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Report on a Study of Invertebrates in Relation to the Kojonup Fire Management Plan

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REPORT ON A STUDY OF INVERTEBRATES IN RELATION TO THE KOJONUP NATURE RESERVE FIRE MANAGEMENT PLAN

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ABSTRACT

The influence of a cool spring burn on the density and abundance of soil, litter and surface-living invertebrates, and the activity of the latter group was investigated in a Kojonup nature reserve for which a fire management programme had been proposed.

During the pre-fire sampling period, decomposers were active primarily in winter and to a lesser extent in spring and autumn. Predators were generally less tied to seasons though activity of Araneae, Acarina and Formicidae, groups in which most sampled members are predators, did peak in summer.

The fire initially reduced the catch of most surface-living invertebrates although it did not eliminate any of the broad taxonomic groups present. Most taxa commenced numerical recovery after four months.

Density of soil and litter invertebrates was not altered appreciably by the burn.

This particular cool spring burn did not have as dramatic a negative effect on invertebrate density as has been reported for other fires in Western Australia. It is argued that autumn burns would depress invertebrate levels less than spring burns.

A separate survey showed the five largest Kojonup reserves to be rather similar as to type and diversity of ant fauna, least so for reserve 8617. This reserve is considered the appropriate site for a duplicate study if one were to be carried out.

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INTRODUCTION

The Reserves

There are eight nature reserves within the Kojonup Shire. Kojonup is within the Department of Conservation and Environment's System 4 (Conservation Through Reserves Committee, 1974). System 4 is known as the Wheatbelt, and nature reserves contained within the System are of particular conservation value since much of the original vegetation of the area has been lost due to clearing for agriculture (Kitchener, 1976).

The Wheatbelt is not a natural vegetation zone, rather it comprises a variety of vegetation types. Kojonup is situated within Gardner's (1942) South-West Botanical Province. This is characterised by having a winter rainfall and summer drought, the four wettest months being May to August with more than 175 mm for this period.

The remaining native vegetation, covering most of the area in which the Kojonup nature reserves lie, has been mapped by Smith (1972, 1974) using Specht's (1970) classification which is based on plant life-form, height and projective canopy cover density.

The eight reserves are vested in the Western Australian Wildlife Authority. Three of these reserves (Nos 9091, 9920 & 27769) are situated to the north of Kojonup townsite and each is less than 40 ha in area. The remaining reserves occur south-west of Kojonup and each has an area exceeding 145 ha. Figure 1 shows the location of these five larger nature reserves.

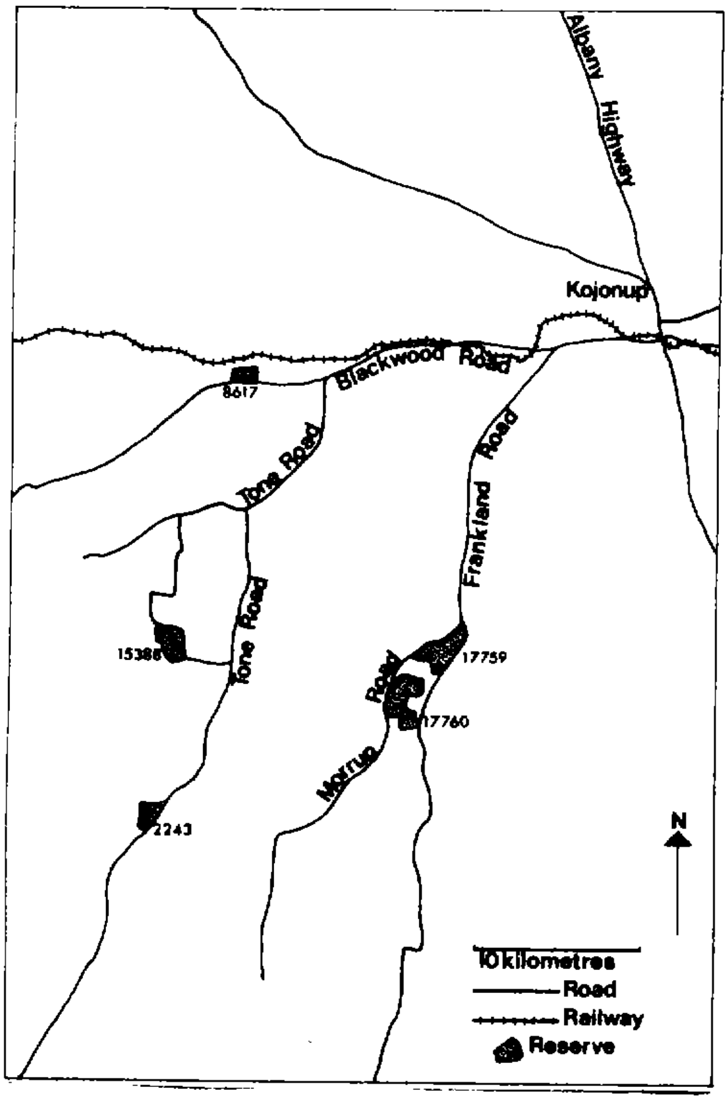

FIGURE 1

LOCATION OF THE FIVE LARGE KOJONUP NATURE RESERVES.

Management Proposals

Burbridge and Evans (1976) stress the need for management of nature reserves, and they partition management into two categories:

1. Management of animals and plants, either individually or as ecosystems, and

2. Management in relation to people.

The use and control of fire has relevance to both categories. A management plan involving fire as a major tool has been developed for the Kojonup reserves by J. Goodsell of the W.A. Department of Fisheries and Wildlife (personal communication, 1974). This plan has the following objectives:

1. To use fire as a resource management tool in order to reduce the hazard of wildfire to wildlife, nearby farms, and to the environmental values of the reserves.

2. To manage habitat by promoting vigour and diversity of vegetation.

3. To integrate hazard reduction and habitat management.

4. To protect the aesthetic qualities of the landscape.

5. To encourage study and research, and

6. To develop standards on which management of the Kojonup reserves can be based.

The fire management plan divides each large reserve into three of four compartments. Compartments from each reserve will be mild burnt (approximately 38 KW/m) in autumn on an eight year cycle. The three small reserves to the north of Kojonup are not included in the plan which is to be terminated and reviewed after a five year trial period.

The Present Study

In May 1976 the author and BIOSTAS (the W.A.I.T. Biology Students Association) commenced monitoring of the effects of prescribed burning on the flora and fauna of the five large reserves. BIOSTAS has been investigating the flora and vertebrate fauna of the reserves while the author has been monitoring the invertebrate fauna, particularly the ants.

The present study is on the effect of burning on the density, diversity, and activity of invertebrates. The results of 15 months pre-burn, and 12 months post-burn, invertebrate monitoring in one reserve, Towerlup Creek No. 17760, are reported.

It should be stressed that this work was performed with a limited budget such that the intensity and variety of sampling methods are inadequate in certain respects. The author is performing similar, but more detailed, studies on the effects of burning on invertebrates at Dwellingup (30, 175 and 500 KW/m autumn burns, and one 1500 KW/m spring burn) and at Karragullen (175 KW/m autumn burn). In view of the fact that there are similarities between the soil and flora of Kojonup and these northern jarrah forest sites, and that 50 per cent of the ant species at Kojonup are common to Dwellingup, the results of the jarrah forest studies probably have some applicability to the Kojonup reserves.

The approach used in this study has been to find the seasonal variation in ground living invertebrate abundance and activity in order to provide a framework against which to consider the effects of burning. Only Towerlup Creek reserve was selected for detailed investigation in view of the large time commitment needed for this type of work.

Sampling was started in a compartment scheduled for burning in the autumn of 1977, and in one other which was to be burnt several years later. The latter compartment served as a control area. The ground-living, or epigaeic, fauna was regularly sampled both before and after the fire in order to obtain data on seasonality of activity and abundance of invertebrates and to monitor the effects of fire. The soil and litter fauna were sampled once after the fire, following the construction of new Berlese extractors for soil fauna.

In order to assess how applicable the results from Towerlup Creek are to the other reserves, the species composition of one invertebrate group, the ants, was compared in the five larger reserves.

DETAILS OF RESERVES

Table 1 summarises information on reserve location, area, former purpose and the date on which each reserve was vested as a Flora and Fauna reserve under the auspices of the Western Australian Wildlife Authority.

