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SOIL INVERTEBRATE BIODIVERSITY IN STRINGYBARK FOREST IN THE NEW ENGLAND TABLELANDS BEFORE CLEARING

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Abstract

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In this study at Newholme, 10 km N of Armidale, in northern New South Wales, we will assess the role of soil invertebrates as ecosystem engineers after a major disturbance — clearing of native vegetation for grazing pastures. The data presented in this paper is from the December 1993 pitfall trapping prior to clearing. The pitfall trapping recorded 22 invertebrate groups, dominated by eight, with Collembola, Acarina and Formicidae being the most abundant groups. Formicidae was further classified into species which revealed the average site had 24 species of ants, and in total there were 57 ant species recorded over 12 sites. Those sites with high ant abundance were dominated by one or more of the following three ant species; *Aphaenogaster* sp. N26, *Iridomyrmex* sp. N60, or *Pheidole* sp. N2. The dominant ant functional group in abundance and number of species was the Climate/Soil Specialist. The following functional groups, in order of declining abundance, were Dominant dolichoderinae, Generalised myrmicines and Opportunists, and were all represented by at the most four species. The remaining functional groups were low in abundance and recorded low species richness, which may be a reflection of trapability rather than reality.

Introduction

In examining the extent of land degradation in Australia one becomes immediately aware of the enormity of the problem, especially in agricultural soils. Solutions to land degradation often revolve around retention or replanting of native or introduced tree species, but minor consideration is given to their interactions with other parameters. The integral role of soil invertebrates in maintaining soil fertility (physical and chemical) is often overlooked. Also there has been little evaluation of the role of soil invertebrates in restoring degraded soils through their input into soil processes. Most of the epigeic soil invertebrates sampled by pitfall trapping (such as ants, beetles, spiders, Araneae and Collembola) do interact with other soil biota and soil properties, and make a significant contribution to nutrient cycling and the maintenance of soil structural properties. The impact of soil fauna on soil processes which include nutrient cycling, soil bioturbation and soil structure formation (Hole, 1981) have only been examined, in part, by a small selection of studies in Australia (Lobry de Bruyn, 1990; Mitchell, 1986; Humphreys, 1985). Research overseas has been more extensive, but has concentrated on earthworm species (Kretzschmar, 1992; Brussaard and Kooistra, 1993) or termite species, usually not known to occur in Australia. A review of the overseas and Australian literature on the role of termites and ants in soil modification (Lobry de Bruyn and Conacher, 1990) emphasised the lack of data on ant-soil relationships as well as subterranean termites and soil processes.

In this study at Newholme (10 km N of Armidale in northern New South Wales) we will identify *key* soil invertebrate groups, which are present in the Stringybark Forest. This forest will then be converted to grazing land (with two levels of tree cover) which we assume will simplify the soil ecosystem, both structurally and functionally. We hope to ascertain which invertebrate groups are lost, persist or increase in abundance in this changed environment, and whether functional diversity is reduced because of ecosystem simplification. The overall aim is to assess the role of soil invertebrates as ecosystem engineers by examining their function in the maintenance of soil structure processes after a major disturbance — clearing of native vegetation for grazing pastures. The term ecosystem engineers is taken from Jones and Lawton (1995) and they describe ecosystem engineers as "organisms that directly or indirectly modulate the availability of resources to other species, by causing physical state changes in biotic or abiotic materials. In doing so they modify, maintain, and/or create habitats." To decide which organisms hold this role in the predisturbance state a series of pitfall trapping combined with mapping was undertaken in December 1993, February 1994 and September 1994. The baseline survey will identify soil invertebrate composition and abundance prior to clearing, establish inter-site variability, soil invertebrate species abundance and activity, and the spatial distribution in the landscape of soil invertebrate species activity. At this stage this paper will report on the December 1993 pitfall trapping data, examining ordinal, ant functional and ant species biodiversity.

Methods

The activity and nest density of soil macrofauna (principally ants, termites, earthworms and spiders) were sampled by a combination of pitfall trapping, soil sampling and mapping (Lobry de Bruyn, 1993a, b). Three baseline pitfall trapping sampling periods were completed prior to clearing (13–20 Dec 1993, 16–23 Feb 1994, and 14–24 Sep 1994). This paper will report only on the pitfall sampling data taken in December 1993, since this is the only sampling period where the ants have been sorted to species. Weather conditions during the December pitfall trapping week were fine and hot with an average minimum daily temperature of 11.8°C and a maximum daily temperature of 29.5°C. There was only one minor rainfall event of 3 mm on 16 Dec 1993, and on the whole the days were cloudless.

