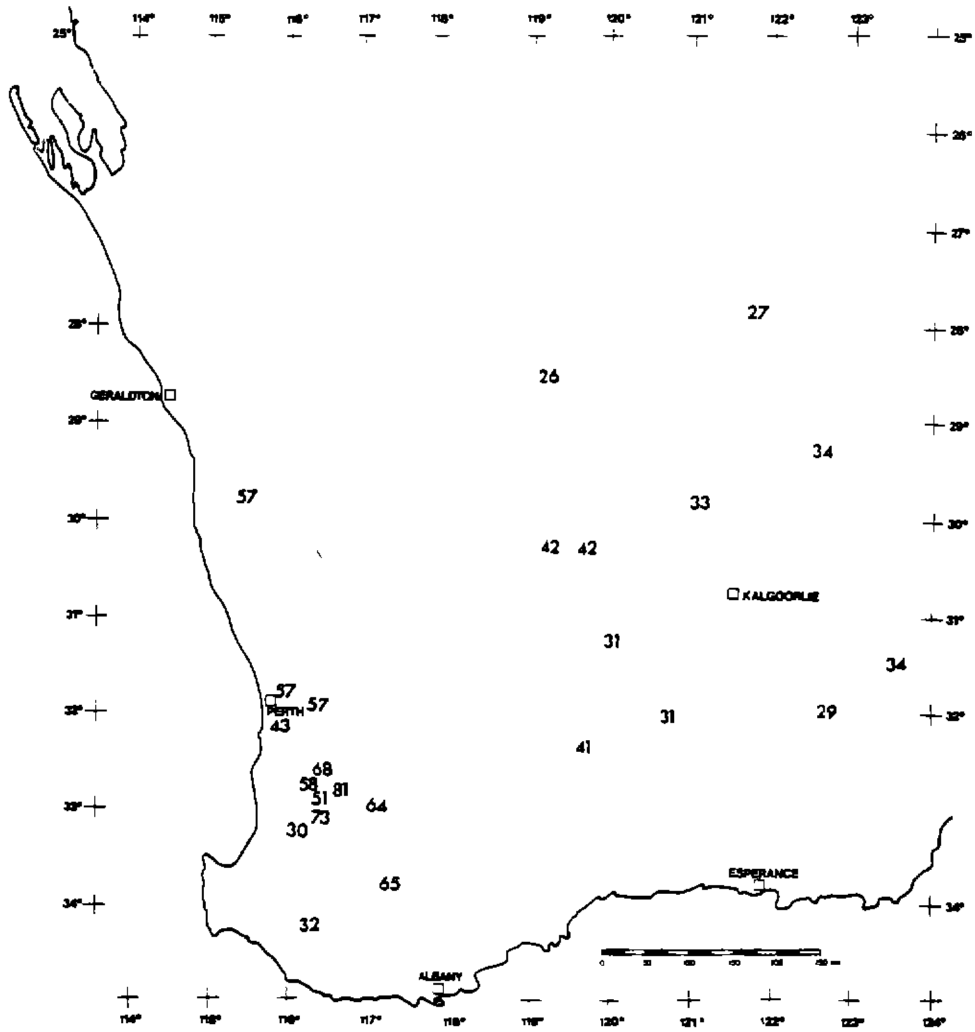

Figure 1. Ant species richness values obtained by pitfall trap grids, transects or large-diameter pitfall traps in the South-West Botanical Province and Eastern Goldfields.

species richness follows the trends of decreasing rainfall and increasing climatic uncertainty and is also consistent with the accepted view that plant species richness declines in this direction.

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DENSITY AND SEASONALITY OF SOIL AND LITTER INVERTEBRATES AT DWELLINGUP

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The density and seasonality of soil and litter invertebrates have been investigated in 11 jarrah (Eucalyptus marginata) forest plots near Dwellingup (32°42'S, 116°02'E). Plots were chosen to investigate differences in soil invertebrate density and seasonality on different soil types with different moisture levels.

Invertebrates were sampled at monthly intervals from June 1980-December 1981. At each of 20 randomly selected points in each plot litter was removed from a 19 x 19 cm quadrat, bulked and sealed in a polyethylene bag. Invertebrates were extracted from the bulked samples in a Berlese funnel. The temperature in the funnel was raised from ambient to 40°C over a 1 week period. Soil cores (54 mm diameter, 97 mm deep) were collected from below the litter samples and extruded into plastic sleeves. Animals were extracted from individual soil cores using a multiple canister heat extractor in which the temperature regime was the same as that for the litter extractor.

Numbers of both soil and litter invertebrates in samples varied with season. Peak numbers occurred in early-winter with a lower peak in early-spring. Density of all taxa varied between plots so data from an average plot, 4PM, are presented here as a typical example of the results. For brevity, data from only five months, representing different seasons are given.

Invertebrates were over 40 times more abundant in the soil than litter. In both strata the samples consisted predominantly of mites (up to 92.6% and 77.5% of total soil and litter fauna respectively) and the second most abundant group was the springtails (up to 16.9% and 39.0% of total soil and litter fauna respectively).

The only comparable figures from the south-west of Western Australia are those of Majer (1984) for Karragullen (32°07'S, 116°04'E) jarrah forest and Springett (1976) for Swan Coastal Plain (31°47'S, 115°52'E) Eucalyptus/Banksia woodland. Majer's samples were collected in the same way as the Dwellingup ones although Springett sampled fauna in the top 25 cm of soil with the litter layer unseparated. Majer's combined soil and litter density values ranged from 5,519 m^{-2} in June to 28,495 m^{-2} in November while Springett found 77-100,000 animals m^{-2}. Densities in the pesent study (Postle, 1984) range from 40,676 m^{-2} in December to 136,860 m^{-2} in April.

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Table 1 - Mean number of invertebrates per m^{-2} of soil (top 97 mm) and litter at different seasons.

Taxon	Spring Oct.1980		Summer Dec.1980		Summer Feb.1981		Autumn Apr.1981		Winter Jul.1981	
	Soil	Litter	Soil	Litter	Soil	Litter	Soil	Litter	Soil	Litter
Nematoda		2					87	6		
Arachnida Pseudoscorpionida	218	39			87	20	87	59	44	17
" Opiliones	22	2							22	
" Acarina	53,886	750	36,491	977	78,788	2,061	119,950	1,691	55,698	1,395
" Araneae		43		28		59		42		31
Crustacea Isopoda	22	17				20	44	25	22	
Diplopoda	22	47	87	9		45	87	62	44	58
Chilopoda	130	9	44		44	6	44	9	175	4
Symphyla	437	31	306		742	9	1,309	9	1,615	2
Pauropoda	873		44		1,179	168	1,309	76	1,571	21
Collembola	4,409	790	1,615		5,238	269	8,905	605	12,222	566
Protura	196		87		306		567		153	
Diplura	131		44		44	3	44	3		
Insecta Thysanura						6		3		
" Blattodea		2								
" Isoptera	371					3		11		
" Dermaptera	22									
" Orthoptera Tettigonioidea		2								
" Embioptera										2
" Psocoptera	196	9	131	90	175	143		11		
" Homoptera		2		3	87	9	393	3	44	
" Heteroptera	22	2				34	87	56	44	31
" Thysanoptera		18	87	48		56		25		4
" Coleoptera adults	240	97	87	3	349	65	349	98	415	34
" " larvae	153	107	262	56	218	112	87	70	44	9
" Diptera adults		9	87		655	9		6	22	6
" " larvae	66	20		6		6	262	70	153	52
" Lepidoptera adults		4		3						
" " larvae		16	44	28		95		22	22	6
" Hymenoptera ants		3		9	44	193	87	177		4
" " others		6			44	6		23	22	
TOTAL INVERTEBRATES PER STRATUM	61,416	2,027	39,416	1,260	88,000	3,397	133,698	3,162	72,376	2,242
TOTAL INVERTEBRATES OVERALL	63,443		40,676		91,397		136,860		74,618	

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SEASONALITY OF EPIGAEIC INVERTEBRATES AT PERTH, DWELLINGUP AND MANJIMUP

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The seasonality of soil and litter invertebrates has been studied for 1 year in woodland at Perth (31°57'S, 115° 47'E), and forests at Dwellingup (32° 52'S, 116° 13'E) and Manjimup (34° 19'S, 116° 11'E). These sites represent a southerly gradient of decreasing temperatures, increasing humidity and generally less marked seasonality of climatic variables.

Invertebrates were collected in pitfall traps (1.8 cm diameter, containing a mixture of alcohol and glycerol (70/30 v/v)) positioned 3 m apart in a 6 x 6 grid at each site. Traps were run for 7 days in each month from March 1976-February 1977. The numbers of animal species trapped per month are given below in order to provide an index of activity. Figure 1 is a schematic representation of the seasonal patterns and shows the seasonal relationships rather than the actual values for the index of activity.

Table 1 - The numbers of species trapped per month and also the total species and individuals of herbivores, parasites/predators, and decomposers trapped at each of the three sites.

(a) Hexapods

Site	1976 M	A	M	J	J	A	S	O	N	D	1977 J	F	Total species trapped at site	Total individuals trapped at site
						Herbivores								
Perth	7	6	2	3	4	4	3	4	5	5	7	5	21	314
Dwellingup	8	2	4	4	6	1	2	6	3	7	4	3	28	98
Manjimup	4	2	2	3	1	2	1	0	2	3	5	1	22	99
						Predators and parasites								
Perth	6	5	6	8	5	6	10	6	8	5	5	4	17	2852
Dwellingup	8	8	6	6	8	4	7	5	11	4	7	4	23	1250
Manjimup	5	3	8	4	3	2	5	5	3	4	3	4	14	364

(b) Other invertebrates

Site	M	A	M	J		A	S	O	N	D	J	F	Total species trapped at site	Total individuals trapped at site
							Decomposers							
Perth	0	1	0	0	2	1	2	6	1	0	0	0	8	26
Dwellingup	0	0	1	2	1	0	3	2	3	2	0	0	8	19
Manjimup	3	1	0	0	0	0	0	0	3	1	3	2	3	65
							Predators							
Perth	6	4	5	8	5	5	6	6	8	6	7	6	19	1065
Dwellingup	7	11	2	4	8	6	10	9	10	10	8	5	21	582
Manjimup	4	4	4	2	1	4	3	1	4	3	3	3	13	341

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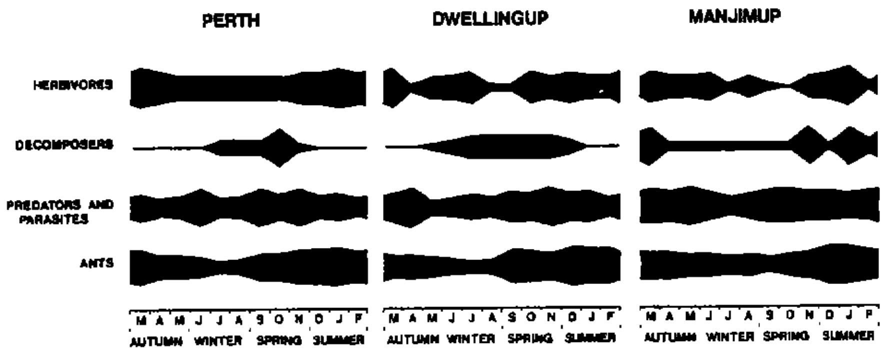
Figure 1 - Schematic diagram of the seasonal activity of herbivores, decomposers and predators/parasites, at Perth, Dwellingup and Manjimup. The width of the bar indicates the level of activity as measured by the numbers of species in each category collected in the pitfall traps.



The herbivore activity is negatively correlated with rainfall at these three sites, and it increases during spring (Figure 1). Spring is the period when many understorey shrubs exhibit growth flushes, owing to the increase in available moisture and the warmer temperatures. The decrease in herbivore activity during the cooler months at all three sites might be connected with the contemporaneously slower growth rate of certain plant species, the direct influence of climatic factors on the life cycles of the herbivores or it might be a combination of both factors. Thus the decreases in activity of the herbivores at Dwellingup (during August-September) and at Manjimup (during June-October) (Figure 1) may be due to the low temperatures during these months.

The length of decomposer activity increases progressively from north to south (Figure 1). It is largely restricted to the wetter months at Perth and Dwellingup and continues throughout the year at Manjimup. This is probably because humid conditions are apparently present for longer at Manjimup. Compared to the decomposers, the activity of the predator/parasite category appears less dependent on season. This is probably because a wide range of organisms, with different feeding preferences and whose activities are not in phase, are preyed on or parasitised. The only trends detectable are slight increases in the activity of predators and parasites in the spring and autumn at Perth and Dwellingup (Figure 1), probably due to the increases in herbivore numbers during those seasons.

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SEASONALITY OF ANTS (Formicidae) IN SOUTH-WESTERN AUSTRALIA

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Data on seasonality of ants are presented separately to those on other epigaeic invertebrates in view of the dominance of this group. Data on foraging activity have been gathered from permanently placed pitfall traps (described in the last paper) situated throughout the South-West Botanical Province. Selected data are here shown to illustrate the main seasonal trends. Seasonal data on winged ant flight activity have also been obtained by a suction trap situated in open woodland at Jandakot (32°10'S, 115°49'E). The trap design was based on the Johnson and Taylor (1955) 18 inch propellor model and was run by Dr J.C. Taylor.

Figure 1 shows the seasonal catch of 19 ant species in agricultural land at Katanning (33°39'S, 117°34'E). The trends are similar to those observed in native habitats except that fewer species are present. All species were strongly seasonal in their activity and maximum foraging occurred between late-December and March. This corresponds with the warmest and driest part of the year and also to the period of seed dispersal in the crop.

Those species which are less dependent on seeds for their diet exhibited less marked seasonal patterns. This is further illustrated by comparing the number of individuals of **Melophorus** sp. 1 (ANIC), which depends heavily on seeds, with **Rhytidoponera inornata**, an omnivore, in pitfall traps run in jarrah forest (Figure 2). **R. inornata** foraged throughout the year, albeit with a winter trough, whereas **Melophorus** sp. 1 exhibited a summer peak and ceased foraging completely from March or May until October. Seed production was not measured directly in the study sites but most species would produce seed in the period of 1 to 3 months after the October flowering peak (Figure 2). The proportion of seeds in the diet of **Melophorus** sp. 1 reflects this peak although invertebrate material is also consumed outside this period. The lack of winter foraging may be an adaptation to the paucity of available seed during this period. Although there are no data on monthly variation in diet composition for **R. inornata**, its year-round foraging probably reflects its ability to switch from a high-seed diet during summer to a winter diet rich in invertebrates, particularly those associated with decomposition (see previous section).

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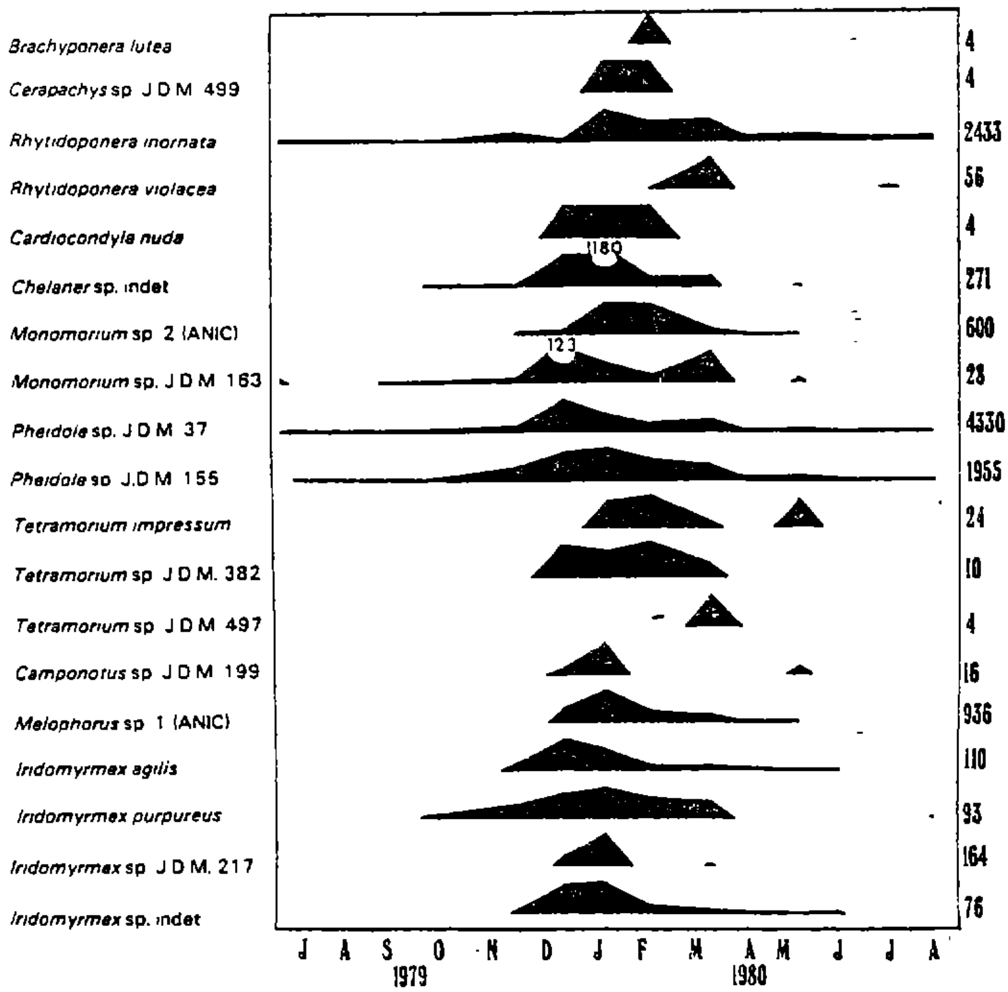

Figure 1. Total ants (1148 trap nights mo^{-1}) obtained at Katanning between July 1979-August 1980. Except where indicated the number to the right of each graph is the maximum monthly catch and the data are scaled with respect to this.

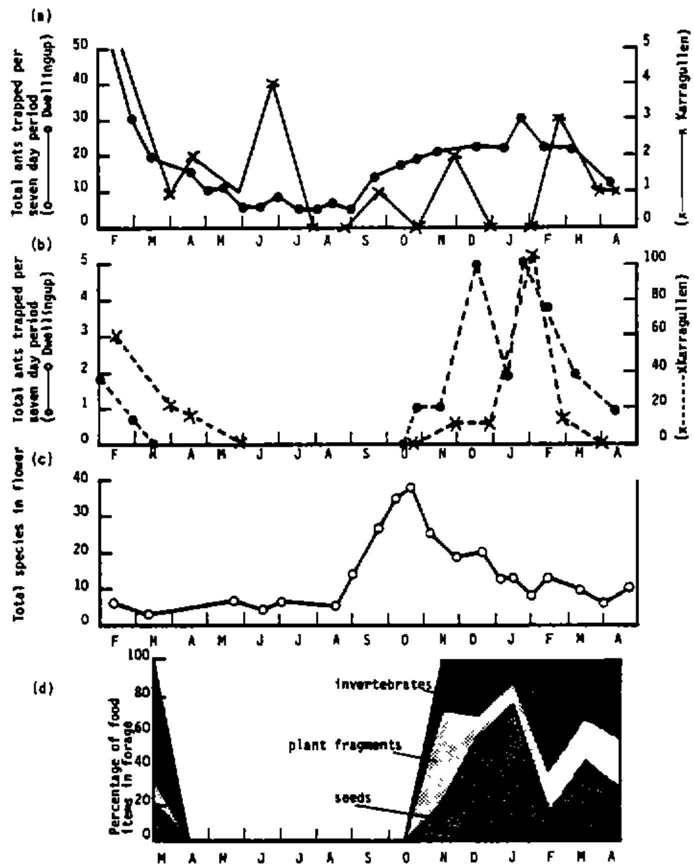

Figure 2. Total Rhytidoponera inornata (a) and Melophorus sp. 1 (b) ants trapped per month in pitfall trap grids run at Dwellingup (32°47'S, 116°11'E) between 1975-76, and Karragullen (32°04'S, 116°07'E) between 1978-79. The third graph (c) shows the total number of plant species in flower at the Karragullen site between 1978-79, and (d) indicates the percentage composition of food items collected from foraging Melophorus sp. 1 workers at Karragullen over the same period (from Majer 1982).