Reserve Name	Number	Map Reference	Area Hectares	Former Purpose	Date gazetted as flora & fauna reserve
Mininup	2243	116° 49'E, 34° 06'S	145	Public utility	1968
Narlingup Tank	8617	116° 52'E, 33° 52'S	145	Resting place for travellers & stock	1964
Mettabinup	15388	116° 49'E, 34° 00'S	157	Use of aborigines	1977
Jowerlup	17759	117° 00'E, 34° 00'S	427	Timber for settlers	1970
Towerlup Creek	17760	117° 00'E, 34° 02'S	551	Timber for settlers	1970

TABLE 1

BACKGROUND INFORMATION ON THE FIVE LARGE KOJONUP NATURE RESERVES.

Reserves 17759 and 17760 are surrounded by cleared agricultural land while the other three reserves lie adjacent to agricultural land along substantial lengths of their borders. The adjacent uncleared areas are relatively small so all five reserves can be regarded as islands of native vegetation. The reserve vegetation is classified as wandoo woodland in 2243, wandoo and flooded gum woodland with some jarrah and wandoo open forest in 8617, wandoo woodland and jarrah open forest in 15388 and jarrah open forest with a small area of low open jarrah forest in 17760 (Smith, 1972, 1974). Reserve 17759 is not covered by Smith's vegetation maps although its vegetation is similar to that of reserve 17760.

The fire history of the reserves, prior to initiation of the management plan, is not well documented although local residents recall that most reserves were burnt in 1966 or 1967. Reserves 17759 and 17760 have been logged in the past and inspection of stumps shows that the present trees are mostly smaller than those originally present. These two reserves are also downgraded due to quarrying for road materials and grazing by domestic stock. Neither activity now takes place in any of the Kojonup nature reserves.

CLIMATE

Climatic data have been extracted from the relevant Climatic Survey data book (Director of Meteorology, undated). The mean monthly maximum and minimum temperatures, mean relative humidity at 1500 hrs and monthly rainfall for the Kojonup P.O. recording station are shown in Figure 2. The mean total annual rainfall is 550 mm, the heaviest rains occurring between May and August. Rainfall is more erratic as the summer months approach.

Figure 2 shows that high temperatures are reached in the summer months, with mean monthly minimum temperatures dropping as low as 5.2°C in June. The mean daily maximum temperature for the year is 21°C and the mean daily minimum temperature is 9.1°C. The mean relative humidity for the year is 75 per cent, with a maximum of 95 per cent in June and a January minimum of 59 per cent.

Actual rainfalls for the duration of the invertebrate sampling period (June 1976 - September 1978) are also included in Figure 2. The 1976 rainfall was exceptionally light, with heavy rains only in August. A total of 435mm fell in 1977 which was light when compared with the Kojonup average, and was distributed relatively late in the year. 410 mm fell between January and September 1978. This was only slightly below the Kojonup average for this period.

METHODS

Description of Towerlup Creek Reserve Study Plots

In May 1976, one 20 x 20 m plot was selected and marked out in representative regions of compartment 1 (designated burn plot) and compartment 6 (control plot). The plots were chosen for similarity of environmental characteristics, although compartment 6 was on a hilltop and was covered with jarrah open forest, while compartment 1 was on a slope bearing some wandoo woodland. This detail of vegetation is not shown on Smith's (1972, 1974) maps.

A grid of 6 x 6 wire markers, spaced 3 m apart, was established in the centre of the burn and control plots for the positioning of pitfall traps. A 1 x 1 m quadrat was placed around each marker and environmental measurements made within the square. These were thickness of litter layer (absent, thin, dense), grade of dead wood (none, twigs only, logs), percentage ground cover, incidence of tree trunks within 1 m of quadrat and presence of absence of topshade over the quadrat. A checklist of the plants species was made for each of the 36 squares. This was used as an indication of plant species richness and also to calculate species equitability (the degree of apportionment of individuals between the species present in the area). Equitability (J') is obtained by the formula:

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

where H' is the Shannon diversity index and S in the total number of species in the population. Further details of these indices are to be found in Pielou (1975). The use of the equitability index is not strictly appropriate in this context, since individual plants were not counted. However, if frequency of occurrence of plants in the 36 quadrats is used instead, the index gives a measure of degree of equitability and dominance exhibited by the plants in each plot.

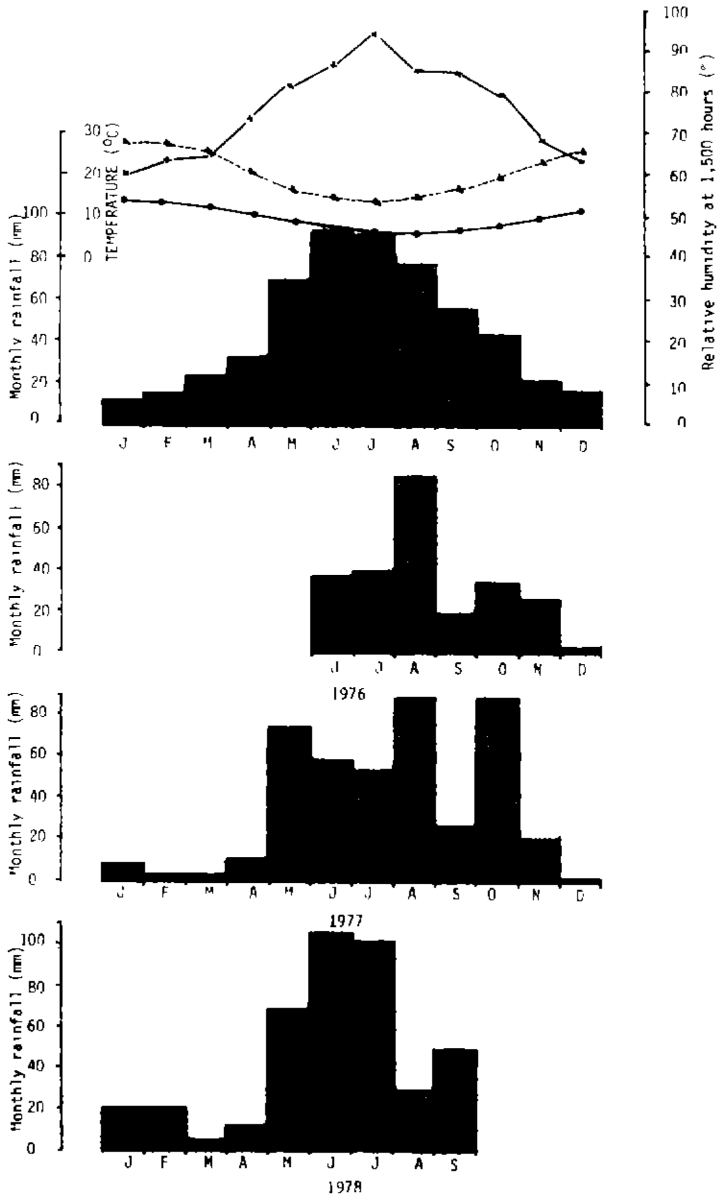

FIGURE 2

MEAN MONTHLY RAINFALL (HISTOGRAM), MAXIMUM (▲------▲) AND MINIMUM (●———●) TEMPERATURE, AND RELATIVE HUMIDITY (X———X) FOR KOJONUP P.O. MONTHLY RAINFALL FOR THE DURATION OF THE INVERTEBRATE STUDY IS ALSO SHOWN IN THE LOWER THREE SECTIONS OF THE DIAGRAM.

Invertebrate sampling in Towerlup Creek Reserve study plots. Pitfall traps were established at each of the 36 wire markers in each plot. Traps consisted of 1.8 cm internal diameter 'Pyrex' test tubes, of 15 cm length, set in plastic tubes in order to facilitate ease of changing (Majer, 1978a). Traps contained 3 ml of alcohol/glycerol (30/70 v/v) preservative. Ants are not differentially sampled by the use of this preservative although certain Coleoptera, Diptera, Hymenoptera, Dermaptera, Orthoptera and Homoptera are attracted to the spirit (Greenslade and Greenslade, 1971). Traps were inserted on 22 May 1976 and left to settle-in in order to minimize trapping error due to digging-in effects. Sampling commenced on June 1976, when traps were run for 7 day periods in most months for a 15 month pre-fire period.

After the plot was burnt on 20 September 1977, sampling continued in burn and control plots at 1 week, and 1, 4, 8, and 12 month intervals after the fire.

Traps were taken to the laboratory for hand sorting of the contents. Invertebrates were recorded at the level of class, order, superfamily, family or subfamily depending on which was adequate to describe a particular feeding habit, and also on taxonomic expertise. Ants were recorded to the species level. For technical reasons, only ants were recorded in the June 1977 and July 1977 pre-fire samples. The taxonomy of Australian ants is not yet well known. Therefore species were given code numbers if determination to species level was not possible. Australian National Insect Collection codes were assigned to species which were compared with specimens in the A.N.I.C. and which had voucher specimens deposited there. The remaining coded ants were given J.D.Majer codes which correspond to the reference collection held at the Western Australian Institute of Technology. These specimens will ultimately be coded with A.N.I.C. numbers when adequate series are collected to allow later comparison with voucher specimens.