Each site is 4 ha. Plots within these sites have been chosen which are all beneath trees, in the mid-slope position, except site E, and on a grey podzolic soil. These sites will be subject to varying patterns of tree removal and fertiliser amendments as well as use of sub-clover. The treatments that will be imposed are as follows:

1. control — retain trees unamended (A, H, L)
2. control — retain trees plus add fertiliser/sub-clover (D, E, I)
3. thinning + fertiliser/sub-clover (C, G, K)
4. clearfell + fertiliser/sub-clover (B, F, J)

The foraging activity of invertebrates was recorded with 20 pitfall traps per plot (40 × 50 m), with one pitfall trap placed randomly within a 10 × 10 m quadrat. There were a total of 240 pitfall traps/sampling period. The pitfall traps were left open for a week, and were 4.5 cm in diameter. They were filled with 70% alcohol and 10% glycerol.

To assist in interpretation of ant biodiversity, the functional groups approach used by Andersen (1990) to document mine restoration success was employed (Andersen, 1993). Greenslade and Greenslade (1984) developed the functional group classification based on habitat and competitive interactions with *Iridomyrmex*. There are seven functional groups into which various genera can be classified. The most important group is the dominant dolichoderinae which is dominated by *Iridomyrmex* sp. These ants are considered to be highly abundant, active and aggressive and strongly influence the presence of other ant species. They predominate in open habitats, with high soil temperatures and where the soil surface is not covered with litter. The remaining functional groups occur in habitats either not favoured by *Iridomyrmex* sp. or have specialisations reducing their interaction with this species. Andersen (1990) sees the group of ant genera such as *Rhytidoponera* sp. which fall into the Opportunists functional group as important indicators of a disturbed site or a site low in *Iridomyrmex* sp. numbers. This group is usually poorly competitive and unspecialised.

Results and discussion

In total there were 22 invertebrate groups, with 11 orders on average recorded per pitfall trap. The most abundant invertebrate groups from all sites, in decreasing order of abundance were, Collembola (1063 per pitfall trap), Acarina (80 per pitfall trap), Formicidae (58 per pitfall trap), Diptera (20 per pitfall trap), Coleoptera (17 per pitfall trap), Hymenoptera (12 per pitfall trap), Araneae (5 per pitfall trap), Hemiptera (4 per pitfall trap) and Dermaptera (1 per pitfall trap) (Fig. 1, Collembola were excluded from the figure because of their high abundance). The remaining invertebrate groups recorded on average less than one specimen per pitfall trap.

A One-Way ANOVA of log transformed data ($\log_{10}x+1$) showed no significant differences in invertebrate abundance between sites for the Araneae, Acarina, and Coleoptera. The two invertebrate groups which were the most variable in abundance were Formicidae and Collembola. It appears that sites B and D, have a lower abundance of ants than most sites, especially sites G, H, K and L ($p < 0.001$) (Appendix 1). However, a significantly higher abundance of ants was recorded for Sites K and L compared

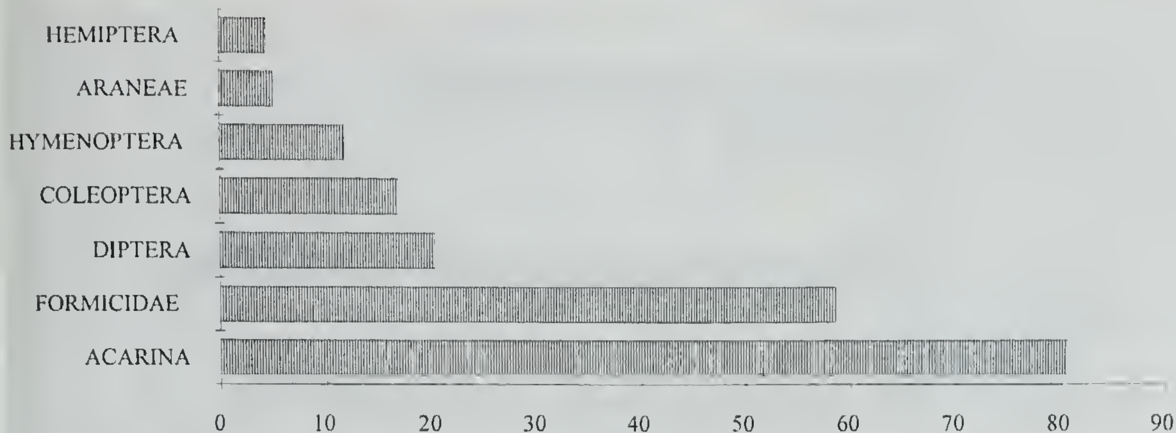

Figure 1. Invertebrate biodiversity at the order level, except for Formicidae, for the average site in December 1993 (n=12 sites). Collembola are excluded due to their high abundance.