Figure 3 shows the number of male and female winged ants sampled per month between January 1973-December 1974. Males provide a better indication of seasonality since they were most frequently trapped. However, the trends of both sexes are generally in concordance.

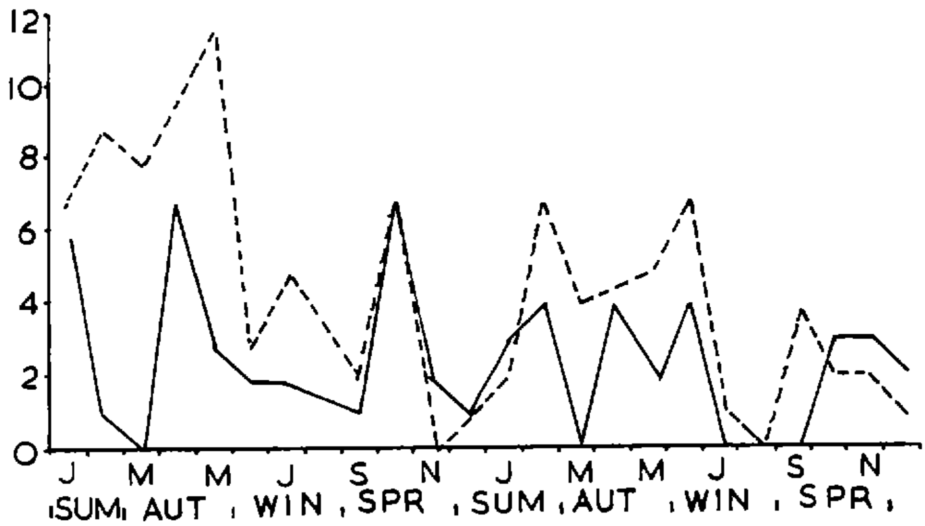

Figure 3. Total male (-------) and female (________) winged ant species sampled per month by suction trap near Jandakot.

The distribution of flight peaks suggests that the Jandakot ant fauna exhibits two basic flight patterns - the majority flying between late-summer to early-winter and others in spring. A few species flew in winter and mid-summer. A number of points may be made. The first is that the major period of winged ant dispersal is equivalent to that of temperate northern hemisphere ants. Secondly, since most females are likely to be establishing nest sites during a period of reduced foraging (winter), the chances of immigrants being predated by existing colonies is minimised. The existence of the smaller spring flight peak may indicate an alternative dispersal strategy adapted to compensate for winter mortality.

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INDIGENOUS EARTHWORMS (Megascolecidae sensu Jamieson) IN JARRAH FOREST OF WESTERN AUSTRALIA

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Number of species

Thirty-three species of native earthworm were described by Michaelsen from the 1905 Hamburg/Southwest Australian expedition. A striking finding was that species had quite localised distributions. Since then there has been very little collecting. In 1980 I began to collect opportunistically. The number of new species collected indicates that the native earthworm fauna for south-western Australia will prove to exceed 100 species, making this the richest worm fauna in Australia. Taxonomic help is required so that the newly discovered species can be formally described.

Phenology

Studies in jarrah forest 25 km SE of Dwellingup (32°43'S, 116°04'E) show that activity of earthworms in topsoil is confined to Autumn, Winter and Spring, when soil moisture exceeds wilting point.

Fire

Natural 'experiments' in jarrah forest 12 km NE of Jarrahdale (32°20'S, 116°03'E) show that low intensity Spring fires (<300 kw m^{-1}) showed no effect on density or biomass. A direct experimental study using a moderate intensity (summer) fire (>700 kw m^{-1}) showed no effect on density or biomass.

Density and biomass

Densities range from 10-40 m^{-2} (to a depth of 15 cm) and biomass (wet weight) from 1-7 gm^{-2}. Earthworms contribute most of the soil animal biomass in the jarrah forest.

Other work

Studies of the effects of silviculture and other land uses on jarrah forest earthworms are in progress.

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A REVIEW OF PYRIC SUCCESSION OF SOIL AND LITTER INVERTEBRATES IN SOUTH-WESTERN AUSTRALIA

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Studies on effect of fire on soil and litter invertebrates are summarised here in note form.

Author	- McNamara (1955)
Location	- Dwellingup (32°47'S, 116°11'E) jarrah (Eucalyptus marginata) forest
Technique	- Fauna of top 28.5 cm of soil extracted by Berlese funnel. Unburnt areas and annually burnt firebreaks compared but no pre-burn data collected.
Results	- Numbers of animals, scored at the order or class level, less in annually burnt areas than unburnt forest.

Author	- Springett (1971)
Location	- Gnangara, Perth (31°47'S, 115°52'E) Pinus pinaster plantation
Technique	- Fauna of top 20 cm of soil sampled by heat extractors from burnt and unburnt plots on three occasions. No pre-burn data collected.
Results	- If scored at order or class level the fauna seemed to have recovered within 3 years of burning. However, significantly less specialised fungal feeders present after this period in the burnt plot.

Author	- Springett (1976)
Location	- Pemberton (34°27'S, 116°02'E) karri (Eucalyptus diversicolor) forest and Dwellingup (32°47'S, 116°11'E) jarrah (Eucalyptus marginata) forest
Technique	- Mesofauna hand sorted from 0.1 m^2 soil samples taken from regularly burnt plots and unburnt controls. No pre-burn data collected
Results	- In both native forests, species diversity and density reduced after burning and did not recover to their pre-burning levels during a normal 5 to 7 year prescribed burning rotation.

Author	- Springett (1979)
Location	- Dwellingup (32°89'S, 116°15'E) Jarrah forest
Technique	- Micro-arthropods obtained from top 15 cm of soil and litter by heat extractors. A hot burnt (600 kW m^{-1}) area was surveyed 14, 15 and 16 months after the burn and comparisons were made with an unburnt area
Results	- The density and diversity of arthropods, the proportion of juveniles and the proportion of fungal feeders were all lower in the burnt plot than the unburnt plot on each sampling occasion.

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Author	-	Majer (1980)
Location	-	Kojonup (34°02'S, 117°00'E) wandoo (Eucalyptus wandoo) woodland
Technique	-	Epigaeic invertebrates sampled by pitfall traps in a cool spring burnt and unburnt plot for 15 months prior to, and 12 months after the burn. Ants scored to species level but other animals to order level
Results	-	The catch of most surface-active invertebrates was depleted after the burn although ant species richness was not reduced. The density of many of the broad taxonomic groups had recovered within 12 months of the fire although that of certain taxa was depleted.

Author	-	Majer (1984)
Location	-	Karragullen (32°04'S, 116°07'E) jarrah (E. marginata) forest
Technique	-	Litter fauna extracted by Berlese funnel and fauna from top 10 cm of soil obtained by heat extractor, for one month prior to, and 13 months after a cool autumn burn. A control plot was also studied
Results	-	The soil and litter invertebrates, when considered at th broad taxonomic level, exhibited a range of responses to fire. These included immediate density reduction, delayed density reduction, temporary absence following fire, density stimulation or unaffected by fire. The effects of fire were still apparent in the litter fauna, and to a lesser extent the soil fauna, 13 months after the fire.

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ANT (Formicidae) SUCCESSION FOLLOWING MINESITE REHABILITATION THROUGHOUT AUSTRALIA

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The recolonisation of ants has been investigated in rehabilitated mines throughout Australia. Sampling has been performed in mines of differing rehabilitation ages using 100 m transects of 20 equidistantly spaced pitfall traps run for 7 days supplemented by hand collecting during day and night-time.

Increase in ant species richness per mine was generally linear over the first 3-5 years although trends became less clear thereafter. By comparing the number of ants in 3 year old mines throughout Australia there was found to be a cline in ant return rate from lowest in the drier Mediterranean climate areas to highest in the tropical monsoonal areas.

Table 1. Estimated number of ants found in 3 year old plots within mines situated in different climatic zones of Australia.

Location	Mine type	Climate type	Annual rainfall (mm)	Number of ant species
Eneabba, WA (29°49'S,115°16'E)	Sand	Mediterranean	550	6
Jarrahdale/Del Park, WA (32°20'S,116°07'E)	Bauxite	Mediterranean	1155-1287	10
Myall Lakes*, NSW (32°20'S,152°30'E)	Sand	Warm-temperate	1205-1362	11
Nth Stradbroke Island, Qld. (27°30'S,153°24'E)	Sand	Sub-tropical	1645	18
Gove, NT (12°30'S,141°50'E) Groote Eylandt, NT (13°59'S,136°28'E) Weipa, Qld. (12°15'S,136°53'E)	Bauxite or Manganese	Tropical monsoonal	1277-2083	22

* data from Fox and Fox (1982).

This cline in ant species richness appears to reflect climatic factors rather than differences in numbers of species of ants in native vegetation throughout Australia. It should be noted that ant return provides a good bio-indicator of abundance and richness of plants and other invertebrate animals (Majer 1983) so the cline in ant return roles may well reflect a gradient in general ecosystem recovery rates. It is suggested that low position of Mediterranean ecosystems on this gradient is related to the relatively low rainfall and the summer drought.

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SOIL AND LITTER INVERTEBRATES OF SOUTH AUSTRALIA

Penelope Greenslade (Co-ordinator)

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In South Australia a wide coastal belt of land experiences a mediterranean climate. This belt includes the Eyre, York and Fleurieu Peninsulas, the Mt Lofty Ranges and all the lower south eastern portion of the State. Moving north and further inland the rainfall becomes lower and less predictable.

The mediterranean climate region of the State (Figure 1) carries the following vegetation types: tall open forest and open forest, Eucalyptus obliqua - E. baxteri (nutrient poor); woodland, E. baxteri (nutrient poor) E. leucoxylon (nutrient rich); open scrub (mallee), E. incrassata - Melaleuca uncincta (nutrient poor), E. socialis, E. diversifolia (nutrient rich); heathland, dry heath. Data on soil and litter invertebrates has for the most part been collected in the Mt Lofty Ranges in open forest and woodland.

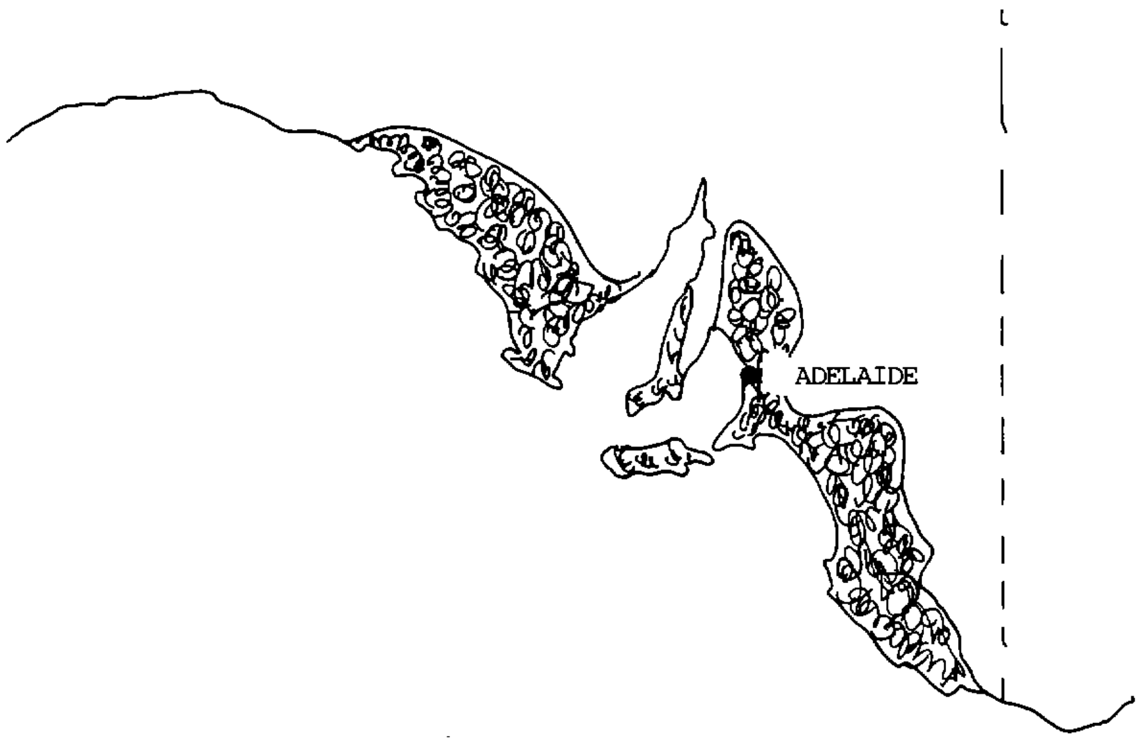

Figure 1. Area of South Australia subject to a mediterranean climate (hatched).

POPULATIONS OF COLLEMBOLA AND ACARINA IN LITTER AND SOIL OF SOUTH AUSTRALIAN FORESTS AND THE EFFECT OF A WILDFIRE

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A quantitative study of the soil and litter fauna of three South Australian low open forests, designated 'dry', 'medium' and 'wet', was made for 2 years.

Table 1. Site details

Site	Dry	Medium	Wet
Name/ Location	South Para Reservoir Reserve 37 km NE Adelaide 4 km W Williamstown PO	Hale Conservation Park 39 km NE Adelaide 25 km SE Williamstown PO	Engelbrook National Trust Reserve 25 km SE Adelaide 1.2 km SE Bridgetown PO
Grid Reference	184715 Adelaide 1:250 000 Sheet S1 54-9 Ed. 1 Series R502	190715 Adelaide 1:250 000 Sheet S1 54-9 Ed. 1 Series R502	177673 Barker 1:250 000 Sheet S1 54-13 Ed. 1 Series R502
Rainfall (mm)	635	690	1050
Elevation above sea level (m)	220-240	320-360	320-380
Vegetation	Ecualyptus obliqua - E. baxteri association, with dense heathy understory		
Soil type	Acid yellow duplex		
Climate	Mediterranean, hot dry summers, cool moist winters		

Monthly samples were taken of the litter (L), and the upper (SU) 0-4 cm and lower (SL) 4-8 cm soil layers. Three years after the initial study was completed the 'wet' site was subjected to a severe bushfire. Partly because of the detailed information we had regarding this site (Hutson and Veitch 1983) we decided to re-activate the original sampling program at the site, and started 1 month after the fire. Currently, 4 years of samples have been collected but only the fauna of the SU samples has been identified and counted; however, as over 70% of the fauna inhabited this layer at this site, some comparisons with pre-bushfire results can be made.

At each site an experimental area measuring 50 x 100 m was divided in plots 10 x 10 m. Each month 12 subsamples of litter (each 0.1 m^2 area) and 20 soil core samples (each 18.1 cm^2) from 0-8 cm depth were taken. The core samples were divided into 20

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upper soil (SU, 0-4 cm) and 20 lower soil (SL, 4-8 cm) subsamples. Sampling points were selected randomly, but with equal numbers of subsamples from each 50 x 50 m half of the sites.

The mean (arithmetic) % abundance of Collembola and Acarina in the three layers for the initial two year study are shown in Table 2.

Table 2. Mean (arithmetic) % abundance of Collembola and Acarina on the three sites

Group	Layer	Site		
		Dry	Med.	Wet
Collembola, Arthropleona	L	15	21	11
	SU	75	67	74
	SL	10	13	15
Collembola, Symphypleona	L	25	39	25
	SU	70	58	71
	SL	5	3	4
Acarina	L	12	13	10
	SU	72	66	72
	SL	16	21	18

The mean (arithmetic) abundance of Collembola and Acarina in all layers at each site are shown in Table 3. Data are available for the wet site after the fire from only the SU layer. Total figures for the wet site in the fourth year after the fire are estimated from these data. The percentages for the wet site are derived from Table 2.

Table 3. Mean abundance (no./m^2) x 10^3) of Collembola and Acarina at the sites

Group	Site			
	Dry	Med.	Wet	Wet (Fourth year after fire)
Collembola, Arthropleona	4.9	9.5	6.7	7.5
Collembola, Symphypleona	0.31	0.39	0.45	0.75
Acarina	35.1	48.6	45.0	45.0

The greatest proportion of animals inhabited the SU layer, with generally more Collembola in the L than SL layer, but more Acarina in the SL than L layer. The medium site had the greatest number of arthropleone Collembola and Acari and the abundance of these animals at the wet site has apparently not changed significantly since the fire. There has been an increase in symphypleone Collembola on the wet site since the fire. During the initial study the greatest number of animals occurred in the winter months on all sites; since the fire Acarina at the wet site have been consistently most numerous during the summer months.

Proportions of collembolan families and acarine orders are shown in Tables 3 and 4 respectively.

Table 4. Proportion (%) of Arthropleona in the Total Population (annual means) on the Sites.

Family	Site			
	Dry	Med.	Wet	Wet (SU layer only, fourth year after fire)
Neanuridae Hypogastruridae	8.5	7.2	5.9	9.5
Onychiuridae	6.3	6.0	8.7	26.3
Isotomidae	71.5	57.8	54.9	49.7
Entomobryidae	13.7	29.0	30.5	14.5

Table 5. Proportion (%) of acarine orders in the Total Population (annual means) on the Sites.

Order	Site			
	Dry	Med.	Wet	Wet (SU layer only, fourth year after fire)
Prostigmata	82.9	78.8	53.3	33.2
Mesostigmata	4.7	3.7	5.8	7.1
Cryptostigmata	11.9	17.2	38.6	57.7
Astigmata	0.5	0.2	2.3	1.9

The isotomid Collembola and prostigmatid Acarina were dominant on all sites. The proportion of Onychiuridae on the wet site has increased signficantly since the fire while the proportion of Entomobryidae has decreased significantly. Similarly with the Acarina, the Prostigmata have decreased while the Cryptostigmata have increased since the fire.

A more detailed analysis of the soil and litter fauna for the initial 2 year study can be found in Hutson and Veitch (1983). Work is continuing on the samples collected from the wet site since the fire and results will be published during 1985-86.

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SOIL AND LITTER ARTHROPODS FROM PINE PLANTATIONS IN SOUTH AUSTRALIA

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In South Australia successive rotations of plantations of the pine, **Pinus radiata**, on the same soils show a decrease in productivity, and the ground surface is often covered with a deep litter layer which implies a slow rate of decomposition. Although soil compaction has been implicated as the cause of this decrease in productivity the composition and density of the soil and litter fauna may also be of significance here. The fauna was sampled by taking soil cores (6.5 cm diam, 9.5 cm depth) from pine plantations of different ages and rotations at Mt Burr Forest (lat 37°33' long 140°30'), and extracting them in Tullgren funnels. The layer of needles above the soil was included in the sample.

No significant differences in density of arthropods were found between samples from different ages or rotations of pine but large differences in numbers were found between seasons. The estimated density for summer was 17,000/m^2 (based on 84 cores) and for spring, summer and autumn combined, 78,000/m^2 (based on 294 cores). Collembola and mites comprised 97% of the arthropods counted and the ratio of Collembola to mites varied from 1:2 in winter to 1:62 in summer. Percentages of the different collembolan families collected varied with sampling time (Table 1). Sminthuridae and Onychiuridae were absent in summer while the isotomids were the most abundant family overall. Hypogastruridae (**Xenylla** spp.) and Neanuridae (Brachystomellinae) were most abundant when numbers of other Collembola were low in summer. Species of **Isotomodes**, **Tullbergia** and **Lepidocyrtus** were common on all plots.