The soil and litter fauna were sampled once on 4 September 1978, approximately one year after the burn. Ten soil core samples, taken from co-ordinates obtained using random number tables, were taken from each plot using a soil corer of 5.4 cm internal diameter and 10.3 cm depth. Ten 19 x 19 cm litter samples were also taken from each sample point. Soil and litter samples were immediately taken to the laboratory where the 20 soil samples were processed individually using a 20 sample-capacity, multiple-canister heat extractor. The litter samples were bulked for each plot and the fauna was extracted using two large Berlese funnels. Both extractor techniques were run for a seven day period, the temperature being increased from ambient to 40^{o}C in stages over this period. The samples were analysed using a stereo-microscope and the fauna was sorted to the broad taxonomic levels used for the pitfall trap samples.

Fire Recordings in Towerlup Creek Reserve Burn Plot

The attempt to prescribe burn compartment 1 in autumn 1977 was not successful due to moist conditions. This area was therefore burnt in the following spring on 20 September 1977, specifically for the purpose of this experiment. Thermostick tablets (93^{o}, 149^{o}, 302^{o} and 732^{o}C) were placed on the ground in order to measure air temperatures during the fire. Flame height and rate of flame spread were also noted. The plot was photgraphed immediately before and after the fire.

Field notes were taken of the effect of burning on litter, dead wood and vegetation. The amount of litter, dead wood and vegetation was visually assessed during each subsequent visit to the plots.

Reserve Comparison Study

Pitfall traps were used to sample the ant fauna in each reserve. A representative area in each of the five large reserves was selected for sampling and ten sets of co-ordinates were selected for each reserve from random number tables. Co-ordinate numbers were paced ot from tracks of firebreaks running through the area. A 1 x 1 m quadrat was placed at each co-ordinate intersention and measurements made within the square. These were the same as for the Towerlup Creek measurements with the exception that plants in the quadrats were not identified. The composition and diversity of reserve flora as a whole was obtained from records obtained by BIOSTAS (Gibbons, 1977). Four standard pitfall traps were placed at the corners of each quadrat and left in the ground for 7 days between 15 and 23 December 1976. This was a period of high ant activity and abundance (Figure 9). The four traps are collectively referred to as a pitfall trap set. The sets were distributed over approximately 2.5 ha of each reserve.

The pitfall traps were taken to the laboratory for sorting of ants. Mountford's (1962) index of similarity was used to investigate the relationship of ant faunas between the reserves. A matrix of indices of similarity was constructed using the following formula:

$$I = 2j/(2ab-(a+b)j)$$

where a is the number of species in site A, b is the number for site B and j is the number of species common to both sites. The pair of sites with the greatest similarity was grouped, and the indices of similarity between this group and the remaining sites calculated as described in Southwood (1966). The process was repeated until all sites were combined so that a dendrogram could be produced which classified the reserves in terms of their similarity of ant fauna.

The reserves,were further compared in terms of their environmental factors using Scheffes' test (Nie et al, 1975). This test divides the reserves into homogeneous subsets for each environmental variable so that the differences in the means of reserves within a subset are not significant. It therefore sorts the reserves out in terms of their environmental factors.

RESULTS

The environmental parameters of the control and burn plot are summarised in Figure 3. The control plot possessed more topshade and a greater density of tree trunks although similar levels of ground cover density, dead wood and leaf litter were found within each plot. The list of plant species for these plots, and also their frequency of occurrence in the 36 quadrats, is shown in Table 2. This table also shows that the burn plot was characterised by a greater plant species richness than the control, although plant species equitability was similar for the two plots.

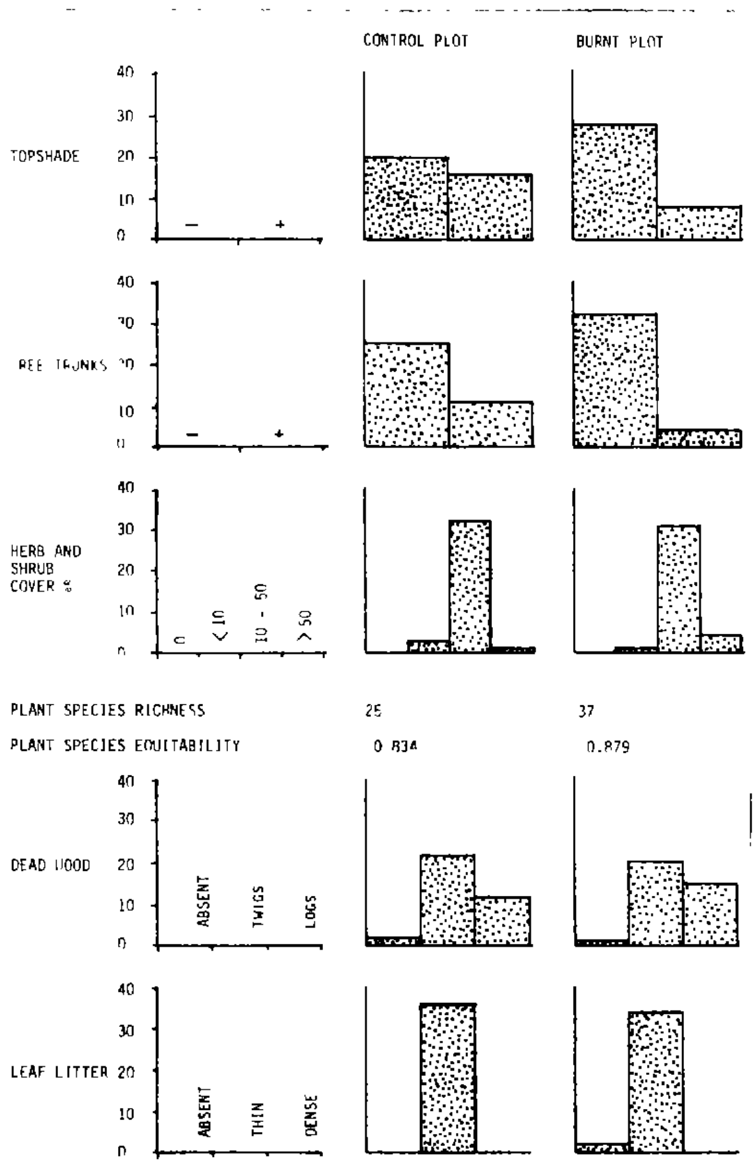

FIGURE 3

COMPARISON OF ENVIRONMENTAL FACTORS OF THE CONTROL AND BURN PLOTS OF RESERVE 17760 (THE VERTICAL SCALE REFERS TO FREQUENCY OF QUADRATS, OUT OF THIRTY SIX, IN EACH RECORDING CATEGORY).

The results of the seasonal pitfall trapping programme are illustrated in Figures 4-9. The range of taxa collected was similar to that obtained using similar sampling techniques at Dwellingup (Majer,1978b). The pre-fire peak periods for occurrence of each taxa in traps, and also their broad feeding habits, are shown in Table 3. The latter pertains to the actual species collected during this programme rather than to the taxa as a whole.