with Sites G and H ($p < 0.001$) (Appendix 1). Numbers of Araneae were low but the pitfall trap catch number is consistent across the various sites. In contrast Formicidae abundance coefficient of variability (CV) increased from 1.1 (for sites A to D) to 2.2 (when all 12 sites were examined) in December 1993 indicating a patchy distribution. Sites B and C have significantly lower abundances of Collembola compared with all other sites ($0.0001 > p < 0.01$). Interestingly with the further analysis of data the CV for Collembola declined from 3.1 (only for four sites) to 2.6 (all 12 sites), similarly the CV for Coleoptera abundances declined from 2.2 to 1.6 indicating a less patchy distribution than first surmised.

Of the invertebrate groups identified in the baseline survey in December 1993 which groups have an important ecosystem function, especially in relation to soil modification? At this stage the December survey has identified three important ecosystem engineers. Collembola and Araneae, the two most abundant orders, would contribute to nutrient cycling by regulating microbial communities which are responsible for 90% of organic carbon turnover. The ants, the third most abundant invertebrate group, carry out a series of important ecosystem functions. Past research in the wheatbelt of Western Australia in a woodland environment (Lobry de Bruyn and Conacher, 1994a, b), has indicated ants perform important roles in soil mixing and water infiltration under ponded conditions.

The implication of the spatial variability in abundance of some invertebrate groups between sites will have important implications once the treatments are imposed, and the realisation that the natural variability of each site may be greater than the treatment effect. Consideration to the variability between sites will also need to be given at the stage of data analysis and interpretation. Three of the six sites which are to be affected by tree removal have significantly higher numbers of ants, while one of these sites has much lower numbers of ants than the other sites. Also two sites (one which will be modified) have much lower levels of Collembola numbers than the remaining ten sites. The ant data was examined further to see if those sites with greater ant abundance also varied markedly in ant species richness or were composed of a different suite of ant functional groups to the other sites.

The average site recorded almost equal proportions (around 30%) of three functional groups: dominant Dolichoderinae, generalised myrmicines, and opportunists. The remaining four functional groups accounted for just over 10% of the remaining ant numbers, with the majority recorded as climate/soil specialists (Fig. 2).

The low numbers of subordinate Formicinae dominated by the genera *Camponotus* sp. was unexpected considering the woodland habitat. The low numbers of catches for subordinate Formicinae, cryptic species and specialist predators may be influenced by their trapability. Those sites with higher numbers of ants were dominated by one of the following three ant species. At site L, *Aphaenogaster* sp. N26 dominated, at site F *Pheidole* sp. N2, at site K, *Iridomyrmex* sp.

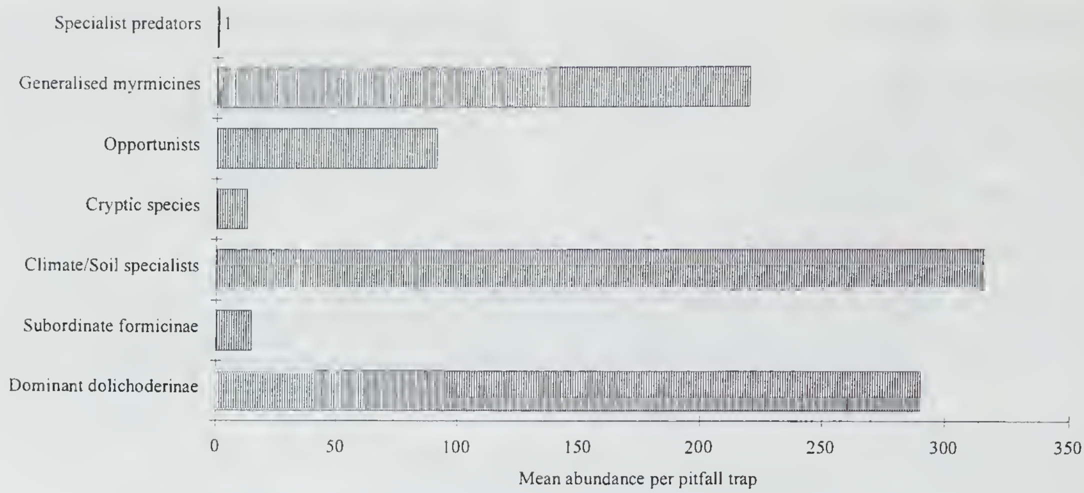

Figure 2. Abundance of ants recorded in each of the ant functional groups at an average site (n=12 sites, 20 pitfall traps per site) in December 1993.