A comparison of the fauna from pine litter and adjacent **Eucalyptus** forest near Mt Burr (Howard 1967) showed that certain groups: termites, terrestrial amphipods (**Tallitris** sp.), pseudoscorpions, enchytraeids and Lepidoptera larvae were rare in the pine litter samples although fairly abundant in native forest. There were only small numbers of Diplopoda, Isopoda, Gastropoda, Lumbricidae and Diptera and Coleoptera larvae in the pine litter.

Pine litter was extracted for Collembola from a number of other sites in Southern Australia. On some of these sites in cool humid seasons, species richness is high but there is evidence that in summer at least there are more cosmopolitan species and individuals in pine litter than in **Eucalyptus** litter nearby (Table 2) and that equitability is lower in pine litter. Lee (this volume) found the cryptostigmatid mite fauna of pine needles had similar characteristics.

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Table 1. Number of Collembola in each family as a percentage of the total number of Collembola collected on each sampling date at Mt Burr, S.A.

FAMILY	TIME OF SAMPLING 1965 Aug.	Sept.	Oct.	Dec.	Jan.	Mar.	Apr.	1966 Jun.	Jul.	OVERALL
Onychiuridae	61.4	10.9	24.7	0	0	8.6	29.7	26.3	19.4	29.42
Hypogastruridae & Neanuridae	6.0	12.6	15.5	77.1	96.2	51.3	16.3	10.1	3.8	13.61
Isotomidae	15.7	54.7	31.9	2.9	0.5	20.3	28.2	28.1	44.3	31.36
Entomobryidae	11.2	16.2	27.3	20.0	3.3	12.6	10.9	17.7	21.5	17.75
Sminthuridae	5.7	5.6	0.6	0	0	7.2	14.9	17.8	11.0	7.86

Table 2. Collembola from pine needles in February 1982 at Second Valley, S.A.

Paired sites	No. of species	No. of cosmopolitan species	Approx. no. of indivs.	No. of cosmo-politans	% cosmo-politans
Eucalyptus woodland	17	1	300	2	0.6
Pinus radiata forest	9	3	1050	1000 *	>95

* nearly all accounted for by individuals of *Xenylla maritima* Tulb. (Hypogastruridae)

Acknowledgements

This work was financed with grants from the South Australian Woods and Forests Department, University of Adelaide and Australian Biological Resources Survey.

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SEASONALITY OF AERIAL, LITTER AND SOIL FAUNA IN DARK ISLAND HEATHLAND, SOUTH AUSTRALIA

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Methods

The seasonal rhythms of aerial, litter and soil fauna were investigated in Dark Island heathland, South Australia.

Ten sets of fifty random sweeps of a collecting net were made through the heathland canopy at midday, on relatively rainless days to sample the fauna of the leaf canopy. The litter fauna were extracted from 100 g of litter samples, collected from under Banksia ornata, B. marginata, Casuarina pusilla and Phyllota remota, by means of a modified Tullgren funnel technique. Soil animals were extracted from 50 g soil samples, collected in open-spaces and under Casuarina pusilla bushes, by means of a modified Tullgren funnel technique.

Results

Figure 1 Relative shoot growth (Moisture Index x Thermal Index) of woody perennial shrubs in Dark Island heathland. Temperate species with temperature response between 10-20°C form sub-shrub and ground strata of the heathland; deeper-rooted subtropical species with temperature response between 15-25°C dominate the vegetation (Specht et al. 1958, Specht 1981).

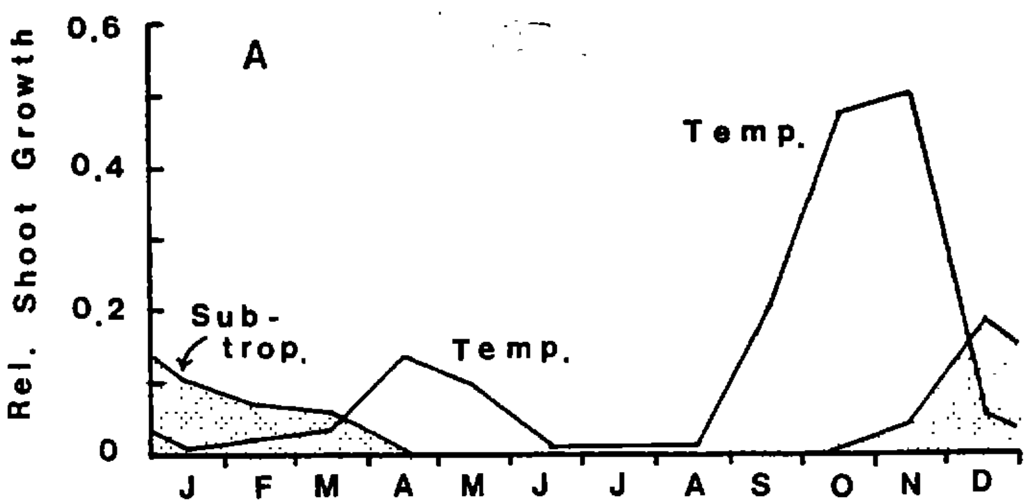

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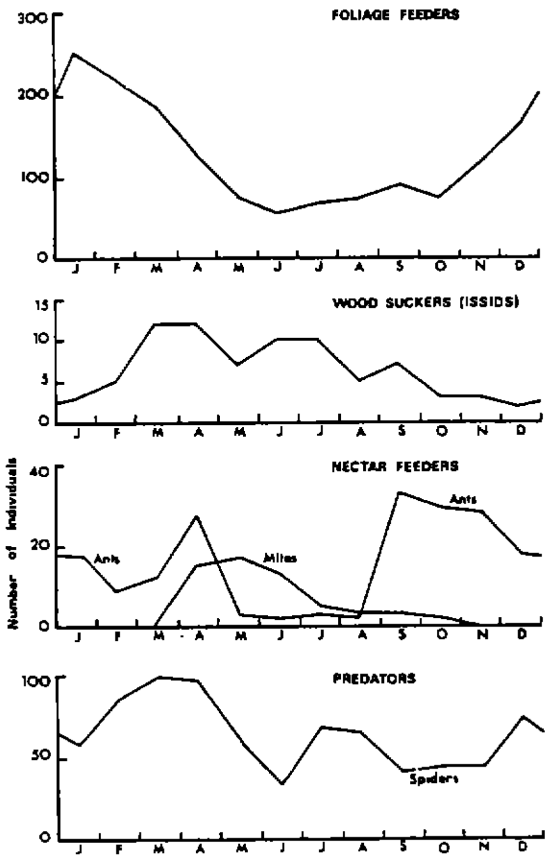
Figure 2 Seasonal rhythm of foliage feeders, wood-suckers, nectar-feeders, and predators recorded at midday in 10 sets of 50 random sweeps of the heathland canopy, at monthly intervals during 1953-54. (Edmonds and Specht 1981).



Discussion

The seasonal fluctuations in the fauna of the Dark Island heathland demonstrate the dependence of animals on their plant hosts. Three distinct seasonal rhythms may be discerned in the producer and decomposer sections of this ecosystem and are reflected in the annual populations.

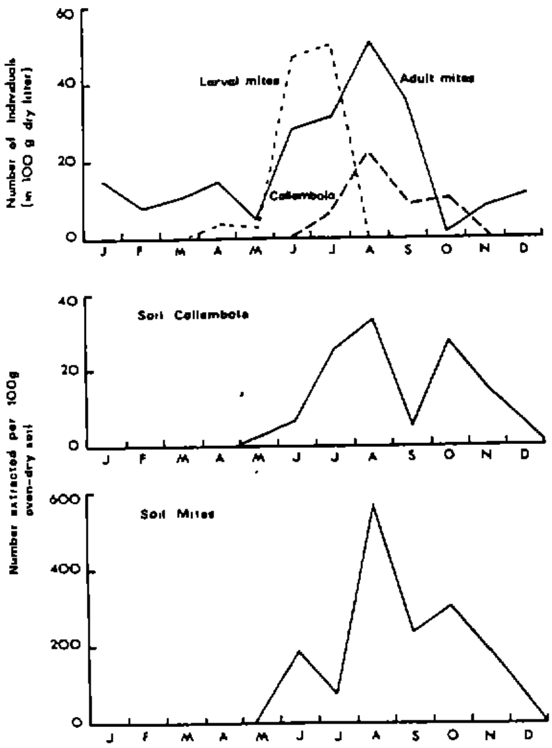
Plant Rhythm 1 (late spring to summer) associated with the deep-rooted woody shrubs with high temperature response (15-25°C).

Plant Rhythm 2 (late winter to spring) associated with the sub-shrub and ground stratum, with lower temperature response (10-20°C).

Plant Rhythm 3 associated with litter decomposition, largely in autumn and spring.

Foliage feeders respond to seasonal shoot growth of the overstorey and understorey strata (Rhythms 1 and 2). Woodsuckers

Figure 3 Seasonal rhythm of mites and Collembola recorded in leaf litter and surface soil samples (0-5 cm) of Dark Island heathland, at monthly intervals during 1953-54 (Edmonds and Specht 1981).



respond to the accumulation of starch in the stems of dominant shrubs during autumn and winter (Rhythm 1) and some species showing Rhythm 2. Nectar feeders follow closely the flower production at the peak of shoot growth in Rhythms 1 and 2. Predators, always high, lag behind the foliage feeders which peak in mid summer. The soil fauna is closely associated with the decomposition of litter during humid seasons. Most species either die or aestivate during the hot, dry summer (Greenslade 1974).

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SEASONALITY AND DIVERSITY OF EPIGAEIC INSECTS IN ADELAIDE

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Data on species richness, abundance, seasonality and frequency in collections were examined by taking three replicates of 50 sweeps of a 33 cm diameter sweep net in low vegetation. Most invertebrates captured were insects though some snails and arachnids were also found. Except for some grassland sites where the net sometimes became too wet for sampling in the winter months, samples were taken monthly for 28 consecutive months in 1952-54 from seven sites. Five of the sites were in the city area and were disturbed, with a mean annual rainfall of about 530 mm and an elevation of about 20-30 m. They included the rubbish filled grassy floor of several large claypits, a suburban garden and an area of grassy parkland. Two of the sites were in the now Belair Recreation Park in the Mt Lofty Ranges SE of the city and carried mostly native vegetation. The latter had a mean annual rainfall of about 760 mm and an elevation of about 300 m. One was in an area of savannah woodland (woodland formation of Specht 1972) and the other which was the least disturbed, in dry sclerophyll forest (open forest formation of Specht 1972).

Nearly 700 species of invertebrates were collected but only 172 species were considered 'significant' i.e. collected more than twice. This discussion is confined to these 'significant' species, but even so very few of these species appeared in more than 10% of the replicates, only seven occurred in more than a third and none in more than half.

Table 1 shows the species richness of the different sites ranging from those in a natural state with a tall (1m high) sclerophyllous understorey to sites with a grass understorey and varying degrees of disturbance.

If the pattern shown by the 'significant' species is representative of the total invertebrates present then less disturbed sites are richer in species than more disturbed sites (contrast site 1 with 2, 3 and 4) and more diverse habitats are richer in species than more uniform ones (compare sites 1, 2 and 3 with sites 4, 5 and 6).

The dry sclerophyll forest with a sclerophyllous understorey appears to be a more stable environment with both less tendency for any speciesto reach very high numbers and with less seasonal variation in abundance than sites with a grass understorey (Table 2).

The highest number of invertebrates on all sites occurred in mid-spring, followed by autumn, summer and the minimum number in mid-winter. Species richness varied similarly.

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Table 1. Comparisons of species richness between site types.

Type of site	Number of 'significant' species	% total 'significant' species (172)
1. Dry sclerophyll forest (elevated, wetter, undisturbed)	104	60
2. Suburban garden	75	44
3. Floor of claypit - rubbish filled	70	41
4. City parkland	68	40
5. Savannah woodland (elevated, wetter, little disturbance)	66	38
6. Floor of claypit - (short grass)	56	33

Table 2. Variation in numbers of invertebrates present according to nature of understorey.

		Maximum number of individuals per 50 sweeps		
Habitat	Nature of understory	Most abundant species	Total invertebrates spring	Total invertebrates winter
Forest	sclerophyllous	25	ca 100	ca 22
Other sites	grassy	415 Nysius vinitor Bergroth (Lygaeidae)	ca 160 (+ 415 N. vinitor)	ca 22

There were more species found on all of the sites than there were species restricted to a single site or common to other combinations of sites. The dry sclerophyll forest has the greatest number of species (Table 3). The lowland grasslands were the only sites with introduced species.

Several species replacements were noted in those areas most disturbed by man such as around houses and in the city, for instance, the introduced **Hylemyia deceptiva** Malloch (Anthomyiida) and **Musca domestica** L. replace a native **Hylemyia** sp. and **Musca vetustissima** Walker. In contrast, certain native species are greatly favoured by home gardens e.g. **Phalaenoides glycine** Lewin

(Agaristidae), a common pest of grapevines, and its pentatomid predators Oechalia schellenbergii (Guerin-meneville) and Cermatulus nasalis (Westward), and also the coreid Mictis profana (Fabr.) which occurs on decorative Cassia and Acacia.

Table 3: Comparison of the numbers of invertebrate species on various sites or combinations of sites.

Formation(s)	(a) Number of significant species restricted to a single site or group of sites	(b) (a) as a % of total 'significant' species (172)	(c) Number of introduced species	(d) (c) as a % of 'significant' species present (see Table 1)	(e) (c) a % of total introduced species (15)
Found in all sites	49	28	3	3	20
Dry sclerophyll	31	18	0	0	0
Low elevation grasslands but with specialized habitats e.g. rubbish not common to all such sites	15	9	8	11	53
Lowland grasslands only	13	8	3	4	20
All grasslands	13	8	0	0	0
Elevated natural sites dry sclerophyll forest/savannah woodland	5	3	0	0	0
Savannah woodland	0	0	0	0	0
Not determined	46	27	1?	4?	7?
Totals	172	100	15	22	100

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NATIVE TERRESTRIAL MOLLUSCS OF SOUTH AUSTRALIAN MEDITERRANEAN AREAS

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Only the truly terrestrial members of our land snail fauna (Subclass Pulmonata, Order Stylommatophora) are included in this survey. They are found in habitats which have been relatively unaltered by human activities; in coastal heaths and sandhills, rocky areas, conservation parks and other reserves.

Table 1 was compiled from the collection in the South Australian Museum. Dead material was collected from the surface soil, from litter or among rocks. Live aestivating specimens were found by sorting litter, digging in sand or soil, looking under rocks, logs and bark. Active specimens were collected either while feeding or from pitfall traps.

Of the 25 or so native families of terrestrial molluscs present in Australia, only eight occur in South Australia. There are no endemic slugs. The only representative of the carnivorous Rhytididae is **Strangesta gawleri**.

Some of the Mediterranean areas of South Australia are separated from each other by physical and climatic barriers. Therefore, it is not surprising that, while collections are likely to be incomplete, many of the species listed here appear to be restricted in their distributions to only one or two of these areas. One such species is **Bothriembryon angasianus**. Six others are members of the punctid and charopid families which are adaped to humid areas. Other punctids and charopids are represented in the collection but until revisionary work on them is complete, neither their distribution nor their generic and specific status can be given. Similarly, the apparently widespread **Paralaoma caputspinulae**, which exhibits a complex and variable array of shell forms, may well be a complex of several species. Although the camaenids listed appear to be restricted in their distribution, each species either occurs, or has very close relatives, in adjacent dryer areas. An exception is **Glyptorhagada bordaensis** whose closest relatives occur in arid regions of the mainland. The widespread pupillids and **Succinea australis** also live in arid regions, as does **Echonitor cyrtochilus**.

Although no area has a rich land snail fauna, the most species are recorded from Kangaroo Island and the least from Yorke Peninsula. This may reflect either a greater diversity of habitats available or a greater intensity of collecting on Kangaroo Island.

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Table 1. Distribution of native land snails in South Australian Mediterranean areas.

Family	Species	Areas EP	OI	YP	KI	SF	FP	LM	SE	Survival Strategies
Succineidae	Succinea australis*	+	+	+	+	+	+	+	+	A
Pupillidae	Gastrocopta margaretae*	.	+	+	+	.	+	+	.	A
	Pupilla australis*	+	+	+	+	.	+	+	+	A
	Pupoides adelaidae*	+	+	+	+	+	+	+	.	A
Rhytididae	Strangesta gawleri*	.	.	.	.	+	+	.	+	B
Orthalicidae	Bothriembryon mastersi*	+	+	+	+	.	.	.	.	C
	B. angasianus	+	.	.	.	.	.	.	.	?
Punctidae	Laomavix collisi*	.	.	.	.	.	.	.	+	B
	Magilaoma penolensis*	.	.	.	.	.	.	.	+	B
	Miselaoma parvissima*	.	.	.	.	.	.	.	+	B
	Paralaoma caputspinulae*	.	+	+	+	+	+	+	+	B
	Other punctids (1)	+	+	+	+	+	+	+	+	B
	Excellaoma retipora* (2)	.	.	.	+	.	+	.	.	B
Charopidae	Elsothera murrayana*	.	.	.	.	.	.	+	.	B
	E. reteporoides (1)	.	.	.	+	.	+	.	.	B
	Other charopids (1)	+	+	+	+	+	+	+	+	B
Euconulidae	Echonitor cyrtochilus*	+	.	.	.	+	+	.	.	A
Camaenidae	Glyptorhagada bordaensis*	.	.	.	+	.	.	.	.	A
	Meracomelon sutilosa*	.	.	.	+	.	+	.	.	A
	M. cassandra*	.	.	.	.	.	.	+	.	A
	M. tomsetti	.	.	.	+	.	.	.	.	A
	M. patruelis	+	+	.	.	.	.	.	.	A
	M. stutchburyi*	.	.	.	.	+	.	.	.	A
	Findomelon luteofuscum (3)	.	.	.	.	+	.	.	.	?
	Lacustrelix sp. (3)	.	.	.	.	+	.	.	.	?
	Sinumelon flindersi	.	.	.	.	+	.	.	.	C
	Sinumelon sp.	+	.	.	.	.	.	.	.	C
	Totals	10	9	8	13	11	12	9	9	

+, represented in the SA Museum collection. EP, southern Eyre Peninsula: OI, islands off southern Eyre Peninsula: YP, southern Yorke Peninsula: KI, Kangaroo Island: SF, southern Flinders Ranges, south of Wilmington: FP, Fleurieu Peninsula and Mt Lofty Ranges: LM, lower Murray Valley, south of Mannum: SE, south-eastern South Australia, south of Kingston - Naracoorte.

(1) F.M. Climo, unpublished notes.

(2) A charopid - not a punctid (Climo, unpublished notes).

(3) A. Solem, pers. comm.

* Names follow Smith and Kershaw, 1979.