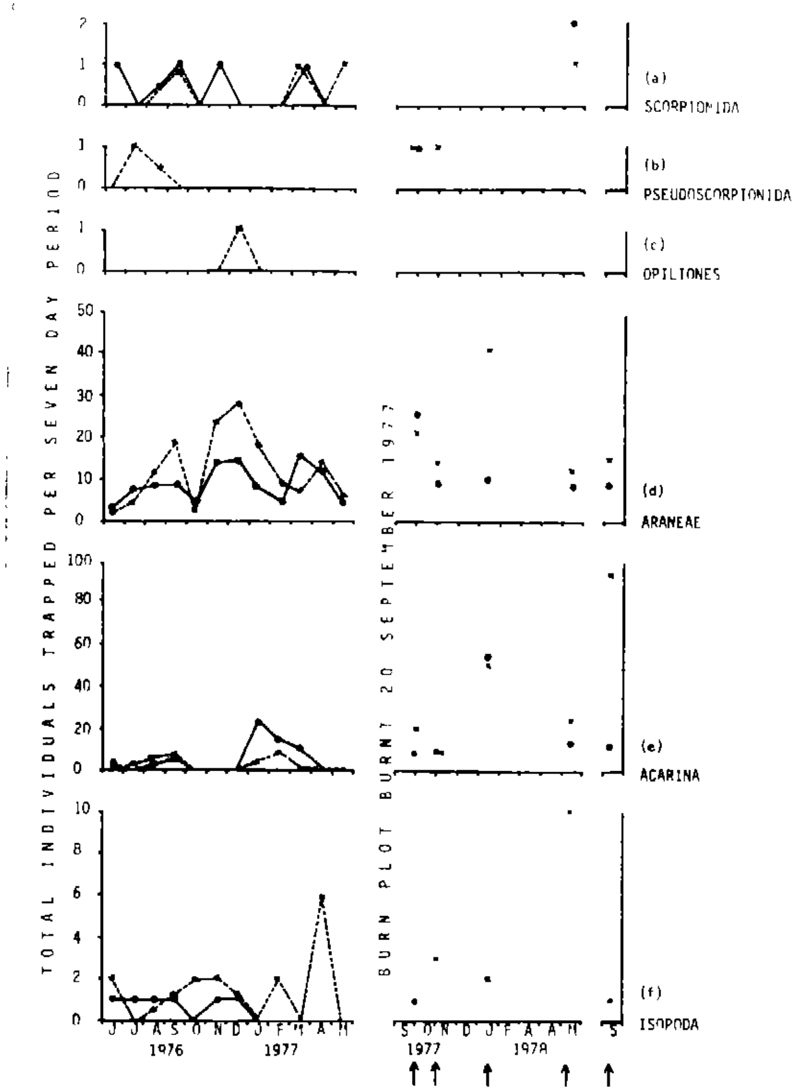

FIGURE 4

MONTHLY CATCHES OF INVERTEBRATES IN THE CONTROL PLOT (●———●) AND BURN PLOTS (X----X) OF RESERVE 17760, AND CATCHES FOR THE POST-FIRE SAMPLES (SAMPLING TIMES INDICATED BY ARROWS).

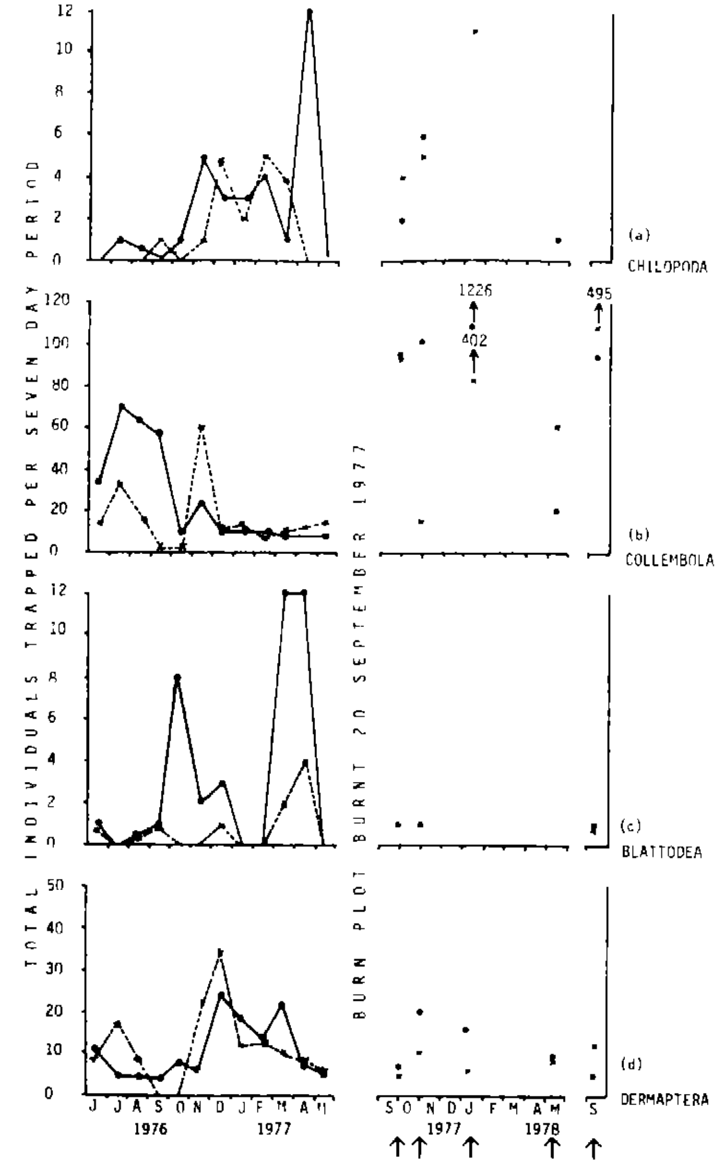

FIGURE 5

MONTHLY CATCHES OF INVERTEBRATES IN THE CONTROL PLOT (●———●) AND BURN PLOTS (X----X) OF RESERVE 17760, AND CATCHES FOR THE POST-FIRE SAMPLES (SAMPLING TIMES INDICATED BY ARROWS).

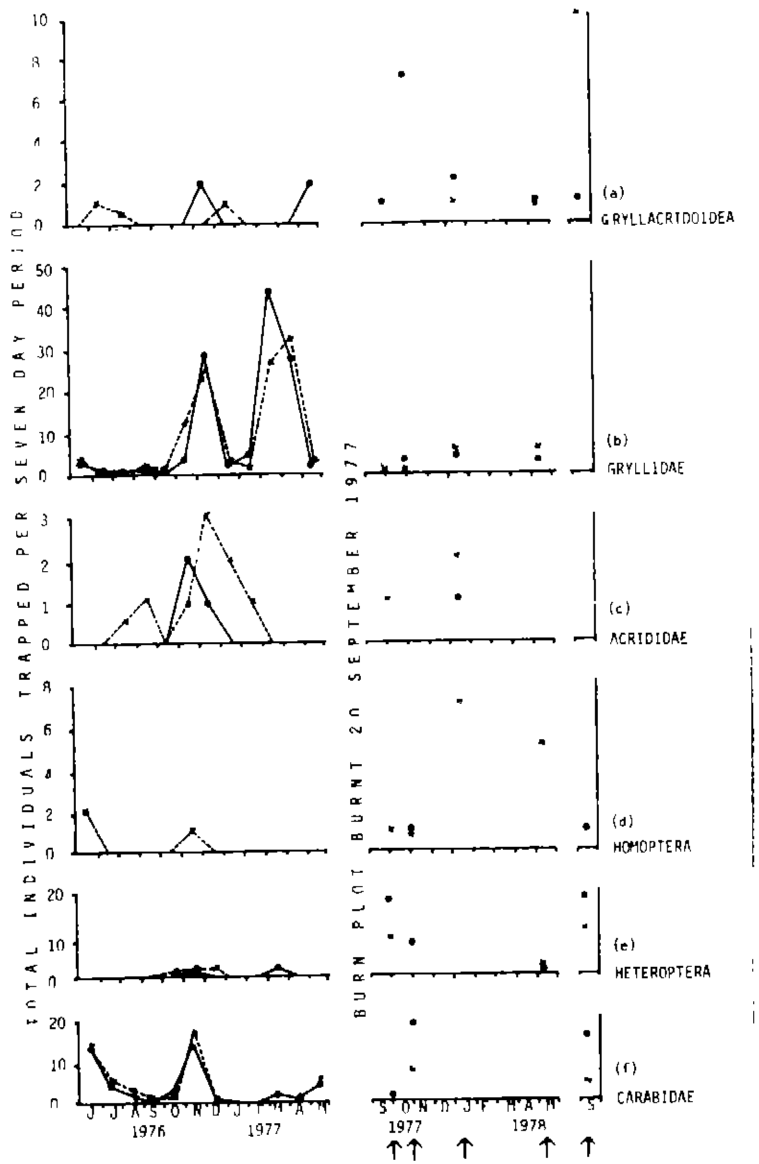

FIGURE 6

MONTHLY CATCHES OF INVERTEBRATES IN THE CONTROL PLOT (●——●) AND BURN PLOTS (X----X) OF RESERVE 17760, AND CATCHES FOR THE POST-FIRE SAMPLES (SAMPLING TIMES INDICATED BY ARROWS).