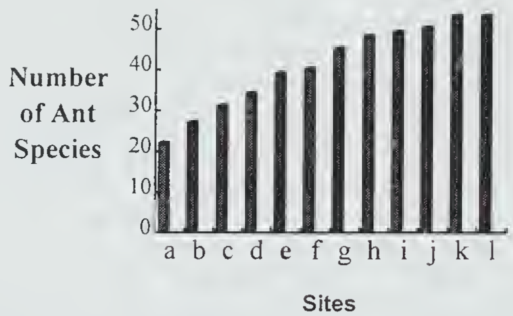

Figure 3. The ant species accumulation curve for sites A to L in December 1993.

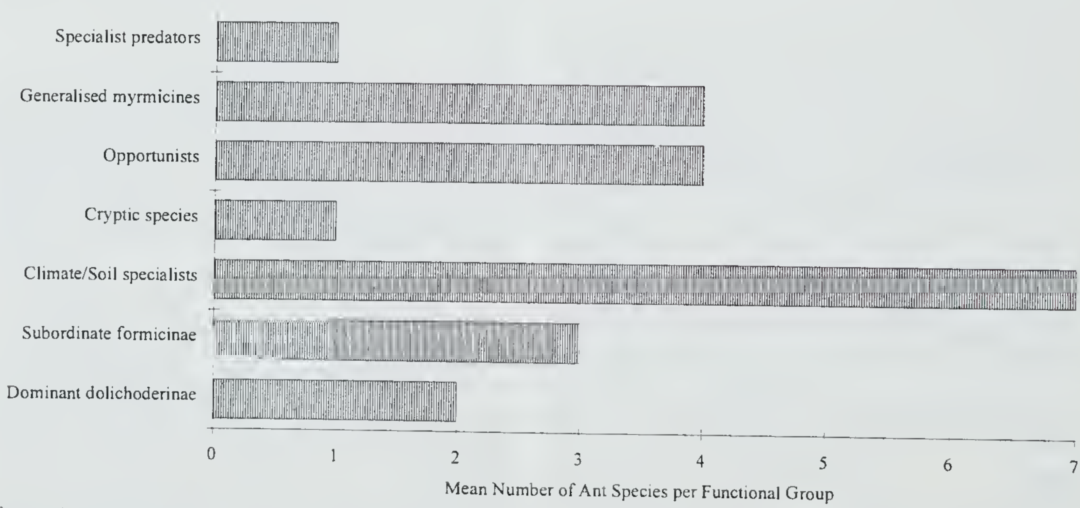

Figure 4. Number of ants species recorded in each of the ant functional groups at an average site (n=12 sites, 20 pitfall traps per site) in December 1993.

N60, and at site G a combination of equally high numbers of *Aphaenogaster* sp. N26 and *Iridomyrmex* sp. N60. On the other hand, sites B and D, which had low ant abundance recorded below average numbers of *Aphaenogaster* sp. N26, *Pheidole* sp. N2 , and *Iridomyrmex* sp. N60.

The total number of ant species over all sites in December 1993 was 53 species. There was an average of 22 species of ant per site, ranging from 15 to 28 ant species. Figure 3 shows the accumulation of species per site. More than half the ant species were recorded in sites A and B, with the addition of two to three species in each of the following 10 sites. The new species recorded were often represented by a few specimens (Appendix 2).

The proportion of species in each functional group for an average site is shown in Figure 4. The most species rich ant functional groups were the climate/soil specialists, predominantly *Aphaenogaster* sp. N26 (soil), *Notoncus* spp., and *Prolasius* spp. (both climate), with seven species. While the opportunists (predominantly four species of *Rhytidoponera* spp., mostly *Rhytidoponera metallica*), subordinate formicinae and the generalised myrmicines were all represented by four species each. The other three functional groups (cryptic species, specialist predators and dominant Dolichoderinae) had on average less than two species per site each. Interestingly the sites with the highest ant numbers also had the greatest number of ant species and vice versa.