A. Seals to hard surfaces, mostly under rocks but also under bark and litter.

B. Shelters under litter, vegetation or rocks, secretes a thin epiphragm.

C. Burrows into sandy soil under rock and vegetation, secretes a calcareous epiphragm.

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DIPLOPODA OF SOUTH AUSTRALIAN MEDITERRANEAN AREAS

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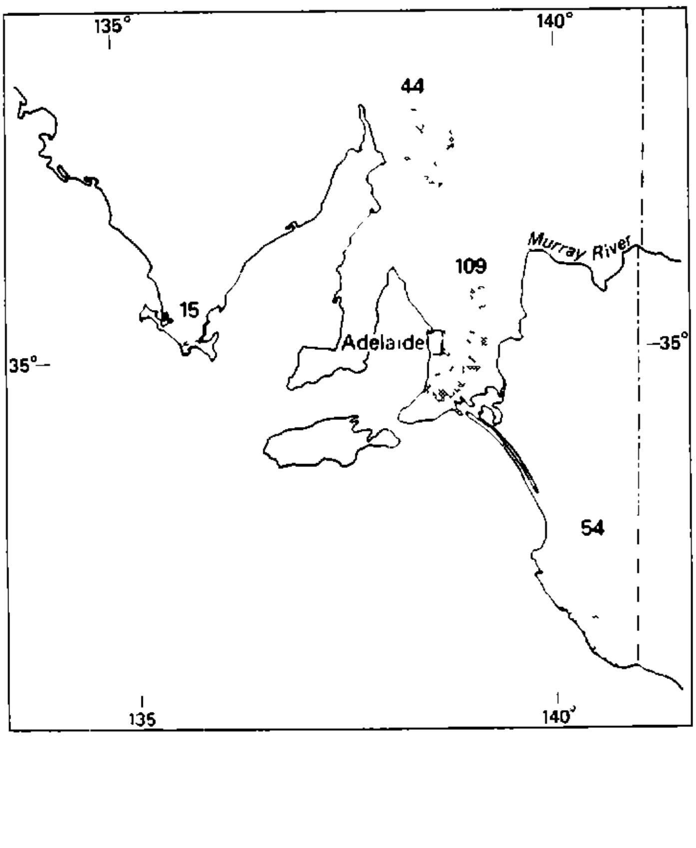
Millipedes are important in the decomposition of organic matter. They can be urban nuisances and agricultural pests. Virtually nothing is known of the millipede fauna of South Australia (Baker 1978, Jeekel 1982) and little is known of the fauna of other Australian states (Chamberlin 1920, Jeekel 1981).

Figure 1 illustrates areas which were surveyed for millipedes during July-October 1983. The numbers of sites sampled within each area are indicated. At each site, searches were made through leaf litter and beneath loose stones, bark and logs for varying periods of time (always more than 10 minutes) depending upon the success rate of finding millipedes. Where possible, species were identified.

Figure 1. Areas sampled for millipedes in South Australia. The numbers of sites sampled in each area are indicated.



Only four families of millipedes were collected (Polydesmidae, Paradoxosomatidae, Cambalidae and Iulidae) (Table 1). All the Iulidae were introduced species: **Ommatoiulus moreletii** (which is widespread in the Mount Lofty Ranges and on Eyre Peninsula - see

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Baker 1978 for more details), Brachyiulus pusillus (found at Kangarilla, Mount Lofty Ranges), Brachyiulus lusitanicus (Strathalbyn, Mount Lofty Ranges) and Ophyiulus verruculiger (Bridgewater, Mount Lofty Ranges). One species of Polydesmidae, the introduced Brachydesmus superus was found near Penola in the south-east of South Australia and also near Clarendon in the Mount Lofty Ranges. Another introduced species, Oxidus gracilis (Paradoxosomatidae) was found in suburban Adelaide and at Port Lincoln, Eyre Peninsula. Except for B. pusillus and B. superus these are new records for Australia. B. pusillus and B. superus have been recorded previously in Tasmania (Jeekel 1981).

Table 1. Number of records of Diplopod families in South Australia

	Lower Flinders Ranges	Lower Eyre Peninsula	Mount Lofty Ranges	South-east
Sites sampled	44	15	109	54
Polydesmidae	0	0	1	1
Paradoxosomatidae	21	9	64	13
Cambalidae	4	4	15	0
Iulidae	1	15	38	0

The native Australian millipedes, Oncocladosoma castaneum (Paradoxosomatidae) and Dimerogonus orophilus (Cambalidae) were collected at Bridgewater and are possibly widespread throughout the Mount Lofty Ranges. Further studies of subtle variations in gonopod morphology are necessary, however, before distributions can be documented. Other unidentified species were collected and are now lodged in the South Australian Museum.

Table 2 summarises the known distributions of families of millipedes in Australia (data from Hoffmann 1979, Jeekel 1981, Baker, unpublished data and present study, P.M. Johns pers. comm.). The fauna of South Australia appears to be less diverse than that of other states of Australia.

O. moreletii is a significant nuisance pest in south-eastern Australia (Baker 1978). B. pusillus, B. lusitanicus, O. verruculiger, B. superus and O. gracilis are not known to have caused a significant problem as yet in South Australia. B. pusillus and B. lusitanicus are natives of Europe but are now cosmopolitan. They are not known to be of economic importance or nuisance value elsewhere in the world. O. verruculiger is a native of central Italy. It has been recorded from New Zealand (Johns 1967) where it may cause a significant nuisance when in large numbers. O. verruculiger could easily be confused with a slender specimen of O. moreletii and care should be taken to distinguish these two species.

B. superus is common in arable land in Europe where it can be a severe pest feeding on the roots of sugar beet seedlings (Baker 1974).

O. gracilis is cosmopolitan but of tropical origin, possibly Asian. Large populations are known to occur in glasshouses in Europe and the USA where they can cause economic damage to plants (e.g. cucumbers) (Edwards and Gunn 1961). Urban infestations by *O. gracilis* have been reported in Tennessee (O'Neill and Reichle 1970).

Table 2. Distributions of Diplopod families in Australia.

		Qld	NSW	Vic	Tas	SA	WA	State Unknown
Synxenidae	)							
Polyxenidae	)*	X			X	X	X	
Lophoproctidae	)							
Sphaerotheriidae		X	X	X	X			
Siphonotidae		X		X	X		X	
Spirobolellidae		X	X					
Rhinocricidae		X						
Pachybolidae		X	X					
Cambalidae	)							
Iulomorphidae	)*	X	X	X	X	X	X	
Spirostreptidae								X
Blaniulidae					X			
Iulidae				X	X	X	X	
Siphonophoridae		X						
Schedotrigonidae		X	X	X	X			
Paradoxosomatidae		X	X	X	X	X	X	
Polydesmidae					X	X		
Cryptodesmidae		X	X	X	X			
Dalodesmidae		X	X	X	X		X	
Total		12	8	8	11	5	6	1

* Due to taxonomic confusion these are combined here.

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DIPLOPODA OF A DRY SCLEROPHYLLOUS WOODLAND (EUCALYPTUS OBLIQUA - E. BAXTERI) IN THE MOUNT LOFTY RANGES, SOUTH AUSTRALIA

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Millipedes are detritivores and as such can exert marked effects on the recycling of nutrients from litter to the soil. In Australia, the biology of only one species, the introduced **Ommatoiulus moreletii** (Iulidae), has been studied in any detail (Baker 1978a, b, c).

Forty pitfall traps (plastic jars 9 cm diameter, 9 cm deep) were set flush with the soil surface in each of two areas of dry sclerophyllous woodland (**Eucalyptus obliqua-E. baxteri**) (Englebrook Reserve) at Bridgewater in the Mount Lofty Ranges, South Australia. One faced north-west, the other south-west. Trees were noticeably more common on the south-west slope. The traps were set about 10 m apart in transects in March 1983 and were checked weekly until March 1984. Each trap was covered by a ceramic tile (15 x 15 cm) set approximately 2 cm above the trap on three nails. The soil in Engelbrook Reserve is an acid yellow duplex. Average annual rainfall is 1050 mm.

Only three species of millipede were trapped, **Ommatoiulus moreletii** and two native species, **Oncocladosoma castaneum** (Paradoxosomatidae) and **Dimerogonus orophilus** (Cambalidae). **O. moreletii**, which invaded Engelbrook Reserve in 1966, was by far the most abundant; **D. orophilus** was rarely trapped (Table 1). **O. moreletii** was more commonly trapped on the south-west slope. Numbers of **O. castaneum** were similar on both slopes.

Table 1. Age distributions and sex ratios of **Ommatoiulus moreletii** and **Oncocladosoma castaneum**

	Stadia 4	5	6	7	8	9	10	11	12	13	14	15	16	Total	χ^2	% males
Ommatoiulus moreletii																
North-west slope	7	27	25	7	11	21	74	67	64	19	4			326	265.9*	34.2
South-west slope	5	11	10	8	22	170	364	152	101	40	10	1	2	896		33.2
Oncocladosoma castaneum																
North-west slope			3	26	7									36	1.0	55.6
South-west slope				33	12									45		55.6
Dimerogonus orophilus																
North-west slope	Stadia not discernible													0		
South-west slope														3		

* Significant at $P < 0.05$.

Most **O. moreletii** were trapped in autumn (Figure 1). Many were also caught in spring-early summer. The catch during autumn was dominated by breeding adults. Most **O. castaneum** were trapped in early summer. Breeding adults were trapped from autumn to spring.

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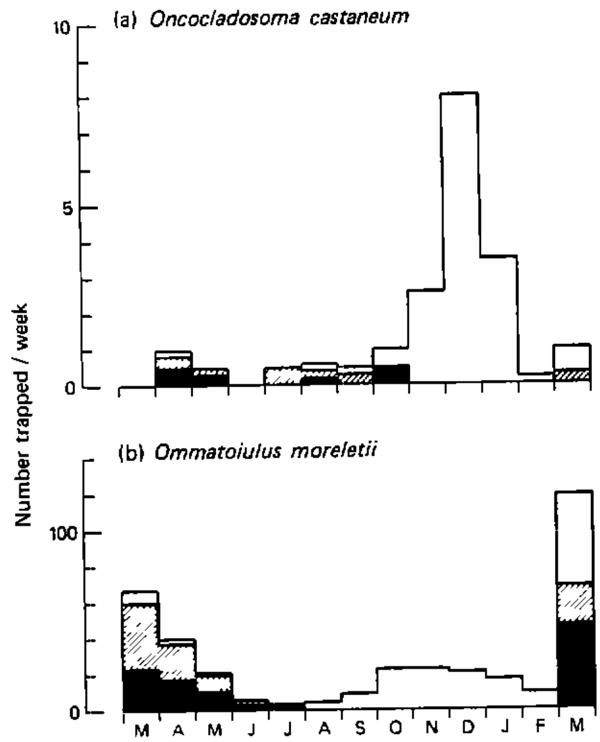
Figure 1. Numbers of millipedes trapped (north-west and south-west slopes combined). Shaded columns indicate gravid females; hatched columns indicate copulatory males.



The life cycle of O. moreletii consists of an egg, pupoid and up to 16 stadia (Baker 1978b). Maturation is variable with respect to stadium in O. moreletii but most individuals mature by stadia 10 or 11 (Baker 1978b). Stadia 4 to 16 were trapped in Engelbrook Reserve, the majority being in stadia 9 to 12 (Table 1). The life cycle of O. castaneum consists of an egg, pupoid, seven juvenile stadia and one adult stadium (the eighth). Only three stadia were trapped in Engelbrook Reserve, the majority being in stadium 7.

Female O. moreletii were more commonly trapped than males but approximately equal numbers of the sexes of O. castaneum were caught (Table 1). Baker (1978c) demonstrated that for most of the year the sex ratio (% males) of O. moreletii collected by hand from the leaf litter and soil surface in Engelbrook Reserve was approximately 40%. The predominance of female O. moreletti in the traps therefore probably reflected their greater abundance rather than greater activity. Equal numbers of male and female O. castaneum have been found in leaf litter and on the soil surface at Engelbrook Reserve (Baker, unpublished data).

Three D. orophilus were trapped, one in each of April (gravid female with 50 body segments), May (copulatory male with 67 segments) and December (juvenile male with 40 segments).

In summary, there were differences in the total numbers of O. moreletii and O. castaneum trapped in Engelbrook Reserve, the season when each species was most commonly trapped and the age distribution, maturity and sex ratio of active animals.

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MITES OF SOUTH AUSTRALIAN SOILS

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I. Ologamasidae (Mesostigmata)

The Ologamasidae is the dominant family of Mesostigmata in the region. These mites are fluid feeders and predatory on microarthropods and nematodes, but only those species which have long, heteromorphic legs are able to feed on Collembola (Lee 1974). In earlier publications these species have been referred to as Rhodacaridae (Lee 1973). An estimate of their abundance was obtained (Table 1) by taking core samples (surface area 20 cm^2) of soil and leaf litter in late winter and extracting them inverted and undisturbed in dessicating funnels which incorporated a forced draught type of ventilation. Two sites were sampled, one was an open forest on Mt Lofty summit (34°59'S, 138°45'E) and the other a woodland gully (34°58'S, 138°42'E) in the foothills. Seasonal changes were obtained (Table 2) with a less efficient (<33% of individuals were extracted per unit area) sampling method, taking handfuls of soil and leaf litter from a quadrat (surface area 250 cm^2) and transporting loose in polyethylene bags before extraction in simple desiccating funnels.

Table 1. Estimated numbers of all stages of Ologamasids x 10^{-3} m^{-3}

Ground cover	Foothills (woodland)	Summit (open-forest)
Leaf litter	6.81	6.66
Moss	3.08	3.45

Out of 22 species collected, 13 were recorded from both sites but correlation coefficients showed a significant association of the Ologamasinae species into two communities each characteristic of a single site. The association was not significantly afffected by the ground cover which was either moss or leaf litter, although the mites were more abundant in the litter. The 'foothills site', and another nutrient rich site (34°58'S, 138°36'E) on the nearby plain, appeared to be favourable for **Athiasella** species, whilst the 'summit site', and another nutrient poor site (34°53'S, 138°30'E) on the nearby coastal dunes, appeared favourable for **Gamasellus** species. Considerably lower numbers were found in summer (Table 2). All stages of **Athiasella** species were found throughout the year suggesting they are multivoltine whilst two of the **Gamasellus** species are clearly univoltine (**G. tragardhi** oversummering as females and **G. cocinnus** as deutonymphs).

Table 2. Mean numbers of all stages of Ologamasids collected per fortnight, range in brackets.

	Foothills (woodland)	Summit (open-forest)
Summer (Dec-Feb)	32 (2-83)	18 (0-74)
Autumn (Mar-May)	67 (24-112)	79 (12-143)
Winter (Jun-Aug)	110 (20-197)	135 (91-200)
Spring (Sep-Nov)	206 (87-358)	84 (40-125)

II. Sarcoptiformes (Cryptostigmata and Astigmata)

Cryptostigmata and Astigmata feed on micro-organisms and plant material by ingesting solids. A study of these groups has begun (Lee 1981, 1982) using the quadrat sampling method as above and preliminary data is presented here (Table 3: note that "estimate of adults x $10^{-3}m^{-3}$" is calculated by multiplying the number of adults collected by three to compensate for less efficient sampling, and for the pine forest site multiplied by a further four since, because the litter was about 12 cm deep, only a quarter the surface area was sampled).

Table 3. Numbers of adult Cryptostigmata and Astigmata by family at seven sites (May-August). Numbers in parentheses indicate the number of species in each family.

	NATIVE					EXOTIC	
	Mallee-broombush	Mallee-heath	Coastal closed-scrubland	Savannah woodland	Open forest	Pine forest	Pasture
Latitude South	35°15'	35°57'	38°03'	34°58'	34°59'	35°12'	35°02'
Approximate annual rainfall in mm	350-400	450-500	700-750	900-950	1150-1200	850-900	500-550
No. species							
Acaronychidae (2)	10	-	-	-	26	-	-
Brachychthoniidae (5)	6	68	707	-	123	344	-
Cosmochthoniidae (2)	22	1	1	6	12	-	1
Phthiracaridae (1)	-	-	-	-	2	319	-
Oppiidae (21)	62	424	1582	451	1220	8535	1
Eremaeozetidae (2)	4	47	-	-	-	-	-
Oribatulidae (25)	300	724	105	32	444	50	254
Acaridae (4)	1	3	4	-	-	22	5156
Anoetidae (3)	-	-	-	-	5	44	2
Other 32 families(55)	138	175	3045	1436	1021	583	48
Number of specimens	543	1442	5444	1925	2848	9897	5462
Number of species	32	33	38	30	48	27	11
Number of families	18	14	22	16	28	12	9
Estimate of adults x $10^{-3}m^{-3}$	3.3	8.7	32.7	11.6	17.1	237.5	32.8

Diversity was low on the cultivated sites, where only two species were abundant (i.e. they comprised more than 5% of adults). These were **Oppiella nova** (Oppiidae), 8187 adults, in pine forest and **Tyrophagus similis** (Acaridae), 5156 adults, in pasture. These two species are cosmopolitan and together comprise about half of all the adults collected although taken from only a fifth the total area of all the samples. In native vegetation there was a trend towards increased abundance and diversity with increase in rainfall, but diversity and abundance were not strictly correlated. Greatest diversity was associated with the highest rainfall on a nutrient poor soil under open-forest near the summit of Mt Lofty, but greatest abundance was found at the coastal site where there was a deep (3-6 cm) litter layer, little light penetrated the canopy, and the soil was often moist because of the nearby emergence of a fast flowing underground stream. Substantial faunal differences between sites were found even at family level; the mallee-broombrush and mallee-heath sites being the most similar. As in other mediterranean regions, the Oppiidae and Oribatulidae showed the greatest species richness, the Phthiracaridae were associated with pine forest and the Acaridae with pasture. The absence of the Belboidea was noteworthy, as was the presence of Eremaeozetidae at low rainfall sites. This last family has mainly been recorded from moist tropical areas, including some arboreal habitats in cloud forest.

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PHENOLOGY AND DIVERSITY OF EPIGAEIC COLLEMBOLA IN THE MT LOFTY RANGES

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Although the majority of Collembola live in soil and leaf litter, there are many entomobryids and sminthurids that live above the ground on shrubs, herbs and grasses. These Collembola were sampled at Belair Recreation park (lat. 35°01' long. 138°37', alt. 300 m, rainfall 762 mm p.a., age since last fire >15 yrs) in the Mt Lofty Ranges near Adelaide in an open woodland of Eucalyptus leucoxylon and E. odorata. There was an understory of Leptospermum, Hibbertia, Hakea and Lepidosperma species with some invasions by an exotic shrub, Chrysanthemoides monilifera and by exotic grasses. Sampling was carried out at approximately monthly intervals for four years by sweeping the grasses, sedges and shrubs with a net.

Twenty one species of Collembola were collected (Figure 1); three Entomobryidae and seven Sminthuridae were common. Isotomidae and Neanuridae were found sporadically although Hypogastruridae were more frequent. Most species (15 or 70%) were winter active and only four, all Sminthuridae, had clear summer maxima. Two species were found in all seasons. The winter species of Sminthuridae belonged predominately to the Katiannini, a tribe with southern biogeographical affinities and associated with grasses which grow during the winter (short day length). All the summer group belonged to the genus Corynephoria with many species in northern Australia and unlike the winter-active Katiannini possessing tracheae. Immature stages of the winter-active Sminthuridae were found immediately after the breaking rains of Autumn as the summer fauna declined. In late spring, this summer fauna developed slowly as temperatures rose. Hatching of Corynephoria continued in summer, as shown by the presence of early instars accompanied with summer rainfall. A similar pattern of seasonal activity was found on Kangaroo Island and on other sites in the Mt Lofty Ranges (Mt Lofty summit, Engelbrook Reserve, Bridgewater) where sampling was less frequent.

A similar replacement of Katiannini species by Corynephoria was found when vegetation was sampled along a steep rainfall gradient in Autumn (Figure 2) from the summit of Mt Lofty to the river Murray. The change in the composition of the fauna is not therefore determined by alteration in day length but by changes in temperature and humidity.