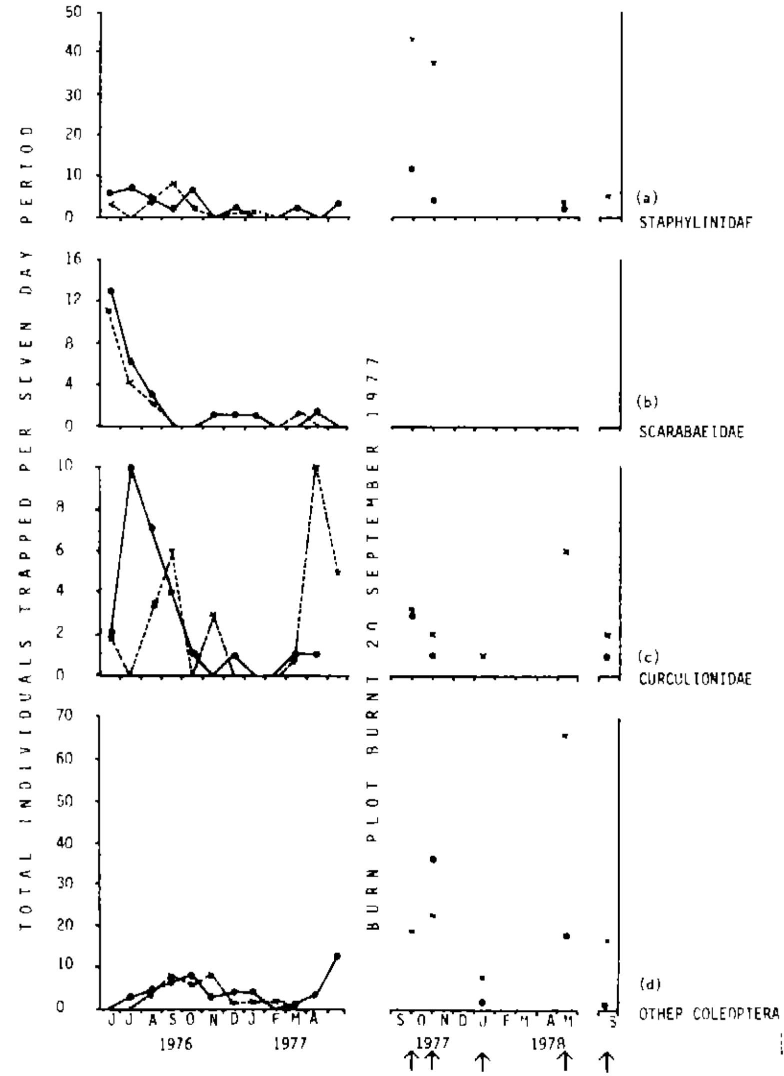

FIGURE 7

MONTHLY CATCHES OF INVERTEBRATES IN THE CONTROL PLOT (●——●) AND BURN PLOTS (X----X) OF RESERVE 17760, AND CATCHES FOR THE POST-FIRE SAMPLES (SAMPLING TIMES INDICATED BY ARROWS).

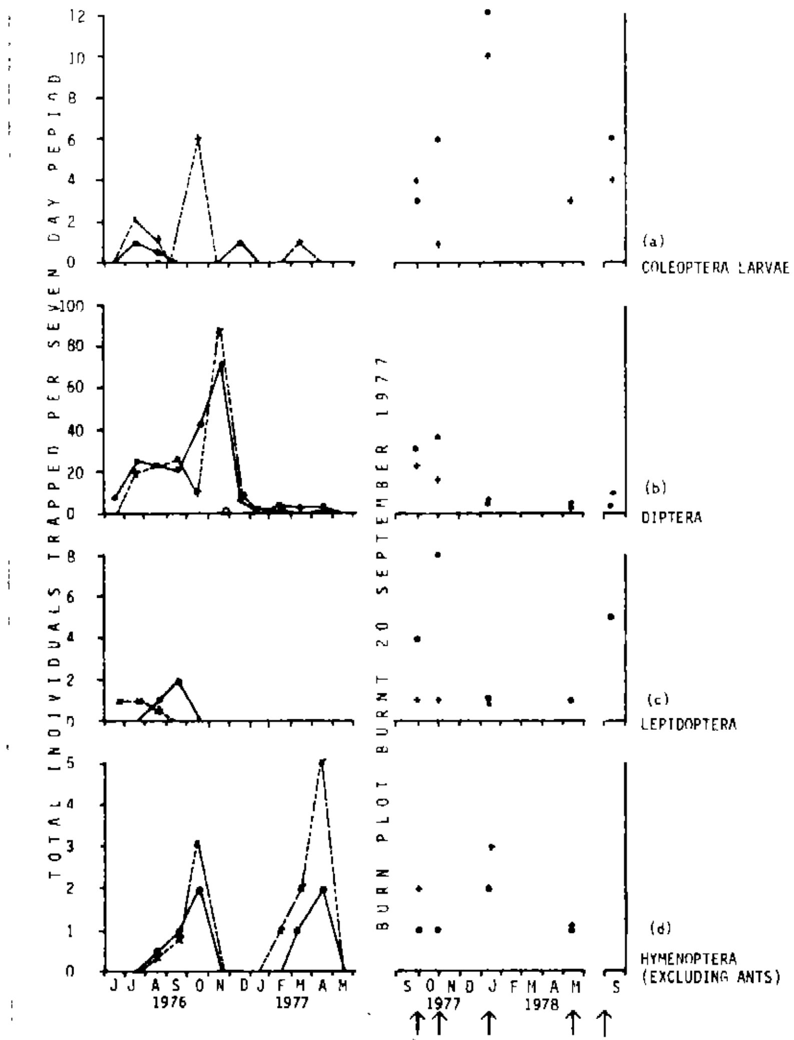

FIGURE 8

MONTHLY CATCHES OF INVERTEBRATES IN THE CONTROL PLOT (●———●) AND BURN PLOTS (X----X) OF RESERVE 17760, AND CATCHES FOR THE POST-FIRE SAMPLES (SAMPLING TIMES INDICATED BY ARROWS).

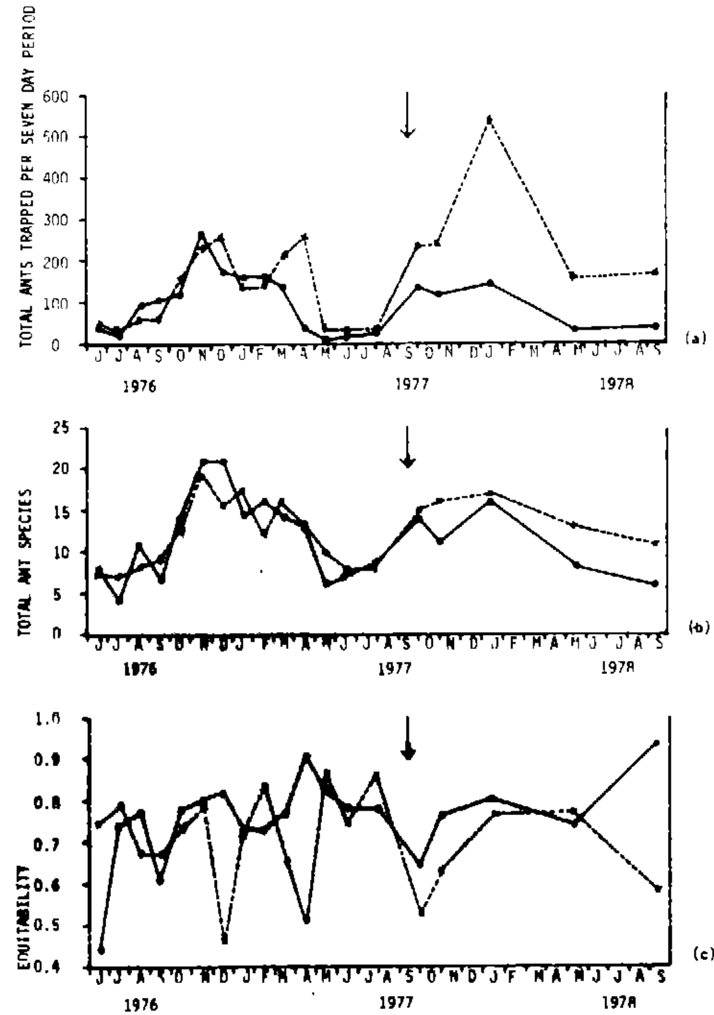

FIGURE 9

NUMBER OF INDIVIDUALS (a) AND SPECIES (b) OF ANTS CAUGHT PER WEEK FOR THE PRE-FIRE AND POST-FIRE SAMPLING PERIOD IN THE CONTROL (●———●) AND BURN PLOT, (X----X) OF RESERVE 17760. THE EQUITABILITY OF ANTS WITHIN EACH SAMPLE IS ALSO SHOWN (c). THE ARROW INDICATES DATE OF BURN.