A significant adaptation of summer active species appears to be the possession of tracheae (Figure 1). Consequently respiration can be independent of gaseous diffusion across the cuticle. It is likely that this may permit the cuticle to become more impermeable so providing resistance to desiccation. The eggs of these summer-active species have a high threshold temperature for hatching. The winter-active species seem to survive the summer as a desiccation resistant egg whose dormancy breaks in the autumn as described for Sminthurus viridis (Wallace 1968).

Figure 1. Records of collembolan species collected each month as a percentage of total samples (346).

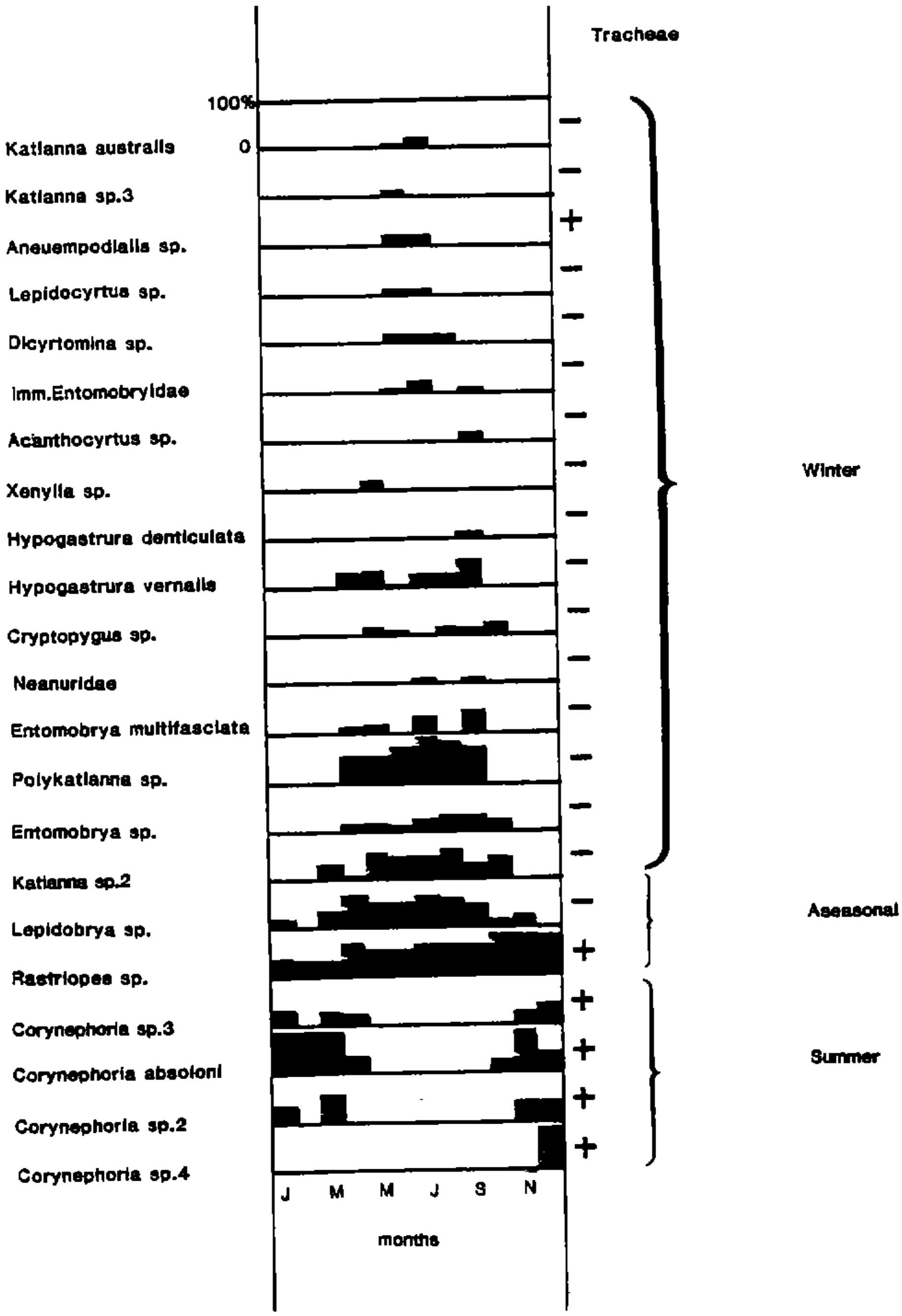
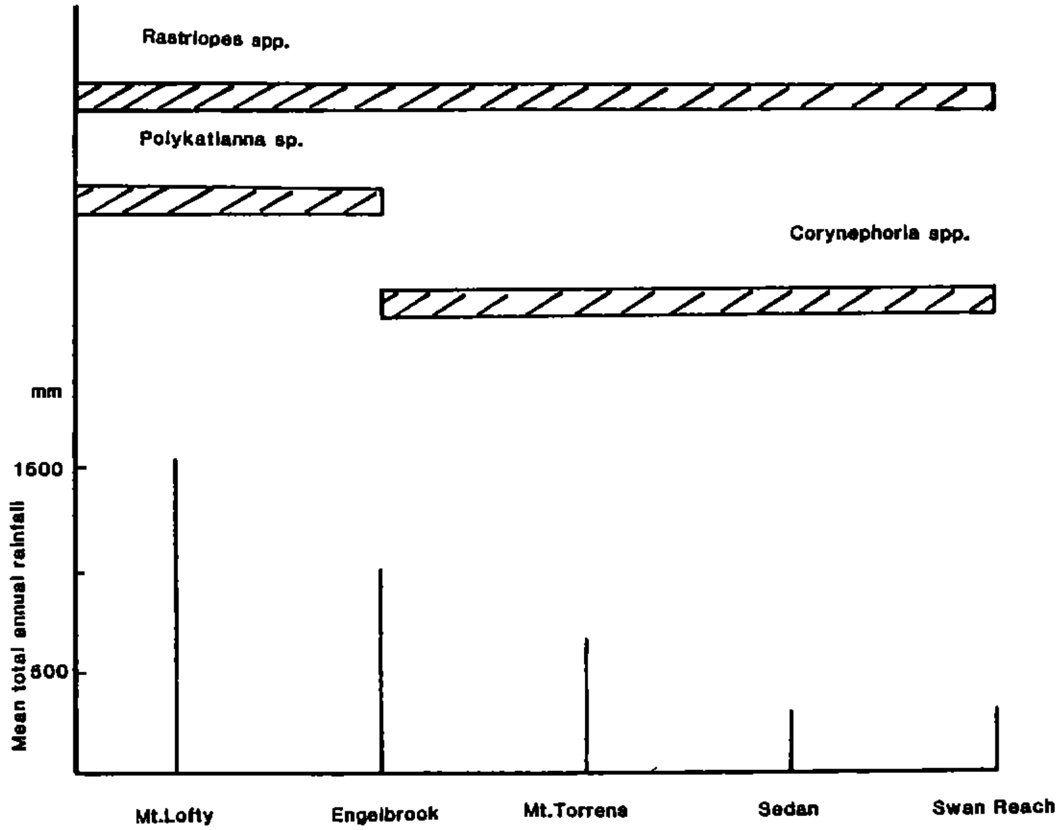


Figure 2. Records of collembolan species collected from five sites along a rainfall gradient in Autumn.



One of the aseasonal species at Belair, Rastriopes sp., had two contrasting colour forms; a dark brown and black mottled winter form and a yellow summer form. The development of pigment in Sminthuridae has been shown to be dependent on the temperature at which the immature stages develop (Walters 1964).

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FORAGING ACTIVITY OF SOME TENEBRIONID BEETLES IN A SOUTH AUSTRALIAN MALLEE AREA

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Pitfall traps were set in Ferries McDonald Conservation Park (35°15', 139°08') throughout 1977 in order to investigate the species composition, seasonal activity, and diet of ground-foraging adult tenebrionids in the area.

The park consists of 8 km^2 of surviving mallee-broombush (*Eucalyptus incrassata* - *Melaleuca uncinata*) vegetation, of undulating topography and deep sandy soil interspersed with calcareous rocks. In each of three locations about 2 km apart four pitfall traps, consisting of plastic buckets of about 1.5 l capacity, were set about 2 m apart and joined or flanked by five upright strips of galvanised iron acting as barriers to divert animals into the traps, which contained a solution of chloral hydrate. Traps remained in place for one week and during activity periods were set at intervals of 2-4 weeks.

Table 1. Species and numbers of tenebrionids trapped

	Date cleared and numbers										
Species	12/1	28/1	11/2	24/2	18/3	5/4	May-Sept.	13/10	9/11	8/12	Totals
Helaeus intermedius Breme	1	4	30	10	-	1	-	-	-	4	50
Helaeus castor Pascoe	6	5	11	20	5	6	-	-	-	1	44
Helaeus moniliferus Pascoe	-	-	-	8	5	-	-	1	-	4	18
Celibe latus Blackburn	-	-	-	3	1	1	-	-	-	3	8
Celibe satelles Blackburn	-	-	2	1	1	-	-	-	-	-	4
Onosterrhus acuticollis Carter	-	-	-	-	2	1	-	-	-	-	3
Celibe blackburni Macleay	-	1	-	-	-	-	-	-	-	-	1
Totals	7	10	33	42	14	9	0	1	0	12	128
Av. min. T during trapping period (°C)	15.7	12.6	15.1	16.0	13.0	12.0	4.5-7.8	8.7	8.3	13.9	

Only one tenebrionid was collected during the period from early April through early November, when average weekly minimum

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temperatures did not rise above 9.4°C. The data show a general initiation of tenebrionid activity in December and a peak during February, but no clear indication of any displacement in activity periods between species. Camping in the area revealed no evidence of daytime activity, even in the early morning. Thus it appears that all of these ground-foraging tenebrionids time their adult activity to coincide with the hottest period of the year, at night only, and that evidence of competitive exclusion in niche hypervolumes is to be sought among dimensions other than temporal activity patterns.

The gut contents of 25 individuals of H. **intermedius** and 22 of H. **castor** were examined. It was found that all contained triturated vegetable matter but 13 of those of **intermedius** and one of **castor** unexpectedly included arthropod remains as well, specifically (in order of frequency) those of ants, caterpillars, beetles, spiders, and bugs. Since the **Helaeus** are not adapted for predation, they must be acting as scavengers of dead arthropods during the night hours when ants are not very active. The figures suggest a difference in diet as being one of the factors in niche separation. Another may be choice of daytime shelter, since only **intermedius** was found in another group of traps set at the entrances to rabbit burrows throughout the period. Indeed, its ability to take advantage of the numerous rabbit burrows in the area may be a factor contributing to the relative abundance of H. **intermedius**.

BUTTERFLIES (LEPIDOPTERA: HESPERIOIDEA, PAPILIONOIDEA) IN SOUTH AUSTRALIAN MEDITERRANEAN AREAS

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Insects in these two superfamilies are diurnal and appear in South Australia as adults predominantly from early spring to late autumn. A minority of species, perhaps 10 per cent, appear as adults for only three or four weeks during this period. The remainder have a much more extended flying period, and some species may produce a number of generations in a single year. Consequently, at any given time the total butterfly population in a particular area may be represented not only by flying adults but also by the various early stages (eggs, larvae, pupae) of a number of species.

The data given here are from observations made over a period of some 50 years (Table 1). The fauna of five areas has been used for comparison. These areas are not equal in size but this factor is not considered significant as most species included have wide distributions within these areas and beyond. The areas cover most of southern South Australia experiencing a mediterranean climate.

Data from four of these areas are considered reasonably complete, but those from central and southern Eyre Peninsula may be altered if, as is considered likely, further field work results in the addition of other species to its fauna lists.

Those species which have been introduced by european man, or which have become established because of the introduction of suitable larval food plants, have not been included because they are not considered part of the natural ecosystem.

The columns listing the dominance of subfamilies in each area have been included to show the particular significance of the subfamily Trapezitinae in southern Australia. This will probably contrast sharply with data from other mediterranean areas of the world.

Annual variation in populations is an unpredictable factor encountered in many surveys. Some of the species included in the data presented here may be abundant in some years and apparently absent in others. In the case of at least one species (Delias aganippe) the butterfly may be virtually absent from the local fauna for as long as ten years, before reappearing for perhaps one season in considerable numbers. These large fluctuations in numbers is no doubt due to a variety of factors beyond the scope of this report.

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Table 1. Distribution of butterflies observed at five areas over a period of 50 years.

	Lat. and Long.	Broad vegetation type	No. of species	No. of genera	No. of families	No. of spp. with 1 generation each year
Central and southern Eyre Peninsula	34°10'S, 135°50'E	woodland	20	14	4	9
Yorke Peninsula	34°30'S, 137°30'E	woodland	27	20	4	11
Cleland Conservation Park	34°58'S, 138°42'E	open forest	26	20	5	11
Ngarkat Conservation Park	35°46'S, 140°28'E	open woodland	21	17	5	9
Lower Southeast	37°30'S, 140°30'E	open woodland (coastal)	31	24	4	16

	No. of spp. with more than one generation each year	Dominant subfamily	Second most dominant subfamily	Third most dominant subfamily
Central and southern Eyre Peninsula	11	Lycaeninae	Trapezitinae	Nymphalinae
Yorke Peninsula	16	Lycaeninae	Trapezitinae	Nymphalinae
Cleland Conservation Park	15	Lycaeninae	Trapezitinae	Nymphalinae/ Satyrinae
Ngarkat Conservation Park	12	Lycaeninae	Trapezitinae	Nymphalinae
Lower Southeast	15	Lycaeninae	Trapezitinae	Satyrinae

SOME SOUTHERN AUSTRALIAN CARRION FLIES OF THE FAMILY CALLIPHORIDAE (DIPTERA)

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Calliphorid flies normally breed in carcasses or other decomposing organic matter, and some produce myiasis in sheep and are therefore of economic importance.

Data on species distribution have been collected by placing fly traps baited with sheep brains at a number of points across southern Australia. The traps were left in position from between one day and one week. Traps were also placed at Tennyson, a suburb of Adelaide, S.A. (34°33', 140°47'), over a one year period and cleared weekly in order to obtain information on seasonal occurrence.

The geographical distributions of some calliphorid flies based on trap records and published data from other authors are given in Figure 1. Table 1 shows the number of individuals of some calliphorid species trapped during 1980 at Tennyson. The highest number of species of calliphorid flies and the highest number of individuals, are found from spring to mid summer in Adelaide. Calliphora vicina is absent during summer, Calliphora nociva is most abundant in summer, Lucilia spp. are present for most of the year but numbers dwindle in winter, and, Calliphora stygia, Calliphora augur, and Chrysomya rufifacies are of minor importance in the blowfly fauna of Adelaide.

Table 1. Seasonal occurrence of blowflies at Tennyson, S.A. during 1980

	Lucilia spp.	C.stygia	C.augur	C.nociva	C.vicina	Ch.rufifacies
January	99	0	4	184	0	0
February	87	0	1	98	0	0
March	47	3	0	52	0	0
April	82	1	0	7	6	0
May	72	5	0	4	4	0
June	2	3	0	0	1	0
July	4	3	0	0	2	0
August	0	6	0	9	22	0
September	19	9	0	23	16	0
October	55	12	0	12	7	0
November	99	12	0	12	7	1
December	50	20	0	58	0	1

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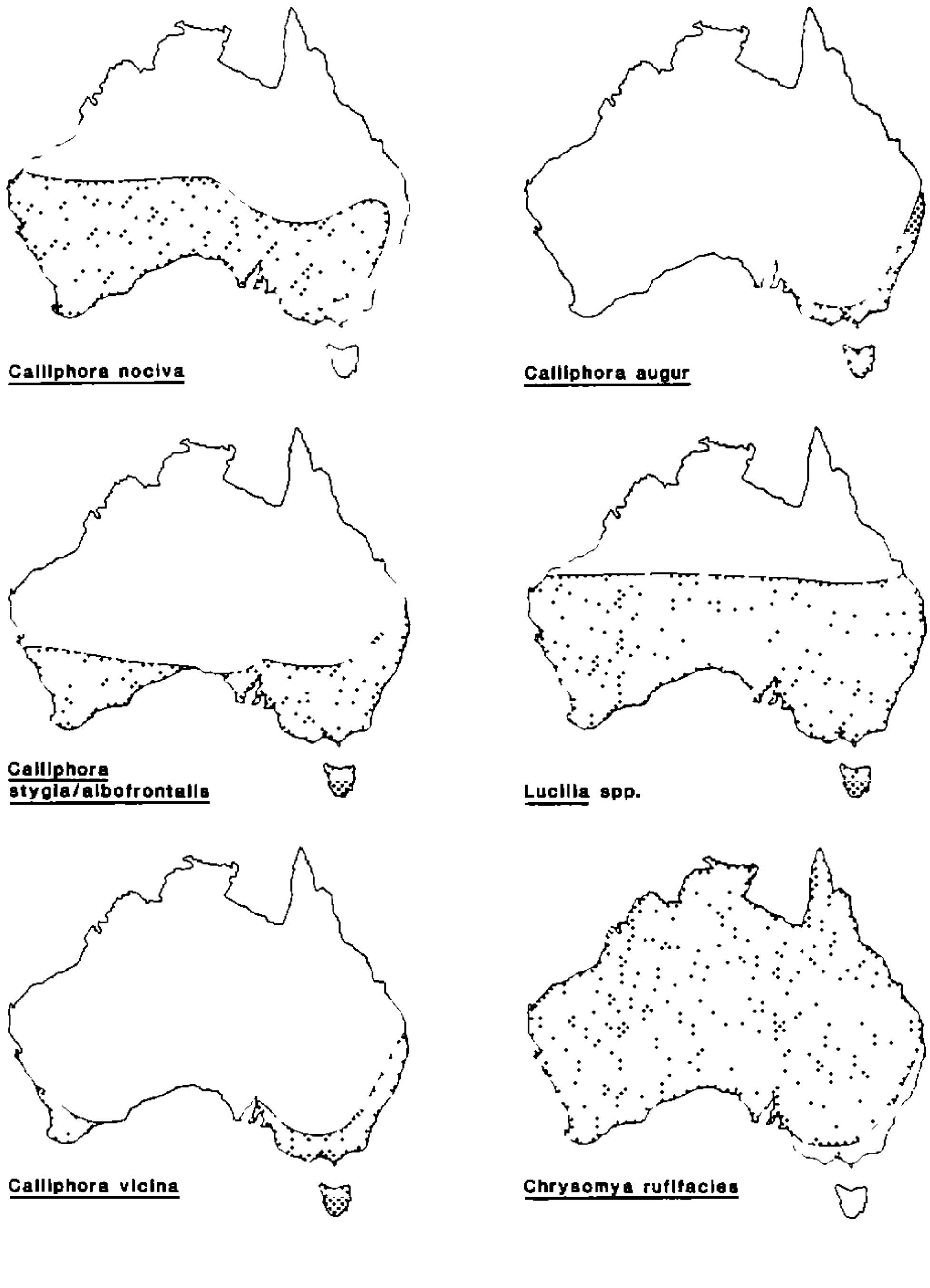
Figure 1. Distribution maps of six calliphorid species in Australia.



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SEASONAL PATTERNS IN THE ACTIVITY OF ANTS IN BELAIR RECREATION PARK, SOUTH AUSTRALIA

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Ants are a conspicuous component of most Australian sclerophyll communities and may play an important role in determining both the physico-chemical structure (e.g. as modifiers of soil structure and nutrient availability) and biotic features (e.g. as competitors, predators and mutualists of other arthropods and as seed-eaters and seed-dispersers) of these communities. Little is known about the structure of ant communities in most Australian sclerophyll communities. The seasonal patterns of ant abundance and species richness in a forest in South Australia are reported here.