	Control	Burn
Astroloma epacridis (DC.) Druce	-	16
Astroloma pallidum R.Br.	2	3
Astroloma sp.indet.	1	-
Boronia spathulata Lindl.	-	5
Bossiaea eriocarpa Benth	1	11
Bossiaea ornata (Lindl.) Benth.	29	13
Brachysema praemorsum Meisn.	-	1
Conostylis setigera R.Br.	1	11
Daviesia preissii Meisn.	-	3
Drosera macrantha Endl.	3	6
Drosera macrophylla Lindl.	-	1
Drosera sp.indet.	6	-
Dryandra preissii Meisn.	-	2
Dryandra sessilis (R.Br.) Druce	17	16
Eucalyptus marginata Sm.	7	-
Eucalyptus wandoo Blakely	3	1
Gahnia aristata (F Muell) Benth.	2	1
Hakea lissocarpha R.Br.	-	13
Hakea trifurcata (Sm.) R.Br.	1	-
Hakea undulata R.Br.	-	3
Hemiandra pungens R.Br.	2	-
Hibbertia montana Steud.	8	-
Hibbertia sp.indet.	-	9
Kennedia prostrata R.Br	-	1
Lepidosperma angustatum R Br.	-	1
Lepidosperma sp.indet.	-	2
Leucopogon sp.	-	1
[illegible] *serpyllifolia* R.Br.	1	-
Lomandra sp.indet.	-	3
Lomandra sp.nov.	-	4
Loxocarya fasciculata (R.Br.) Benth.	23	23
Neurachne alopecuroides R.Br.	17	13
Patersonia sp.indet.	-	1
Pterostylis recurva Benth.	1	2
Pterostylis vittata Lindl.	3	1
Scaevola striata R.Br.	5	2
Schoenus sp.indet.	24	25
Stipa ? trichophylla Benth.	-	10
Stylidium brunonianum Benth.	-	13
Stylidium piliferum R Br	6	6
Thysanotus patersonii R.Br.	-	2
Thysanotus sp.indet.	3	-
Trymalium ledifolium Fenzl.	10	6
Xanthosia huegelii (Benth.) Steud.	-	1
Xanthorrhoea ? preissii Endl.	7	-
Xanthorrhoea sp.indet.	-	8

TABLE 2

CHECKLIST OF PLANT SPECIES OCCURRING WITHIN RESERVE 17760 STUDY PLOTS AND THEIR FREQUENCY IN THIRTY SIX QUADRATS. SURVEY PERFORMED 22 MAY 1976.

At this point the limitations of pitfall trapping should be emphasised. The catch is influenced by both the density and the activity of an animal,and is therefore not a direct indicator of density (Southwood, 1966). Seasonal trends in catch may indicate changes in activity and/or density. For similar reasons the techniques cannot be used for comparing the densities of different taxa since there is a greater chance of the more vagile groups such as the predators being caught. Finally, pitfall trap performance is influenced by the nature of the vegetation layers (Southwood, 1966). Interpretation of post-fire catches should therefore be approached with caution as the greatly simplified post-fire ground and vegetation structure means that most taxa are more likely to be trapped.

The pre-fire seasonal trends were similar to those observed for epigaeic invertebrates at Dwellingup (Majer, 1979). Taxa associated with the decomposition process such as Collembola (Figure 5b), Blattodea (Figure 5c), Scarabaeidae (Figure 7b) and certain Lepidoptera larvae (Figure 8c) were mostly trapped in winter, spring or autumn indicating that their activity was confined to more humid periods. By comparison with the seasonality of these taxa at Dwellingup (Majer, 1978b), they were here found to be more closely tied to the winter months. This was probably associated with the lower rainfall at Kojonup.

Class	Taxon*	Main period of occurrence in pitfall traps before burn.	Feeding Habits	Change in burn plot fauna, relative to control plot, with period since burn*				
				1 week	1 month	4 month	8 month	12 month
Arachnida	O.Scorpionida	All year	Predators	?	?	?	-	?
"	O.Pseudoscorpionida	Winter	Predators	?	?	?	?	?
"	O.Opiliones	Summer	Predators	?	?	?	?	?
"	O.Araneae	All year but high in summer	Predators	-	-	+	+	=
"	O.Acarina	All year but high in summer	Predator families only	+	?	?	+	-
Crustacea	O.Isopoda	Autumn-winter-spring	Dead plant material and other detritus	-	?	?	?	?
Chilopoda	-	All year but low in winter	Predators	?	+	+	-	?
Collembola	-	All year but low in summer and autumn	Decaying plant material	-	-	-	+	+
Insecta	O.Blattodea	Autumn and Spring	Probably omnivorous scavengers	-	?	?	?	=
"	O.Dermaptera	All year but high in spring and summer	Omnivores	?	?	-	+	+
"	O.Orthoptera SF.Gryllacridoidea	No trend	Probably omnivorous scavengers	?	?	-	?	+
"	O.Orthoptera F.Gryllidae	Autumn, spring and early summer	Omnivores	=	-	=	+	?
"	O.Orthoptera F.Acrididae	Spring and early summer	Herbivores	=	?	-	?	?
"	O.Hemiptera SO.Homoptera	Winter and spring	Plant sap suckers	?	-	+	+	-
"	O.Hemiptera SO.Heteroptera	Spring-summer-autumn	Mainly seed or fungus feeders or predators	-	-	?	+	-
"	O.Coleoptera F.Carabidae	Autumn-winter-spring	Predators	-	-	?	?	-
"	O.Coleoptera F.Staphylinidae	Autumn-winter-spring	Predators	+	+	?	+	+
"	O.Coleoptera F.Scarabaeidae	Winter	Dead plant material and root feeders	?	?	?	?	?
"	O.Coleoptera F.Curculionidae	Autumn-winter-spring	Herbivores mostly seed feeders	-	-	+	+	+
"	O.Coleoptera (other families)	All year but low in summer	Various	+	-	+	+	+
"	O.Coleoptera (larvae)	Winter-spring	Mostly feeding on plant material	-	-	-	+	-
"	O.Diptera	All year but high in spring	Various	-	-	+	+	+
"	O.Lepidoptera (larvae)	Winter-spring	Live and decaying plant material	-	?	?	?	?
"	O.Hymenoptera (excluding ants)	Spring and autumn	Various	=	-	?	-	?
"	O.Hymenoptera F.Formicidae	All year but high in summer	Predators, honeydew and seed feeders	+	+	+	+	+

* O, Order; SO, Suborder; SF, Superfamily; F, Family, S, Subfamily

*, no change; -, reduction; +, increase with respect to last sample; ?, don't know.

TABLE 3

SUMMARY OF TAXA COLLECTED IN THE PITFALL TRAP SAMPLING PROGRAMME SHOWING THEIR SEASONAL OCCURRENCE, THEIR FEEDING HABITS AND THE CHANGE IN BURN PLOT CATCH, IN RELATION TO CONTROL PLOT VALUES.

No generalisations may be made on the seasonality of predators at Kojonup although the Araneae (Figure 4d), predaceous Acarina (Figure 4e) and Formicidae (Figure 9a) all had summer peaks. Herbivorous taxa were undersampled so it was not possible to characterise periods of plant consumption using pitfall trap data. Observations made during field visits suggest that herbivory is at its peak in spring.

The compartment of reserve 17760 containing the burn plot was ignited at 1300 hours on 20 September 1977. Conditions prevailing at the time included a 15 km/hr wind, relative humidity of 38 per cent and fuel moisture of 8 per cent. Burning of the plot and surrounding area took approximately two hours.

The Thermostick tablets showed that the air immediately above the ground reached somewhere between 302^{o} and 732^{o} during the burn. The flame height ranged from 30-45 cm suggesting that fire intensity was approximately 27 KW/m. Burning was patchy leaving a mosaic of unburnt litter and vegetation within the plot. Adjacent areas which were not prescribe burnt were situated as close as 50 m to the plot.

In order to obtain an indication of the effects of burning on fauna, the ratio of burn plot to control plot catch of each taxon is compared between each post-fire sample and the pre-fire sample of the corresponding month. The post-fire samples are shown in Figures 4-9 and the effects of burning are summarised in Table 3. The results are classified as catch decreased, catch increased, catch not changed or not interpretable. The data do not lend themselves to more detailed statistical analysis.

Interpretation of the post-fire catch should be performed with Southwood's (1966) warning on vegetation influence in mind. An immediate post-fire drop in catch would certainly indicate a drop in number or activity. An immediate increase may represent an increase in the activity or ease of capture of the animal, although an increase sometime after an initial post-fire decrease probably indicates a subsequent recovery in density or activity.

Most taxa were reduced in at least the first two post-fire burn plot samples. Exceptions were the predatory Acarina (Figure 4e), the Staphylinidae (Figure 7a), Coleoptera (other families) (Figure 7d) and the Formicidae (Figure 9), which were all more abundant following burning. Of the taxa which were initially reduced by burning, most groups exhibited some recovery within four to eight months after the fire. No attempt was made to calibrate pitfall trap catches for animal density, so it was not possible to make pre- and post-fire density comparisons.

A cumulative list of Formicidae collected in the two plots is given in the last two columnsof Table 4. Thirty five species were found in the control plot while the burn plot yielded forty. Figures 9a, 9b and 9c respectively show the total ants trapped per sample, the total ant species trapped per sample and the ant species equitability values for each sample. The trends in abundance and species richness partly reflect changes in activity of the various species, rather than large changes in density and species present (unpublished data). More individuals and species of ants were trapped after the fire than before in the burn plot (Figures 9a and 9b). Both increases persisted for the entire post-fire sampling period. There was an initial drop in the equitability of foraging ants caused by abnormally high cathces of *Rhytidoponera inornata* , *Crematogaster* sp 42 (J.D. Majer) and *Pheidole latigena*. Inspection of the pre- and post-fire species lists showed that there was no loss of any of the ant species following the burn.

The post-fire soil invertebrate densities were 5,631 and 10,039 per square metre and the litter densities were 4,272 and 4,883 per square metre for the control and burn plots respectively. The soil invertebrate densities were significantly higher in the burn plots ($p < 0.05$ using Students t-test). It was not possible to statistically compare the litter samples because the original ten collections were bulked for the purposes of invertebrate extraction. The overall densities, however, suggest that there is no difference between plots.

Subfamily	Tribe	Species	Reserve comparison survey					17760 monitoring program	
			2243	8617	15388	17759	17760	Control	Burn
Myrmeciinae		*Myrmecia ? nigriceps* Mayr							
		M. chasei (Forel)							
		M. urens gp.			•				
Ponerinae	Ectatommini	*Rhytidoponera inornata* Crawley	•	•	•	•	•	•	•
		R. violacea (Forel)	•	•	•	•	•	•	•
		Heteroponera imbellis (Emery)						•	•
	Ponerini	*Brachyponera lutea* (Mayr)							•
		Hypoponera ? congrua (Wheeler)	•		•		•		•
Myrmicinae	Myrmicini	*Chelaner* sp. 380 (J.D.M.)							•
		Oligomyrmex sp. 440 (J.D.M.)							•
		Podomyrma sp. 426 (J.D.M.)							
		P. sp. 477 (J.D.M.)							
		Pheidole latigena Forel		•	•			•	•
		P. sp. 379 (J.D.M.)		•		•	•	•	•
		P. sp. 429 (J.D.M.)							•
		Solenopsis sp. 438a (J.D.M.)						•	•
		Tetramorium sp. 6 (A.N.I.C.)					•	•	•
		Monomorium sp. 1 (A.N.I.C.)	•	•	•	•	•	•	•
		M. sp. 2 (A.N.I.C.)	•	•	•	•	•	•	•
		Genus near *Monomorium* sp. 438b (J.D.M.)						•	
	Meranoplini	*Meranoplus* sp. 11 (A.N.I.C.)						•	•
		M. sp. 12 (A.N.I.C.)							
	Crematogastrini	*Crematogaster* sp. 4 (A.N.I.C.)	•			•			
		C. sp. 42 (J.D.M.)				•	•	•	•
		C. sp. 50 (J.D.M.)		•				•	•
	Dacetini	*Colobostruma* sp. 437 (J.D.M.)							
		Epopostruma sp. 159 (J.D.M.)							•
Dolichoderinae	Tapinomini	*Iridomyrmex conifer* Forel							
		I. darwinianus (Forel)						•	•
		I. purpureus (Fr.Smith)	•	•	•	•	•	•	•
		I. glaber (Mayr)					•	•	•
		I. sp. 19 (A.N.I.C.)	•		•	•	•	•	•
		I. sp. 20 (A.N.I.C.)		•	•	•	•	•	•
		I. sp. 21 (A.N.I.C.)	•	•	•	•	•	•	•
		I. sp. 8 (J.D.M.)					•		
		I. sp. 373 (J.D.M.)							
		I. sp. 433 (J.D.M.)						•	
		I. sp. 434 (J.D.M.)						•	
Formicinae	Melophorini	*Notoncus hickmani* Clark						•	•
		N. gilberti Forel	•			•	•	•	•
		Prolasius sp. 376 (J.D.M.)		•					
		Melophorus sp. 1 (A.N.I.C.)	•		•	•	•	•	•
		M. sp. 111 (J.D.M.)		•		•	•	•	•
		M. sp. 209 (J.D.M.)	•	•	•		•	•	•
		M. sp. 304 (J.D.M.)							
		M. sp. 383 (J.D.M.)			•	•	•	•	•
		M. sp. 384 (J.D.M.)	•	•	•	•	•	•	•
		M. sp. 385 (J.D.M.)	•	•	•	•	•	•	•
	Plagiolepidini	*Stigmacros aerata* Forel						•	•
		S. sp. 188 (J.D.M.)							•
	Camponotini	*Camponotus michaelseni* Forel		•		•		•	•
		C. ? obniger Forel						•	•
		C. sp. 107 (J.D.M.)							
		C. sp. 110 (J.D.M.)	•			•		•	•
		C. sp. 182 (J.D.M.)	•					•	•
		C. sp. 199 (J.D.M.)	•		•				
		C. sp. 288 (J.D.M.)							
		C. sp. 393 (J.D.M.)							
		C. sp. 394 (J.D.M.)							•
		C. sp. 430 (J.D.M.)							
		C. sp. 431 (J.D.M.)		•					
		C. sp. 432 (J.D.M.)						•	
		C. (Colobopsis) sp. 359 (J.D.M.)							
		Notostigma sanguinea Clark							
		Polyrachis sp. 390 (J.D.M.)							•
		TOTAL SPECIES	**17**	**17**	**17**	**19**	**21**	**35**	**40**

TABLE 4

CHECKLIST OF ANTS COLLECTED DURING THE SURVEY OF THE FIVE LARGE NATURE RESERVES AND ALSO IN THE FIRE MONITORING PROGRAMME IN RESERVE 17760. SPECIES WHICH HAVE NO LOCATION MARKED WERE HAND COLLECTED FROM UNSPECIFIED KOJONUP NATURE RESERVES.

The species of ants found in the five reserves during the reserve comparison study are shown in Table 4. The census undersamples the total ant community since the December sampling period did not account for species active at other times of the year. Figure 10 relates the five reserves in terms of their ant species similarity. Two sub-groups were apparent, these were 15388 with 2243, and 17760 with 17759. Reserve 8617 was the least similar reserve in terms of its ant fauna.

It is noteworthy that the degree of similarity between the ant faunas of the reserves corresponds well with their relative geographical relationships (Figure 1).

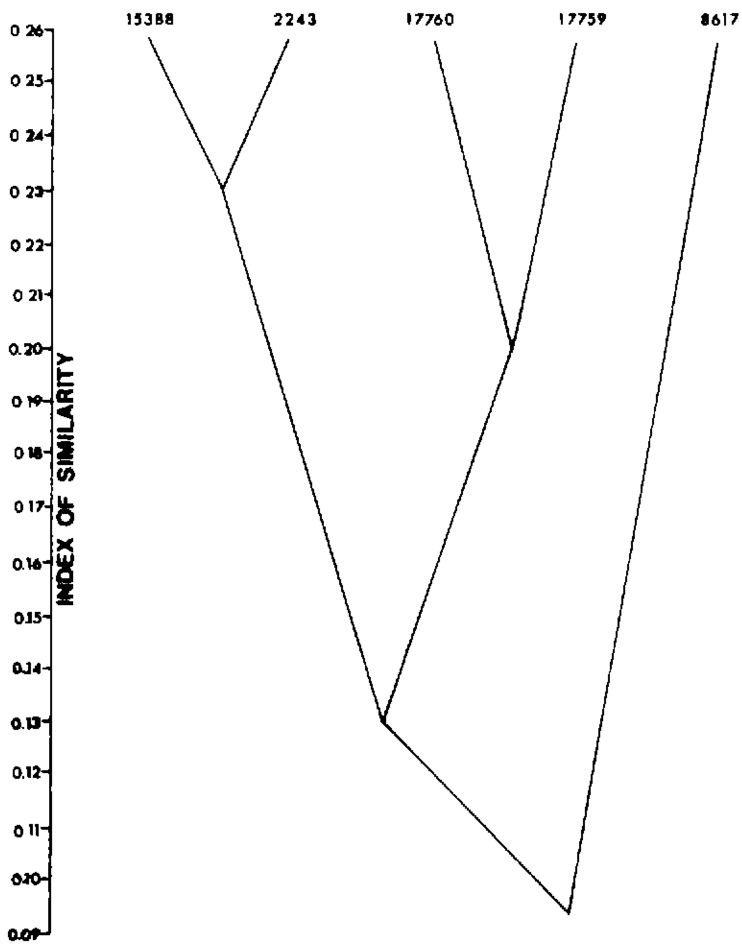

FIGURE 10

DENDROGRAM, DERIVED USING MOUNTFORDS INDEX OF SIMILARITY, SHOWING AFFINITY OF THE ANT FAUNA IN FIVE LARGE KOJONUP NATURE RESERVES.