Methods

Seasonal patterns of abundance and species richness of foraging ants were examined by pitfall trapping. Twenty traps (following the design of Majer 1978) were placed at 2 m intervals on a 6 x 8 m grid in Belair Recreation Park (35°00'S, 138°40'E, 455 mm) and collected weekly for 80 weeks (August 1982-February 1984). The site consists of open stands of **Eucalyptus obliqua** with an understorey dominated by **Acacia pycnantha**.

Results and Discussion

Pitfall trapping showed marked seasonal patterns in both ant abundance and species richness (Figures 1 and 2). In 1982-83, ant foraging activity was greatest in spring and autumn and showed a pronounced decrease in winter. Catches ranged from a mean maximum of 7.0 ants trap $^{-1}$ week $^{-1}$ in November 1982 to a mean minimum of 0.10 ants trap $^{-1}$ week $^{-1}$ in July 1983. A minor 'trough' in activity also occurred during mid-summer (December 1982-January 1983). Species richness of ants trapped on the grid generally followed this same pattern, although a mid-summer depression did not occur in 1983 but did in 1984. A maximum of 19 species was trapped during one week in November 1983 while a minimum of two species was trapped during a week in July 1983. A tentative total of 39 species from 26 genera were trapped on the grid over the 80-week period.

Some ant species differed strongly in their seasonal activity patterns (Figure 3). Of the 11 most abundant ant species, only two showed continuous seasonal activity (**Chelaner** sp. 1 and **Amblypone australis**). The three most abundant species (**Iridomyrmex** sp. 1, **Pheidole** sp. 1 and **Rhytidoponera** sp.) showed greatest activity from late spring to late summer with a pronounced decrease in foraging activity during winter. The trough in the activity of **Iridomyrmex** sp. 1 and **Pheidole** sp. 1 during mid-summer probably accounts for most of the overall decline in ant abundance during that period. With the exception of **Amblypone australis**, no ant species had higher foraging activity in winter than during other times of the year.

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The temporal distribution of ant activity is complex. Overall there is a predictable waxing and waning of foraging activity that follows the seasons, but when the activity schedules of individual species are examined, a large amount of asymmetry in corresponding periods between years is observed (Fig. 2). For example, the foraging activity of Chelaner sp. 1 was greatest in August in 1982 but did not peak until November in 1983. For Epostruma sp. 1, activity was much lower in 1982 than in corresponding periods in 1983. This study does not resolve the factors determining activity but temperature and rainfall are undoubtedly of major importance.

Figure 1. Seasonal abundance (average number of ants $trap^{-1}$ $week^{-1}$) of ants caught in pitfall traps over a 80 week period, August 1982-February 1984.

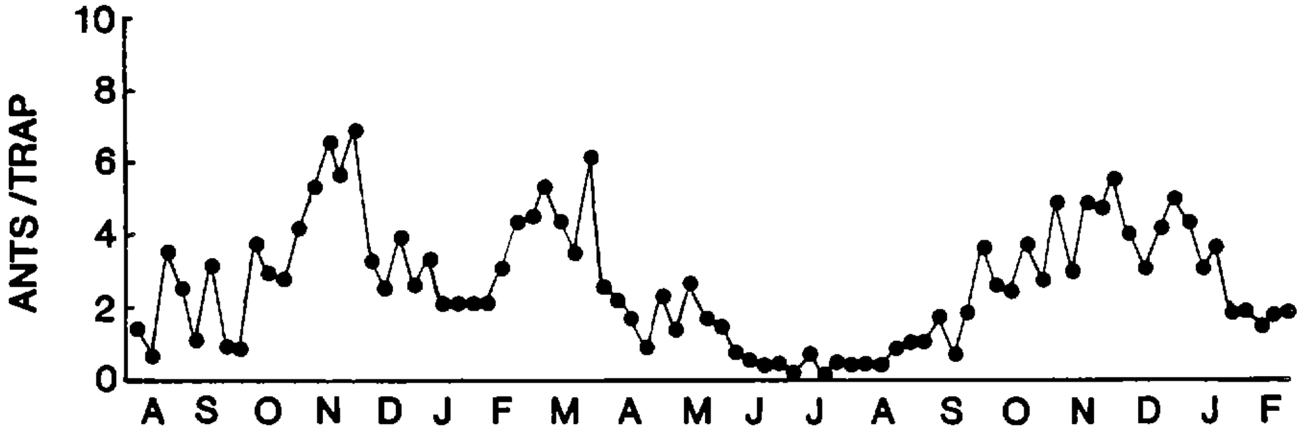


Figure 2. Species richness (species trapped $week^{-1}$) of ants caught in pitfall traps over a 80 week period, August 1982-February 1984.

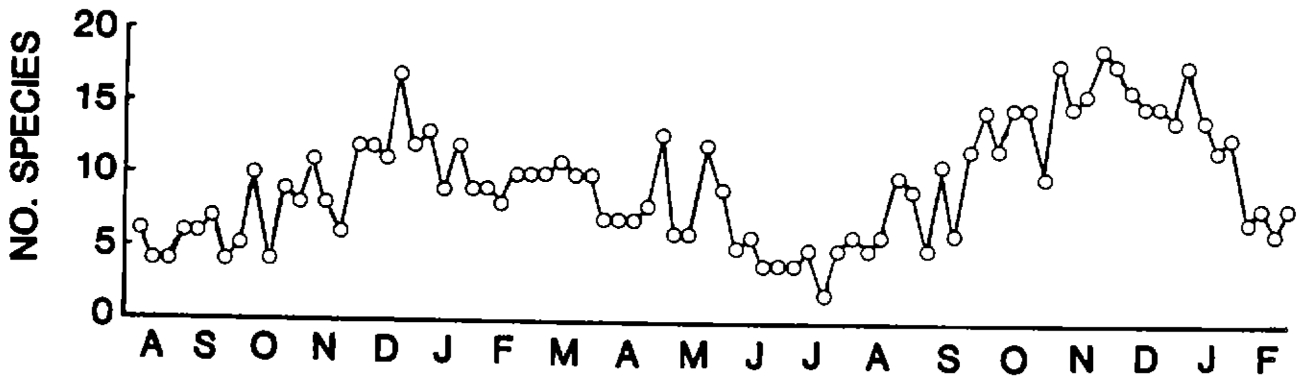
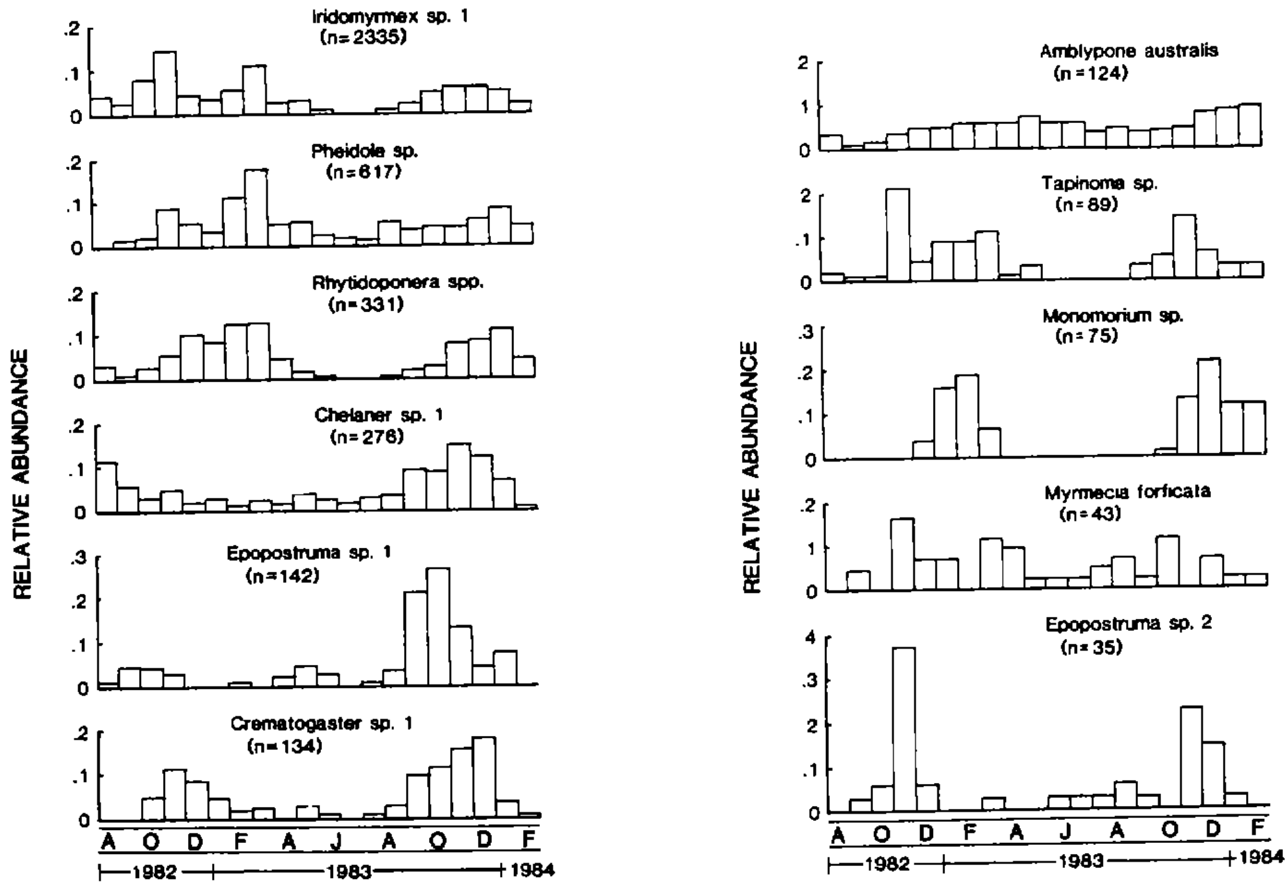


Figure 3. Seasonal foraging activity of the eleven most abundant ant species as detected by pitfall trapping, August 1982-December 1983. Bars represent the relative abundance of a given ant species for each four-week period over the study period. n = the total number of individuals trapped.



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EFFECT OF LOW-INTENSITY FIRE ON THE ACTIVITY OF ANTS AND OTHER INVERTEBRATES AT BELAIR RECREATION PARK, SOUTH AUSTRALIA

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Fire is a major force structuring communities in mediterranean ecosystems. The immediate effects of a planned, low-intensity fire on the activity of soil and litter macroinvertebrates in South Australia are reported here.

Methods

On Yirri Wirra Ridge in Belair national Park (35°100'S, 138°40'E, 455 mm), 20 pitfall traps (following the design of Majer 1978) were set out at 2 m intervals on each of two 6 x 8 m grids to determine the immediate effect of a low-intensity fire on soil/litter macroinvertebrates. A fire was planned at one site while the other was used as a control, yielding comparisons between sites and pre- and post-fire periods. For ants, species composition and abundance was determined for seven consecutive weekly periods prior to and following fire. Other invertebrates were segregated to the order level and abundance was determined.

Both sites consisted of open stands of Eucalyptus obliqua with an understorey dominated by Acacia pycnantha. The test site was burned on 30th March, 1983 (autumn) and generated a low-intensity fire which scorched vegetation to approximately 5 m height. Fire effects were relatively uniform, razing almost all of the understorey shrubs and herbs, but litter was not completely ashed over most of the site.

Results

Ants were the most numerous macroinvertebrate group caught in pitfall traps and comprised 26% of the total invertebrates trapped before fire and 63% after fire. Ant species composition at the control and test sites was similar prior to fire but relative species' abundances did differ. Following fire at the test site, catches of ants increased approximately ten-fold from the immediate pre-fire level and was about nine times greater than the catch at the control site (Figure 1). Species richness of ants trapped following the fire also increased, from a pre-fire average of 10.7 species per week to a mean of 16.7 species per week after fire (Figure 2).

The foraging activity of many ant species increased after the low-intensity fire. Catches of three of the six most abundant species increased significantly after fire (Table 1), while the absolute abundance of only one species, Iridomyrmex sp. 1, declined. The most abundant species after fire, Chelaner sp. 2, was never trapped prior to fire.

Increased catches of ants following fire was not paralleled by other macroinvertebrates (Figure 3). Their abundance was dominated by dermapterans and acarines, declined over the 14 week

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Figure 1. The effect of low-intensity fire on the weekly catch of ants at Yirri Wirra Ridge, Belair National Park, S.A. Filled circles indicate control site, open circles represent the test site. The fire is indicated by a solid vertical bar.

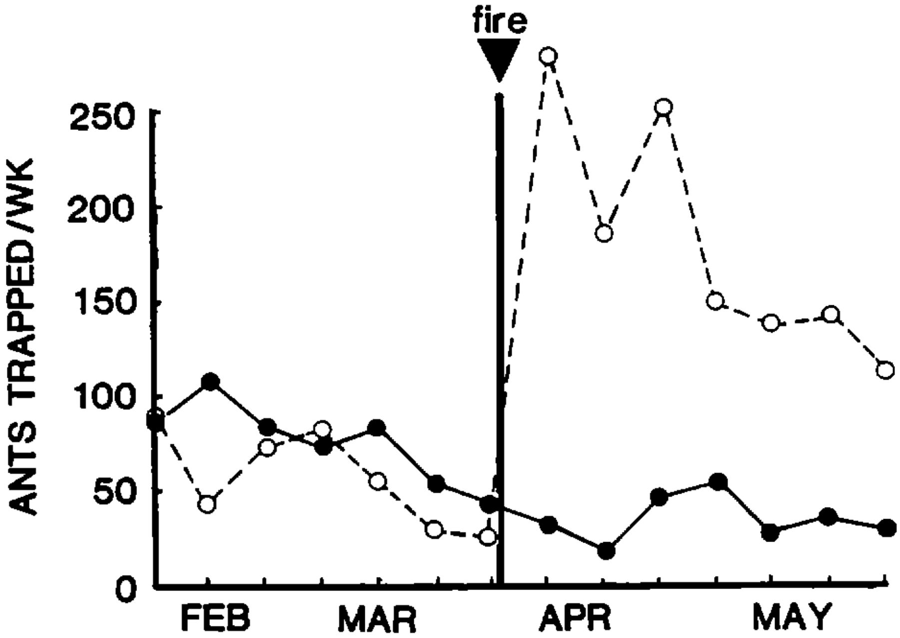

Figure 2. The effect of low-intensity fire on weekly species richness of ants trapped at Yirri Wirra Ridge, Belair National Park, S.A. Filled circles indicate control site, open circles represent the test site. The fire is indicated by a solid vertical bar.

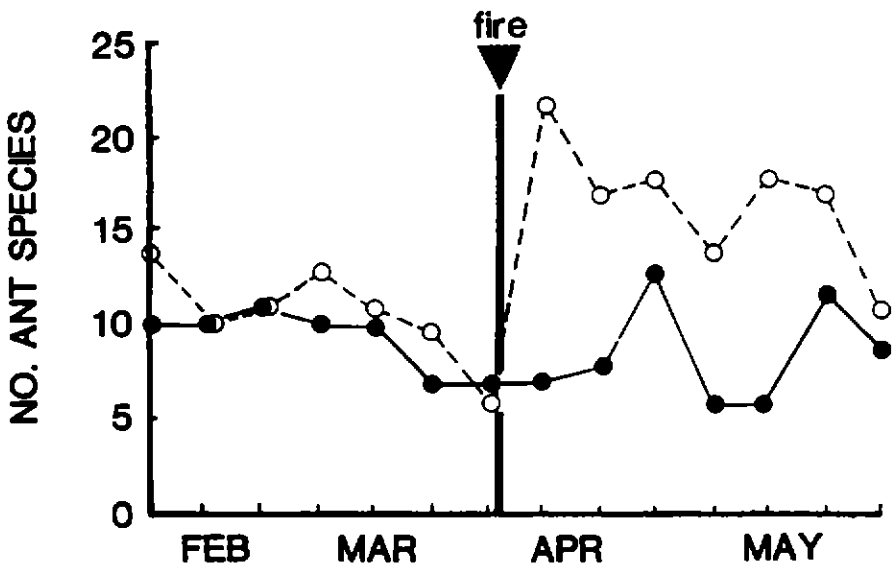

Figure 3. The effect of low-intensity fire on the abundance of macroinvertebrates (excluding ants) trapped at Yirri Wirra Ridge, Belair National Park, S.A. Filled circles indicate control site, open circles represent the test site. The fire is indicated by a solid vertical bar.

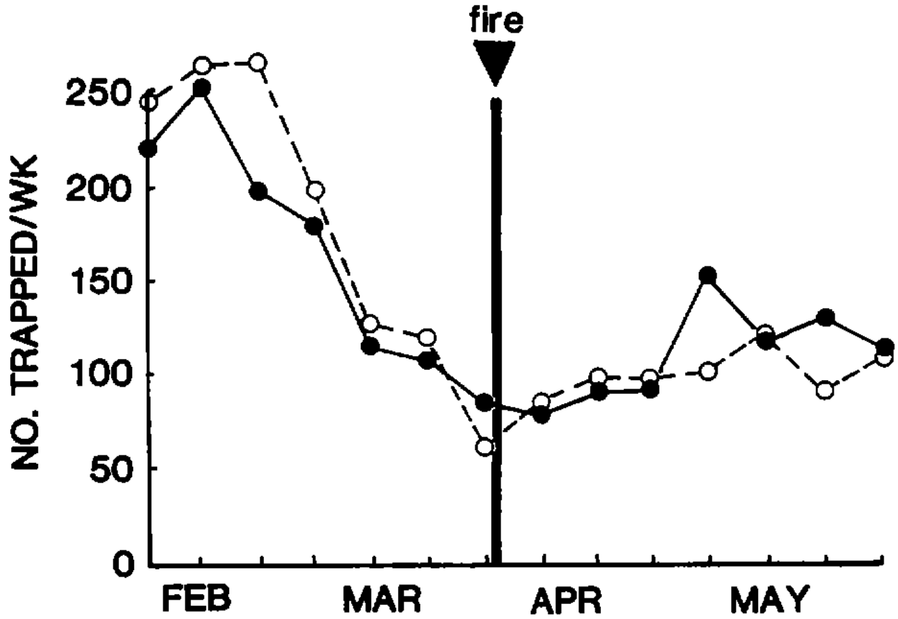

Table 1. Effect of a low-intensity fire on the relative abundance (proportion of total catch) of the six most abundant ant species, Yirri Wirra Ridge, Belair Recreation Park, S.A. Number of ants trapped in seven week pre- and post-fire periods are in parentheses. A total of 397 and 1268 ants were trapped before and after fire respectively. Species which increased significantly after fire are indicated by an asterisk (Mann-Whitney u-test, $p < 0.01$).

Species	Prefire	Postfire
Chelaner sp. 2	0(0)	.38(485)*
Crematogaster sp.	.05(20)	.09(114)*
Iridomyrmex sp. 1	.22(89)	.05 (62)
Iridomyrmex sp. 2	.24(95)	.18(225)
Mesostruma sp.	.03(11)	.05 (62)*
Rhytidoponera sp.	.20(80)	.07 (93)
	.74	.82

period, independent of the fire. The relative abundance of these macro invertebrates, when segregated at the level of order, did not differ strongly between the control or test sites nor did the fire markedly alter their relative abundances at the test site.

Discussion

This low-intensity fire caused marked changes in the catches of ants (Figures 1, 2) but did not strongly affect abundance of other macroinvertebrates caught in pitfall traps (Figure 3). Much of the litter layer, although charred, was not 'ashed' so microhabitat destruction for these soil/litter arthropods may not have been as great as would occur in more intense fires.

A comparison of these results with those of O'Dowd and Gill (this volume) suggests that the effect of fire on overall ant foraging activity is general and independent of fire-intensity.

References

Majer, J.D. (1978) An improved pitfall trap for sampling ants and other epigaeic invertebrates. Journal of the Australian Entomological Society 17, 261-262.

SOIL AND LITTER INVERTEBRATES OF VICTORIA

Penelope Greenslade (Co-ordinator)

The papers in this section concern fauna from parts of Australia which, strictly speaking, do not have a mediterranean climate. They have been included because the study sites used in these works carry a typical mediterranean-type vegetation.

INVERTEBRATES COLLECTED BY PITFALL TRAPS IN MALLEE AND HEATH IN THE BIG DESERT, VICTORIA

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During 1980 the ants of adjacent mallee and heath sites were studied in an area 5 km west of the northwestern shore of Lake Albacutya, Wyperfield National Park (35°42'S, 141°52'E) (Andersen 1982). One of the techniques used was pitfall trapping, and the ants recorded from these traps have already been reported (Andersen 1983). The results presented here are those of all invertebrates collected in the pitfall traps to examine seasonal differences in activity, and differences in abundances between the mallee and the heath sites. Thirty 7 cm diameter pitfall traps, partly filled with 70% ethanol, were operated at each site

Table 1. Invertebrates collected in pitfall traps, 1980.

		Mallee					Heath				
		Jan	Mar	Jun	Nov	Total	Jan	Mar	Jun	Nov	Tota
Arachnida.	Scorpionida	1				1			1		1
	Acarina	36	2	7	2	47	28	3	10		41
	Araneae	19	14	13	15	61	26	2	8	4	40
Crustacea.	Isopoda				2	2				1	1
Diplopoda				3	27	30				1	1
Collembola		5	1	51		57	13		17		30
Insecta.	Thysanura	4	2			6	9				9
	Blattodea	2	1			3					0
	Mantodea					0	1				1
	Isoptera	5	1		13	19	6				6
	Orthoptera	4			2	6	1				1
	Psocoptera					0				1	1
	Hemiptera	9	1		5	15	2	1	1	1	5
	Coleoptera										
	(adults)	13	5	27	11	56	4	7	15	4	30
	(larvae)				2	2					0
	Diptera										
	(adults)	20	14	44	19	97	45	13	50	13	121
	(larvae)					0				1	1
	Lepidoptera										
	(adults)		3	1		4					0
	(larvae)				1	1				1	1
	Hymenoptera										
	(ants)	1856	482	206	646	3190	1828	395	262	524	3009
	(others)	29	17	1	16	63	11	4	8	6	29
Total		2003	541	353	761	3658	1974	425	375	656*	3430

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for 48 hours in January, March, June and November 1980. Invertebrates were identified to the level of order (Table 1) and total numbers of individuals were analysed for differences between sites and seasons using two way ANOVA.

The composition of the invertebrate fauna in both mallee and heath was similar with ants dominating at both sites. Differences in total abundances between the mallee and heath were not significant. Seasonal differences in abundances were highly significant ($p < 0.0005$), with peak numbers in summer at both sites.

Acknowledgements

This project was financed by a grant from the Westpac Bank to Dr T.P. O'Brien, Professor M.J. Canny and Dr G. Ettershank at Monash University.

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THE ARBOREAL INVERTEBRATE FAUNA OF THREE MALLEE SPECIES IN THE BIG DESERT, VICTORIA

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The arboreal invertebrate fauna of three species of mallee eucalypts (Eucalyptus dumosa, E. foecunda and E. incrassata) was studied in an area 5 km west of the northwestern shore of Lake Albacutya, Wyperfeld National Park (35°42'S, 141°52'E). Samples were taken by beating over a 1 m^2 cloth. One sample was taken from each of 10 individual mature trees for each eucalypt species in January, March, June and November 1980.

The invertebrates were identified to the level of order, and results are presented on the abundances and seasonal activity of each order (Table 1). The total number of individuals from each species of mallee for each month (Table 2) are analyzed for differences between host plant species and seasonal activity using two way ANOVA.

Table 1. Numbers of invertebrates/10 beat samples.

	E. dumosa				E. foecunda				E. incrassata			
	Jan	Mar	Jun	Nov	Jan	Mar	Jun	Nov	Jan	Mar	Jun	Nov
Acarina	2		2	3	1			6	3	1	8	4
Araneae	14	14	4	10	22	16	6	12	17	8	5	5
Collembola			6				7				6	
Blattodea	1					1			1	3		
Orthoptera	1											
Psocoptera			4	1			4			1	3	2
Hemiptera	5	2	3	7	3	3	5	2	7		5	3
Thysanoptera	1	1		1	2			1	2			1
Neuroptera						1						
Coleoptera	11	133	2	9	20	67	6	14	63	12	1	6
Diptera	1	1		1	8		2	1	11			
Lepidoptera			6				2					
Hymenoptera												
Formicidae	43	41	27	42	10	17	31	26	91	14	21	9
Other		2		3	1		3		3	1		2

Table 2. Total numbers of invertebrates.

	Jan	Mar	Jun	Nov	Total
E. dumosa	78	194	54	77	403
E. foecunda	67	105	66	62	300
E. incrassata	198	40	49	32	319
Total	343	339	169	171	1022

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The composition of the fauna of each eucalypt species is similar (Table 1), with Coleoptera and Formicidae being the dominant taxa. Differences in abundances between the eucalypt species and between seasons are not significant. In all three eucalypt species, there is one peak in seasonal abundance, in March for E. dumosa and E. foecunda, and in January for E. incrassata. For E. dumosa and E. incrassata, these peaks coincided with host plant flowering, but the reason for the peak in numbers on E. foecunda is not known.

Acknowledgements

This project was financed by a grant from the Westpac Bank to Dr T.P. O'Brien, Professor M.J. Canny and Dr G. Ettershank at Monash University.

SEASONAL ACTIVITY OF COLLEMBOLA AT WILSON'S PROMONTORY

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Collembola were collected in pitfall traps at two sites: one a heath of **Casuarina pusilla - Leptospermum myrsinoides**, and the other a woodland with **Eucalyptus baxteri** at Tidal Overlook, Wilson's Promontory, Vic (lat 390°02'S long 146°19'E mean annual rainfall 106 cm, well distributed throughout the year). Fifteen traps of 3.5 cm diameter containing a 70% ethanol-glycerol mixture were placed at each site and exposed for 48 hours at 2 monthly intervals during 1982. Results are given in Tables 1 and 2.

Table 1. Total number of Collembola trapped for both sites.

Family+	No. of spp.	Jan.	Mar.	May	July	Sept.	Nov.
Entomobryidae	6	185	33	4	6	38	37
Neanuridae) Hypogastruridae)	6	-	-	6	75	1	1
Isotomidae	4	-	-	7	13	1	-
Sminthuridae) Dicyrtomidae)	3	-	1	17	2	1	-
Total	19						

Table 2. Total of species and individuals trapped in heath and woodland.

	Jan.	Mar.	May	July	Sept.	Nov.
Heath (individuals	120	17	19	32	14	15
(species	3	3	9	2	5	2
Woodland (individuals	65	17	15	61	28	22
(species	2	2	4	7	5	3

\+ Families and genera represented:
Entomobryidae: **Lepidocyrtoides, Paronellides, Entomobrya, Lepidocyrtus**; Isotomidae: **Tomocerura, Isotoma**; Sminthuridae: **Rastriopes, Aneuempodialis**; Dicyrtomidae, Neanuridae: **Setanodosa, Pseudachorutes, Pseudachorudina**; Odontellidae.

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There was a marked seasonal difference in catches of the different families: Entomobryidae were trapped in greater numbers in summer, Isotomidae and Neanuridae in winter, and Sminthuridae and Dicyrtomidae in autumn. Both sites showed the same pattern. Most individuals were trapped in summer although species richness was highest in the months May to September. These patterns are similar to those found in woodland in South Australia (Greenslade, P. in press) except that numbers of Entomobryidae trapped in the summer are lower than in spring and autumn in South Australia. There was only a slight difference in species composition between sites, with some litter inhabiting entomobryids (Lepidocyrtus sp., Entomobrya cf. virgata Schott) recorded only in the woodland. Lepidocyrtoides sp. (?spp.) was numerically dominant in summer, and Subclavontella in winter.

Reference

Greenslade, Penelope (in press) Small Arthropods. In Ecology of South Australian Forests ed. H. Wallace Government Printer Adelaide.

COCKROACHES (BLATTODEA) AND CARABIDAE (COLEOPTERA) COLLECTED BY PITFALL TRAPS IN THE BIG DESERT, VICTORIA

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Most native cockroaches are ground dwelling, nocturnal, and with unknown feeding habits (Mackerras 1970). Many of the cockroaches in the Big Desert are diurnal, and many shelter in Triodia bushes.

The Carabidae of the Big Desert are mainly nocturnal hunters or scavengers. Most of the species caught in pitfall traps are ground-dwelling, either in burrows or amongst the plant litter.

Drift-fence pitfall traps were set up in four major vegetation types: mallee (2 sites), mallee-heath (7), scrub-mallee (2), and heath (2), all situated within an arc 6.6 km north of Chinaman Well (35°53'S, 141°39'E). Each site consisted of two perpendicular trap lines, each with 8 x 25 cm diameter traps connected by a drift-fence. Traps were permanently left in position, and open for 5 days during September, November, December 1979, January, February, March, April, June, August, September, October and December 1980.

Results are presented on the abundance and seasonal activity of the cockroaches (Table 1) and Carabidae (Table 2) for the four major vegetation types, and analyzed for differences between vegetation types and seasons using two way ANOVA and log x+1 transformations (cockroaches) or log transformations (Carabidae).

Table 1. Number of cockroaches in each vegetation type /5 day trapping period.

	Mallee	Mallee-heath	Scrub-heath	Heath	Total
Summer	1.00	0.75	0.38	0.50	2.63
Autumn	1.00	1.14	2.25	0.75	5.14
Winter	0.00	1.21	0.50	0.75	2.46
Spring	3.63	7.43	6.88	3.25	21.19
Total	5.63	10.53	10.01	5.25	31.42

The differences in cockroach abundances between the four vegetation types are not significant. Differences in seasonal activity are highly significant ($p < 0.0005$), with activity greatest in spring in all four vegetation types.

Table 2. Number of Carabidae in each vegetation type per 5 day trapping period.

	Mallee	Mallee-heath	Scrub-heath	Heath	Total
Summer	0.75	3.50	1.00	5.50	10.75
Autumn	1.00	3.64	2.50	9.25	16.39
Winter	3.50	3.71	1.75	5.75	14.71
Spring	3.13	21.50	13.38	24.88	62.89
Total	8.38	32.35	18.63	45.38	104.74

The differences in Carabidae abundances between the four vegetation types are significant ($p < 0.01$), with the mallee sites having the lowest number of animals. This is probably due to the more open understorey and shrub layers and sparser litter in these sites. Differences in seasonal activity are highly significant ($p < 0.0025$), with Carabidae activity highest in spring in all vegetation types except the mallee.

Acknowledgements

This project was financed by a grant from the Westpac Bank to Dr T.P. O'Brien, Professor M.J. Canny and Dr G. Ettershank at Monash University and by the Museum of Victoria.

Reference

Mackerras, M.J. (1970) Blattodea (cockroaches). In The Insects of Australia. pp. 262-274. CSIRO and Melbourne University Press, Melbourne.

SOIL AND LITTER INVERTEBRATES OF THE AUSTRALIAN CAPITAL TERRITORY

Penelope Greenslade and J.D. Majer (Co-ordinators)

The papers in this section concern fauna from parts of Australia which, strictly speaking, do not have a mediterranean climate. They have been included because the study sites used in these works carry vegetation which resembles that in mediterranean climatic zones.

EFFECTS OF A HIGH-INTENSITY FIRE ON ANTS AND OTHER INVERTEBRATES IN THE BRINDABELLA RANGE

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Fire is a major factor structuring animal and plant communities in most Mediterranean ecosystems. We report here the immediate effects of a planned, high-intensity fire on the activity of soil and litter macroinvertebrates in a montane eucalyptus forest in southeast Australia.

Methods

At Bushrangers Creek (35°25'S, 148°48'E, 1025 m), 40 pitfall traps (following the design of Majer (1978)) set out on a 15 x 40 m grid were used to determine the weekly abundance and diversity of macroinvertebrates both prior to and following a high-intensity fire. For ants, species composition and abundance were determined for five consecutive weekly periods before and after the fire. For other invertebrates, specimens in the immediate prefire and postfire samples were identified to order and segregated to "morphospecies".

The site can be characterised as montane forest dominated by relatively pure stands of Eucalyptus delegatensis (see O'Dowd and Gill (1984), for more detailed site descriptions). The planned fire was conducted on 18th February, 1980 (summer). Complete scorch occurred for 90% of the canopy trees at the site (up to a height of 35 m). The understorey was completely razed and the litter mineralised, producing an ashbed.

Results

Table 1. Effects of a high-intensity fire on total number and species richness of ants trapped wk^{-1} over a 10 week period. Pre- and Postfire means followed by a different letter are significantly different at $p<0.001$ (Mann-Whitney u-test).

	Prefire Weeks						Postfire Weeks					
	1	2	3	4	5	$\bar{x}$	1	2	3	4	5	$\bar{x}$
ants trapped wk^{-1}	188	177	177	176	176	179 [a]	938	553	557	795	558	680 [b]
ant species richness	18	13	17	13	13	14.8 [a]	20	23	25	25	21	22.8 [b]

Ants were the most numerous macroinvertebrate group caught in pitfall traps and comprised about 29% of the total individuals trapped before fire and over 93% after fire. Following the fire,

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the number of ants trapped increased markedly from prefire levels, averaging 179 ants per week before fire and a mean of 680 ants per week after fire (Table 1). Species richness of ants trapped also increased from a prefire average of 14.8 species per week to a mean of 22.8 species per week after fire. The absolute abundance of all ant species trapped increased after fire and did so significantly for four of the six most commonly trapped ants. The relative abundance of some species trapped changed markedly after fire (Table 2). Fire did not eliminate any ant species on the grid and one species, **Notoncus spinisquamis**, was only trapped after the fire.

Table 2. Effect of a high-intensity fire on the relative abundance (proportion of total catch) of the six most abundant ant species at Bushrangers Creek, ACT. Number of ants trapped in five week pre- and post-fire periods are in parentheses. A total of 894 ants were trapped before fire and 3401 after fire. Ant species which increased significantly following fire are indicated by an asterisk.

Species	Prefire	Postfire
Iridomyrmex sp. 1	0.39 (347)	0.15 (510)
Iridomyrmex sp. 2	0.10 (86)	0.19 (650)*
Prolasius sp. 1	0.10 (86)	0.16 (528)*
Prolasius sp. 3	0.08 (76)	0.10 (328)*
Rhytidoponera victoriae	0.07 (66)	0.06 (192)
Sigmacros sp.	0.09 (82)	0.13 (453)*
	0.83	0.79

The abundance and diversity of other invertebrate groups declined markedly following the high-intensity fire (Fig. 1, Table 3). The total abundance of macroinvertebrates in pitfalls (excluding ants) decreased from 434 to 67 individuals, a 6.5-fold decrease. Morphospecies richness declined by half, from 94 species prior to fire to 44 species following fire.

Discussion

High-intensity fire caused marked changes in the macroinvertebrate fauna as measured by pitfall trapping. Except for ants, their abundance and species richness decreased dramatically in the immediate aftermath of fire (Fig. 1, Table 3). High-intensity fire, involving mineralisation of the litter and upper soil, probably destroys many soil/litter invertebrates in situ and this contributes to the observed reduction in their diversity.

Foraging activities of ants, on the other hand, increased six-fold overall. Most ant species are probably resilient to fire in that they nest in soil, an excellent insulator. Several factors may contribute to the increased catches of ants following fire: (1) habitat modification; (2) release from competition and/or

Figure 1. Effects of high-intensity fire on cumulative species richness of macroinvertebrates (excluding ants) in pitfall traps. Filled symbols represent the week immediately prior to the fire. Open symbols represent the week immediately following the fire.

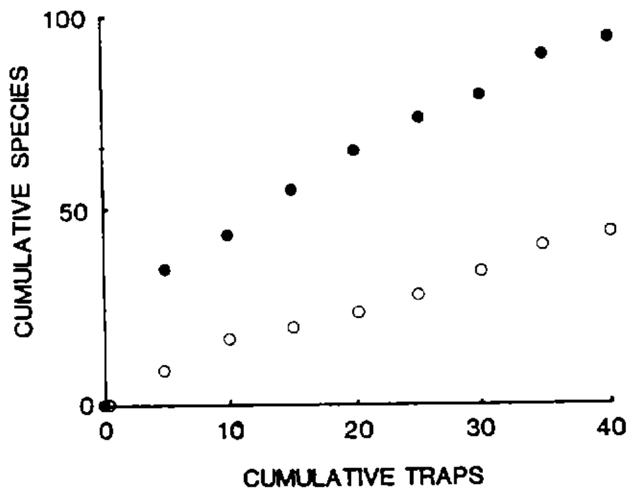

Table 3. Relative frequency and number of macroinvertebrates caught in pitfall traps in the week preceding and following the experimental fire at Bushrangers Creek, ACT.

Taxa	Prefire number	Prefire frequency	Postfire number	Postfire frequency
Class Insecta				
Dermaptera	23	0.038	0	-
Orthoptera	0	-	2	0.002
Hemiptera	20	0.033	2	0.002
Homoptera	8	0.013	0	-
Coleoptera	146	0.239	7	0.007
Diptera	70	0.114	20	0.020
Lepidoptera	11	0.018	5	0.004
Hymenoptera				
Formicidae	178	0.291	938	0.934
non-Formicidae	8	0.013	1	0.001
Class Arachnida				
Araneae	41	0.067	25	0.025
Acarina	80	0.131	2	0.002
Chilopoda	0	-	1	0.001
Diplopoda	13	0.021	0	-
Class Crustacea				
Amphipoda	2	0.003	0	-
Isopoda	12	0.020	1	0.001
Class Oligochaeta				
Opisthopora	0	-	1	0.001
Total	612	1.000	1005	1.000
Total non-Formicidae	434	0.709	67	0.064

predation, and, (3) changes in the available food supply. This experiment cannot discriminate between these hypotheses but it is likely that habitat modification plays a major role in two ways. Firstly, by simplifying habitat structure, fire may compress foraging activity of a wide variety of ants on to a single plane, the ashbed. Secondly, by modifying the physical environment, e.g. increasing insolation and altering soil surface factors (temperature, humidity, etc.), a broader range of suitable foraging conditions may be available for a variety of ant species.

References

Majer, J.D. (1978) An improved pitfall trap for sampling ants and other epigaeic invertebrates. Journal of the Australian Entomological Society 17, 261-262.

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INVERTEBRATES FROM LITTER UNDER SELECTED EUCALYPT AND PINE FORESTS IN THE AUSTRALIAN CAPITAL TERRITORY

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Introduction

Five square 0.25 ha plots were sampled in dry sclerophyll forest dominated by **Eucalyptus dives** in the Uriarra Forest management area, about 38 km south west of Canberra, in the Australian Capital Territory (approximately 35°19'S, 148°51'E). Another 5 square 0.25 ha plots were sampled in a **Pinus radiata** plantation in compartment 172, about 3 km south of the plots in the eucalypt forest. The pine was planted on a site originally covered by eucalypt forest of about the same quality, floristic composition and topography as the eucalypt site sampled. All plots were at an altitude of about 750 m. Total litter mass for the five **Eucalyptus** plots was 17.5, 16.7, 13.5, 16.0 and 13.6 t ha^{-1} respectively. Litter under the pines was fairly uniform with 8.9, 9.4, 9.4, 8.9 and 12.2 t ha^{-1} respectively on the 5 plots.