Ant species richness, plant species richness (taken from Gibbons, 1977) and the reserve groupings for environmental variables, using the Scheffe´ test, are shown in Table 5. There was no relationship between ant and plant species richness, nor was there any significant difference between reserves in terms of amount of topshade, of tree trunks or of dead wood. Reserves were divided into two groups, (2243, 8617 and 15388) and (17759 and 17760), on the basis of their relatively high and low ground cover densities respectively. Reserves 2243 and 17760 respectively had significantly higher and lower leaf litter loads while the remaining reserves formed an intermediate group for this variable.

	2243	8617	15380	17759	17760
Ant species richness	17	17	17	19	21
Plant species richness	96	133	50	104	128
Topshade	No.diff.	No.diff.	No.diff.	No.diff.	No.diff.
Tree trunks	No.diff.	No.diff.	No.diff.	No.diff.	No.diff.
Ground cover	High	High	High	Low	Low
Dead wood	No.diff.	No.diff.	No.diff.	No.diff.	No.diff.
Leaf litter	High	Intermediate	Intermediate	Intermediate	Low

TABLE 5

COMPARISON OF THE FIVE LARGE NATURE RESERVES IN TERMS OF PLANT AND ANT SPECIES RICHNESS AND OTHER ENVIRONMENTAL FACTORS.

DISCUSSION

This study has provided preliminary data on the variety and seasonal activity of epigaeic invertebrates, and also the density of soil and litter invertebrates of Kojonup reserve 17760. The checklist of ants collected during this study (Table 4) amounts to 65 species suggesting that diversity of this group, at least, is similar to that of northern jarrah forest sites (Majer, unpublished data).

Data on the effect of fire on invertebrate communities in Western Australia are sparse because few investigations have been performed. Most of these studies have tended to be of limited value because they have compared existing unburnt and burnt areas, rather than the same area before and after fire. They have also generally placed animals into broad taxonomic groups.

McNamara (1955) compared the humus fauna of protected jarrah forest and of regularly burnt firebreaks. The fauna was found to be more abundant in terms of numbers and types in the unburnt areas.

Springett (1971) compared the Collembola and Acarina of burnt and unburnt pines at Gnangara, Western Australia. No significant difference existed between levels of these taxa in the two treatments although, if animals were classified in terms of feeding habit, differences became evident. Subsequent work showed that litter decomposition ceased until four years after burning (Springett, 1976). This second paper also reported the effects of fire on the soil fauna of jarrah and karri forests at Dwellingup and Pemberton, respectively. The jarrah plots were sampled 40 and 6 years after they had been burnt while the karri plots had been burnt approximately 35 and 1 year before the study. Burning apparently reduced the density and diversity of invertebrates in both types of forest, and population levels were not considered likely to recover during the normal 5-7 year rotational burning programme.

The reserve 17760 study utilised plots which had probably not been burnt for 10-11 years. Results are not directly comparable with those of the previous studies, since different sampling techniques were used. The Kojonup pitfall trapping programme showed that, although most taxa were reduced by burning, there was no evidence of elimination of any broad taxonomic groups. The Opiliones (Figure 4c) and Scarabaeidae (Figure 7b) were not encountered during the post-fire year, although the former taxon was uncommon and hence likely to be missed by the sampling technique and the Scarabaeidae were absent from both control and burn plots after the fire.

The immediate post-fire increase of certain groups merits further discussion. The miscellaneous Coleoptera category (Figure 7d) comprised a number of families which were associated with timber attack. Evans (1971), working in North America, has noted that such beetles are often pyrophilous and may be attracted by smoke or heat. The same phenomenon may be operating here. The species of ants in the burn plot were primarily ground nesters. Soil temperatures would not have risen appreciably during this cool burn so little direct ant mortality would occur. Observations on individual colonies in burnt areas at Karagullen (Majer, unpublished data) have shown that certain species of ants forage longer and further after fires. This is probably a response to food shortages and could result in more individuals being caught in pitfall traps. The predatory Acarina and Staphylinidae, which also increased in traps immediately after the fire, have not been investigated, although it is possible that their movements also increase in response to food shortage.

Interpretation of the soil and litter fauna is difficult since no pre-fire samples were taken. The apparent absence of a post-fire depression in soil and litter fauna in the burn plot at Kojonup may be due to two factors. The Kojonup fire was considerably cooler than that experienced in Springett's plots, so a lower impact on fauna would be expected. Secondly, unlike Springett's control plots, reserve 17760 had been burnt comparatively recently. The composition of the soil and litter fauna at Kojonup may then have been already depressed by the previous fire and hence the effects of the 1977 burn may have been less obvious.

Observations from the burn explain how certain taxa survive the direct effects of the fire. Many larger invertebrates, such as Blattodea and Gryllidae, walked or jumped away from the advancing fire front. Several species of Araneae and individual species of Gryllidae, Homoptera, Carabidae and the ground foraging ant *Rhytidoponera inornata* were observed climbing up the wandoo trees as the flames advanced. In addition, many invertebrates were found under logs and in the remaining islands of unburnt litter. The various survivors, which may have been supplemented by immigrants from unburnt compartments, probably acted as nuclei for the later build up of post-fire populations.

The survival of ground living invertebrates has also been noted by Gillon (1970), who used quadrat hand collection techniques to estimate invertertebrate numbers before and after burns in West African savanna. Sixty four per cent of the individuals which he observed survived the fire while certain other species flew away to avoid the fire. Within one month, many of the flying groups had returned while the density of ground inhabiting groups had decreased due to changes in microclimate.

An early start to recovery following the burn was also observed at Kojonup. Araneae, Collembola, Dermaptera, Gryllacridoidea, Gryllidae, Homoptera, Curculionidae and Diptera all showed signs of population increase following an initial post-fire decline. Flight probably played a part in this build up although, with flightless groups such as the Araneae, Collembola and some Dermaptera, the survivors of the fire probably formed the basis of the new population. It would be profitable to obtain absolute population estimates for these taxa in order to compare their density with control plot values.

This study has only examined the effect of one cool spring burn. Gill (1975) states that fire frequency, fire intensity, season and fire type are all components of the fire regime. The intensity of this fire was similar to that recommended for the Kojonup fire management plan,so the main way in which this study has deviated from the recommended plan is that a spring, rather than an autumn, burn was examined. The effects of spring and autumn burns on invertebrates are currently being compared at Dwellingup although the data have not as yet been processed. The seasonal patterns observed at Kojonup suggest that spring burns would be the more detrimental to invertebrates. Autumn burns occur when the activity of many predators and herbivores is low or is decreasing. Decomposers would be most affected although the adjacent reserve compartments would contain reservoirs of these animals which would invade in the appropriate seasons following litter build up. Autumn burns are succeeded by rapid plant growth in the winter and particularly in the following spring. There is therefore abundant growth on which herbivores may feed. A spring burn on the other hand depletes the plant biomass and the invertebrate fauna at a time of increasing food demand by predator groups such as ants and spiders. This may cuase a greater perturbation than the autumn burn, when winter allows a time of re-adjustment to the changed conditions. Plant growth is also likely to be less during the summer following the spring burn so that herbivorous invertebrates would have less food than after an autumn burn. Had the experimental burn been performed in autumn, the impact on invertebrates could have been less than that observed in this study.

The reserve comparison study revealed differences in the ant fauna of the various reserves. Ants are generally predators, seed or honeydew feeders and many species are specialists. It is likely that ants can be utilised as indicators of the composition and diversity of the fauna, and possibly the flora, of an area. The latter point is suggested by the fact that Gibbon's (1977) ordination of the plant study plots of the five reserves produced a separation of reserves similar to that obtained by the dendrogram based on composition of ant fauna. The similarity values of ant fauna obtained for these reserves (Figure 10) give an estimate of the relative affinity of the ant fauna in the five main reserves. The values are quite high and suggest that the results of this study, for ants at least, are applicable to other reserves at Kojonup. If duplication of the programme is possible, the effort would be best expended in the least similar reserve, that is number 8617.

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