The climate is continental, with hot summers and cold winters. Winter temperatures are frequently below freezing and snow falls in most winters, although it rarely persists. Mean annual temperature from 1967 to 1972 was 12.6°C, with the highest monthly mean (25.3°C) in February, and the lowest (0.2°C) in July. Average annual rainfall for 1967-72 was 100 cm, but with considerable variation within and between years (51 cm in 1967, 130 cm in 1970).

Sampling

1. Pitfall traps

Forty pitfall traps were dug in at random in each of the 10 plots. Each trap consisted of a 6.5 cm diameter auger hole into which was placed a plastic cup. The cup had a 7.0 cm top diameter, 4.5 cm bottom diameter and height of 9 cm. The top was set flush with the litter surface, with minimum disturbance of adjacent litter. Thirty ml of saturated picric acid + 10% glycerol solution was placed in the cup. Sampling periods for which results are presented here began on 29th April, 8th July, 20th September and 11th November, 1972. Geometric means (/100 cm trap diameter) for different taxa are given in Table 1 and ran for 7 days each.

2. Litter sampling

Forty samples of litter were taken from each plot on each sampling period. A square frame of internal dimension 31.6 x 31.6 cm (0.1 m^2) was used to delimit the litter to be collected: a knife was run round the inside of the frame to cut the litter down to the soil surface, and the sample was lifted and put in a plastic bag. Samples were put in Tullgren type extractors, (Tanton et al. 1983) for extraction of invertebrates. Geometric means (m^{-2}) for 4 selected occasions for different taxa are given

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in Table 2.

Pitfall traps caught more Acarina, but fewer Araneae, pseudoscorpions, Symphyla, Collembola and Hymenoptera (ants) from pine litter than from eucalypt litter. However, some of these differences could be associated with changes in activity rather than absolute abundance. The composition of the fauna extracted from the litter differed. More mesostigmatid and prostigmatid mites, Symphyla, Pauropoda, Collembola, Diptera and Diptera larvae were collected from pine litter than from eucalypt litter. On the other hand, fewer pseudoscorpions, Lepidoptera, Lepidoptera larvae, and Hymenoptera (ants) were found in pine litter.

Table 1. Animals captured in pitfall traps over a 7 day period from eucalypt and pine forest at Condor Creek, Uriarra Forest, Canberra, Australian Capital Territory. Forty traps used on each of 5 square plots each of 0.25 ha. Results expressed as geometric means of number caught per 100 cm (1 m) of trap diameter, together with lower and upper 95% confidence limits. For each collection, lowest and highest population means fo the unburnt plots are given. '*' indicates that confidence limits included zero or negative values and are unreliable.

	EUCALYPT LITTER				PINE LITTER			
Taxon	29 April 72	8 July 72	20 Sept 72	26 Nov. 72	29 April 72	8 July 72	20 Sept 72	26 Nov. 72
Nematoda	0 0 4*	0 4* 0 7*	0	0 0 4*	0 0 4*	0 1.1*	0	0
Mollusca	0	0	0	0	0	0 1 1*	0	0 0 4*
Annelida	0 1 4*	0 0 4*	0 7* 2 1(0 4-3 7)	0 1 4(0.04-2.9)	0	0	0 0 7*	0
Scorpionida	0 7 1(2 9-11)	0	0 7* 2 1(0 1-4 1)	0 0 4*	1 1* 1 7(0 3-3 1)	0	0 4* 1 1*	0
Pseudoscorpionida	0 2 9(1 0-4.7)	0 1 1*	0 7* 3 1(1 0-5 4)	2 6(0 4-4.6) 4.6(2 4-9.0)	0 0 4*	0 1 1*	1 1* 4 3(1 7-6 8)	0 4* 1.1*
Opiliones	0 0 4*	0	0 4* 7 4(2 9-12)	0 0 7*	0	0	0 2 1*	0 4* 0 7*
Acarina	30(20-40) 85(61-110)	25(17-33) 60(42 78)	101(81-121) 187(148-225)	130(101-158) 197(165-229)	139(115-164) 202(157-246)	43(33-52) 63(36-89)	214(190-237) 294(242-347)	197(161-234) 203(173-234)
Araneae	31(24-38) 46(36-57)	100(83-116) 123(104-142)	56(46-66) 119(95-143)	110(84-135) 138(116-161)	14(9-19) 23(16-30)	22(16-27) 33(24-42)	57(42-67) 94(76-112)	30(23-37) 40(29-52)
Isopoda	1 4(0 04-2 9) 4 0(1.4-6 4)	15(10-20) 32(22-41)	0.7* 2.1(0 4-3 7)	4 6(1 0-8 3) 6 4(3 0-9 9)	0 2.9(0 6-5.1)	0 4* 6 0(1 0-9 1)	0.7* 10.3(6 4-14 3)	3 6(1 6-5 6) 6 4(3 3-9 6)
Diplopoda	0 0.7*	0 0 4*	0 1 4*	2 1(0 1-4 1) 3 6(1 3-5 9)	0 1 1*	0 1 1*	0 4* 5 7(1 6-9.8)	1 7(0 3-3.3) 4 3*
Chilopoda	0 4* 1 1*	0 0 4*	1 1* 1 4(0 04-2 9)	0 4* 1.7(0 3-3 3)	0 4* 1 1*	0	0 1 1*	0 0 7*
Symphyla	0 0 4*	0 0 4*	0 7* 2 9(1 0-4 7)	0	0 1 4(0 04-2 9)	0	0	0
Collembola	165(134-195) 326(276-377)	451(319-582) 580(470-691)	579(477-680) 1130(977-1280)	1000(804-1200) 1010(830-1190)	9 7(4 1-15 1) 137(90-185)	163(126-199) 658(472-843)	207(158-256) 774(610-939)	499(432-566) 533(378-688)
Protura	0	0	0	0	0	0	0	0
Diplura	0 7* 8 3(2 0-14)	0 0 4*	0 7* 1 4(0 04-2 9)	0 0 4*	0 0 7*	0	0 0 7*	0
Blattodea	0	0 7* 1 1*	0 4* 0 7*	0 7* 2 6(0 4-4 6)	0	0	0 0 4*	0 4* 0 7*
Mantodea	0	0 0 4*	0 0 4*	0	0	0	0	0
Isoptera	0 0 4*	0	0 0 4*	0	0	0	0 1 1*	0
Dermaptera	0 0 4*	0	0	1 1* 1 4(0 04-2 9)	0	0	0	0
Grylloidea	2 1(0.1-4 1) 35(20 49)	0 0 4*	1 4(0 04-2 9) 3 1(1 0-5 4)	1 7(0 3-3 3) 12(6 9-17)	0 4* 3 9	0 4 3 9	0 2 5*	1 1* 3.1(1 0-5 6)
Embioptera	0	0 0 4*	0	0 0 4*	0 0 7*	0	0	0 0 4*
Psocoptera	0 0 4*	0 0 4*	1 1* 2 9(1 0-4 7)	0	0 1 4(0 04-2 9)	0	0	0
Homoptera	1 1* 3 1(1.0-5 4)	0 1 1*	30(21-40) 104(68-141)	13(8 3-18) 46(19-74)	0 0 4*	0 0 4*	0 4* 65(53-76)	32(21-43) 33(24-43)
Heteroptera	0	0	0	0	0	0	0	0
Thysanoptera	0 1 1*	0 4* 0 7*	3 1(1 0-5 4) 5 8(2 9 11)	2 1(0 4-3 7) 6 4(2 6-10)	0 0 7*	0 1 4(0 04-2 9)	0 1 4(0 04-2 9)	1 1* 1 8*
Neuroptera Larvae	0 0 7*	0 0 4*	0 0 7*	0	0 0 4*	0 0 4*	0 1 4(0 04-2 9)	0 0 4*
Coleoptera	48(35-62) 65(48-83)	7 4(4 0-11) 15(9 9-21)	26(8 1-33) 27(19-36)	40(30-49) 45(35-55)	13(9 7-16) 35(24-45)	3 6(0 7-6 4) 7 1(1 4-13)	12(5 8-19) 31(24-39)	61(43-79) 190(141-238)
Coleoptera Larvae	1 8* 8 3(3 3-13)	1 [illegible](0 3-3 3) 5 0(2 6-7 4)	4 6(2 0-7 3) 7 1(3 1-11)	15(9 9-20) 21(13-29)	0 3 6(0 3-7 0)	0 2 1*	0 1 1*	0 1 1*
Diptera	26(16-35) 36(26-46)	40(27 53) 109(73-145)	43(31-55) 5[illegible](40-75)	14(9 6-19) 37(27-47)	13(8 3-17) 39(23-54)	12(6 7-18) 132(76-188)	57(40-78) [illegible]22(62-153)	12(5 6-19) [illegible](22-36)
Diptera Larvae	0 1 4(0 04-2 9)	3 6(1 6-5 6) 14(8 1-20)	7 1* 14*	1 4* 4.6*(2 0-7 3)	0	4 3(1 6-7 0) 25(3 9-45)	0 0 4*	0 0 4*
Lepidoptera	0 0 4*	0	0 0 7*	1 1* 1 4(0 04-2 9)	0	0	0 0 4*	0 0 4*
Lepidoptera Larvae	0 1 4*	0 0 4*	1 1* 10(5 4 15)	1 1* 4 6(1 [illegible] 7 6)	0 4 3(0 6-8 0)	0	0 0 4*	11(6 4-16) 14([illegible] 5 20)
Hymenoptera (Ants)	159(90 229) 3[illegible](102 595)	36(21-51) 54(2[illegible])	303(181-425) 5[illegible](330-65[illegible])	276(211 339) 467(385 549)	0 3* 2 2*	0.4* 4 3(1 0-7 6)	1 4(0 04-2 9) 9 7(2 3 17)	1 1* 9 0(2 [illegible]-16)
Hymenoptera (others)	5 7(2 0 9 4) 13(7 4-18)	0 4* 2 1(0 4 3 7)	4 6(2 3 [illegible]) 7 4(3 9-11)	6(2 9-9 3) 13(8 8-19)	0 1 4(0 04-2 9)	1 4(0 04-2 9) 10(4 1-16)	0 4* [illegible](1 7 [illegible])	8 9(5 8-12) 13(8 1 18)
Lizards	0 1 4(0 04-2 9)	0	0 7* 1 7*	0 7* 1 [illegible](0.3-3 3)	0	0	0	0 0 4*
Frogs	0 0 7*	0	0 0 4*	0 4* 0 4*	0	0	0	0 [illegible]

Table 2. Invertebrates extracted from eucalypt and pine litter by Tulgren-type equipment at Condor Creek, Uriarra Forest, Canberra, Australian Capital Territory. Forty 0.1 m^2 samples taken from each of five 0.25 ha plots. Geometric means (m^{-2}) for unburnt plots, together with lower and upper 95% confidence limits. Lowest and highest plot means are given for each occasion as an indication of range encountered. '*' indicates that confidence limits included zero.

	EUCALYPT LITTER				PINE LITTER			
Taxon	January, 72	June, 72	November, 72	March, 73	December 71	June 72	October, 72	February, 72
Annelida	0.2*	0.2*	0	0	0	0.4*	0	0.2*
	0.8*	2.3(0.6-4.2)	0.2*	0.3*	0.8(0-1.7)	1.3(0-2.6)		0.9(0-2.0)
Pseudoscorpionida	3.5(1.5-5.9)	33(20-52)	0.4*	[illegible]	0.2*	1.0*	0.8(0-1.7)	0
	[illegible]	5(5-10)	[illegible]	3(1.9-4 [illegible]	[illegible]	[illegible]	[illegible]	4*
Acarina	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Astigmatid	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Cryptostigmatid	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mesostigmatid	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Prostigmatid	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	100(69-144)	1210(1010-1450)	27(19-37)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Araneae	6.4(2.7-11)	21(15-30)	1.3(0.3-2.5)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	43(32-56)	42(32-54)	4.8(2.5-7.5)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Isopoda	0	0.3*	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	2.2(0.4-4.2)	2.2(1.0-3.6)	0.3*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diplopoda	0.2*	3.7(1.0-7.1)	[illegible]	3.1(0.5-6.4)	0.4*	0.8*	0.7(0-1.5)	0
	3.3(1.4-5.6)	5.5(2.4-9.2)	0.8*	7.0(3.7-11)	4.1(1.8-6.8)	1.3*	3.9(1.6-5.6)	4.5(2.0-7.4)
Chilopoda	0.2*	1.4(0.3-2.7)	0	1.7(0.4-3.1)	0.4*	2.3(0.5-4.3)	6.8(3.2-11)	0.7(0-1.5)
	4.5(1.7-8.0)	4.3(2.3-6.7)	1.6*	2.2(0.8-3.7)	4.0(1.3-7.2)	5.3(2.6-8.4)	7.0(3.9-11)	4.6(2.0-7.6)
Symphyla	0	2.4(1.0-3.8)	3.9(1.1-7.3)	0.3*	8.4(4.0-14)	3.3(4.2-13)	4.2(1.1-8.2)	1.1*
	3.2(1.0-5.9)	8.6(4.5-14)	6.8(0.7-15)	0.5*	18(10-29)	14(8.4-22)	[illegible]	6.5(3.2-11)
Pauropoda	0	0.5*	0	0.7(0.02-1.5)	1.0*	3.7(1.2-6.8)	[illegible]	0.6*
	0.7(0.02-1.5)	0.8(0-1.7)		1.4(0.3-2.7)	7.3(4.1-11)	3.7(4.5-14)	[illegible]	2.2(0.6-4.0)
Collembola	3.4(1.3-5.8)	223(134-365)	0.3*	39(24-61)	251(155-404)	10(6.3-15)	[illegible]	402(277-582)
Arthropleona	141(87-224)	821(557-1210)	11(4.3-20)	140(78-246)	2800(2220-3530)	120(80-178)	[illegible]	764(600-972)
Symphypleona	0.2*	18(12-69)	0	6.9(3.2-11)	15(8.8-25)	1.3(0.3)	[illegible]	49(32-74)
	7.2(3.9-11)	279(197-395)	0.6*	17(8.6-30)	128(102-159)	21(13-31)	[illegible]	877(648-1180)
Blattodea	0	1.0(0.1-2.0)	0.2*	0.9(0.1-1.7)	0	0	0	0
	1.8(0.4-3.3)	2.6(1.1-4.4)	1.0*	1.1(0.2-2.0)				
Isoptera	0	0	0.6*	0.2*	1.6*	0	0.5*	1*
	2.0*	0.9*	2.1*	0.2*	12(3.0-26)	2.2*	6.7*	2.4*
Embioptera	0.2*	0.2*	0	0.2*	0	0	0.6*	0.7*
	0.6*	0.8(0-1.7)	0.2*	0.4*	1.2(0.1-2.4)	1.6(0.3-3.1)	2.6(0.9-4.7)	0.9*
Psocoptera	0	5.3(2.5-8.7)	0.8(0-1.7)	5.0(2.5-7.9)	1.2(0.2-2.3)	1.4(0.2-2.7)	14(9.4-21)	12(8.0-18)
	3.2(0.1-7.2)	7.6(3.5-13)	3.3(2.3-5.7)	8.1(3.9-14)	9.0(4.7-15)	2.6(0.9-4.5)	33(22-47)	19(13-29)
Homoptera	0.7(0.02-1.5)	2.9(1.4-4.6)	0.4*	6.3(3.0-10)	5.5(3.0-8.5)	3.9(1.0-7.5)	71(50-99)	2.6(0.6-4.9)
	14(7.2-23)	6.0(2.8-9.9)	3.4(1.4-5.7)	17(9-29)	208(130-329)	827(532-1290)	127(76-208)	15(6.4-27)
Heteroptera	0.4*	3.0(1.0-5.1)	0.4*	5.5(2.7-8.7)	1.6(0.5-2.8)	0.6*	3.6(1.0-6.8)	0.4*
	1.8(0.4-3.5)	3.9(1.9-6.1)	2.4*	5.3(3.1-9.0)	5.0(2.2-8.5)	3.0(1.2-5.1)	5.3(2.6-8.8)	1.9(0.5-3.6)
Thysanoptera	11(6.6-16)	77(57-102)	4.1(1.9-6.6)	55(41-74)	23(16-31)	16(8.8-25)	83(57-120)	9.8(5.8-15)
	57(38-83)	138(107-177)	11(5.1-18)	56(48-89)	83(60-128)	75(48-114)	102(67-154)	35(22-53)
Neuroptera	0	0.2*	0	0	0	0	0	0
Larvae	0.2*	0.8*	0.2*		1.6*	0.1*	0.2*	
Coleoptera	5.1(2.5-8.3)	44(29-64)	1.5(0.4-2.8)	35(25-47)	16(10-23)	19(13-27)	25(17-34)	11(5.8-17)
	50(35-71)	118(87-159)	8.5(3.1-15.0)	48(32-[illegible])	33(21-41)	27(19-35)	33(23-44)	23(15-35)
Coleoptera Larvae	5.5(2.3-9.4)	19(13-26)	3.9(1.9-6.2)	[illegible]	9.7(6.6-13)	3.7(2.0-5.7)	26(16-40)	10(6.6-15)
	29(20-40)	30(21-41)	5.4(2.4-9.2)	[illegible]	26(14-43)	17(10-27)	42(27-63)	20(13-29)
Diptera	0.2*	1.7(0.4-3.1)	0.5*	[illegible]	8.0(5.1-12)	1.3(0.3-2.5)	10(6.6-15)	7.2(3.7-12)
	4.3(2.1-6.9)	2.7(0.9-4.7)	1.2(0.1-2.4)	[illegible]	25(16-37)	21(13-31)	14(9.4-21)	17(12-34)
Diptera Larvae	1.3(0.2-2.5)	7.3(3.5-12)	0	[illegible]	15(8.2-24)	13(8.2-20)	34(20-55)	43(31-59)
	19(11-30)	13(8.2-19)	3.0*	[illegible]	33(25-44)	91(66-124)	118(79-173)	56(41-74)
Lepidoptera	0	0.4*	0.2*	[illegible]	0.2*	0	0	0
	0.9(0.1-1.8)	0.6*	0.4*	0.7(0.02-1.5)	[illegible]	0.5*	1.7(0.6-2.3)	0.2*
Lepidoptera Larvae	3.4(1.7-5.3)	21(16-27)	1.4(0.4-2.5)	12(7.7-18)	3.2(1.5-5.1)	0.9(0.1-1.7)	20(13-29)	1.1(0.2-2.0)
	15(10-20)	29(21-39)	3.0(1.3-4.9)	22(15-30)	8.2(4.5-13)	3.0(1.2-5.1)	20(14-28)	4.6(2.8-6.5)
Hymenoptera (Ants)	7.4(1.9-16)	11(5.1-19)	3.9(1.1-7.3)	13(4.3-25)	1.1(0.2-2.0)	1.2(0.1-2.4)	2.3(0.7-4.1)	1.7(0.3-3.3)
	45(22-83)	34(18-59)	6.8(0.7-16)	61(25-136)	4.3(2.1-6.9)	4.5(1.8-7.8)	5.7(2.4-9.6)	3.1(0.8-5.9)
Hymenoptera (Others)	1.0*	11(6.2-16)	0	4.3(2.2-6.8)	1.5(0.4-2.8)	1.3(0.2-2.5)	2.3(0.9-3.9)	[illegible]
	12(7.3-18)	20(13-30)	2.2(0.6-4.0)	6.4(4.0-9.2)	3.9(2.1-5.9)	4.0(2.0-6.4)	3.0(1.4-4.8)	5.6(3.6-7.9)

In addition occasional recoveries were made of Dermaptera, Diplura, Caelifera, Protura, Scorpionida, Tardigrada, Amphipoda and Onychophora

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