The sort of changes expected with clearing include a more open canopy, higher soil temperatures and less litter. Hence, in future pitfall trapping, an increase in *Iridomyrmex* spp. and a decline in *Aphaenogaster* sp. N26 abundance might be expected. There may also be an increase in numbers of some of the *Pheidole* spp. In terms of soil mixing *Aphaenogaster* sp. N26 is the most prominent nest-builder and has a very aggregated nest distribution. On average *Aphaenogaster* sp. N26 nest density was in the order of 10 nests m^{-2} (unpublished data). The decline of this species could severely disrupt soil forming processes, and the movement of water under high energy rainfall events. *Aphaenogaster* sp. N26 has specialised feeding habits (Davison pers comm. 1995) and a preference for sandier textured soils (Lobry de Bruyn and Conacher 1994a) which may explain the aggregated and patchy nature of *Aphaenogaster* sp. N26 nests. However more work is needed to determine the influence of these factors on nest density and spatial patterning.

Acknowledgements

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Appendix 1: Average catch per pitfall trap for all invertebrate orders and ants in a Temperate Stringybark Forest in December 1993

	SITE A		SITE B		SITE C		SITE D		SITE E		SITE F		SITE G		SITE H		SITE I		SITE J		SITE K		SITE L	
ORDERS	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE	MEAN	SE
ACARINA	71.10	12.94	88.85	30.15	53.60	6.73	38.17	6.32	110.16	20.51	76.10	13.70	84.00	10.18	71.72	9.07	97.72	13.20	105.19	11.76	74.00	10.36	95.75	19.36
ARANEAE	3.95	0.52	3.45	0.48	3.05	0.46	3.83	0.58	5.74	0.63	3.40	0.44	5.30	0.65	6.61	0.61	6.00	0.89	8.44	1.79	4.26	0.62	6.25	0.80
COLEOPTERA	12.95	1.66	26.25	15.51	14.30	2.09	10.44	1.25	13.74	1.88	17.90	1.99	14.40	2.44	23.39	2.48	16.33	2.65	21.56	3.74	18.47	2.22	11.60	2.12
COLLEMBOLA	1170.3	678.2	203.3	47.9	103.2	11.2	777.9	309.7	1107.2	332.0	444.2	67.6	1017.7	558.0	1430.6	782.2	1439.9	433.4	2163.6	1204.8	2555.3	1300.6	342.0	100.0
DERMAPTERA	8.45	1.27	3.15	1.25	0.85	0.36	0.89	0.40	0.05	0.05	0.20	0.20	0.00	0.00	0.00	0.00	0.11	0.11	0.13	0.09	0.00	0.00	0.05	0.05
DIPTERA	20.00	2.33	28.00	6.14	38.45	8.24	32.56	4.60	11.11	1.53	13.80	1.43	16.60	2.15	20.61	3.09	11.56	2.09	16.13	3.54	16.05	1.90	18.35	2.34
FORMICIDAE	48.55	15.03	28.45	4.92	45.30	6.81	18.11	2.46	44.47	5.14	75.40	22.62	72.15	15.26	44.44	6.74	79 61	35.28	47.19	9.12	68.95	8.75	129.65	70.76
HEMIPTERA	10.74	5.29	3.70	0.81	5.50	0.84	2.89	0.41	4.06	0.74	5.60	1.36	4.40	0.58	3.67	0.50	2.53	0.48	2.88	0.50	3.26	0.55	3.30	0.53
HYMENOPTERA	9.90	0.95	9.20	1.61	17.05	1.52	15.33	1.61	9.58	1.10	12.40	1.61	11.10	1.30	12.11	1.09	8.72	1.08	14.00	1.58	11.16	1.23	10.20	1.02
LEPIDOPTERA	0.74	0.18	0.30	0.13	0.45	0.14	0.39	0.14	0.05	0.05	0.05	0.05	0.10	0.07	0.11	0.08	0.22	0.10	0.19	0.10	0.05	0.05	0.10	0.07
ORTHOPTERA	0.10	0.07	1.00	0.42	0.95	0.28	0.39	0.12	0.00	0.00	0.30	0.13	0.30	0.11	0.22	0.10	0.22	0.10	0.75	0.28	0.11	0.07	0.15	0.15
PSOCOPTERA	0.50	0.21	0.00	0.00	0.20	0.09	0.50	0.35	0.00	0.00	0.10	0.07	1.40	0.84	0.39	0.14	0.22	0.17	0.44	0.18	0.16	0.09	0.10	0.07
THYSANOPTERA	1.25	0.47	0.85	0.23	0.84	0.24	1.06	0.41	0.89	0.24	1.40	0.28	0.75	0.19	0.61	0.16	0.56	0.18	0.63	0.24	0.53	0.30	0.90	0.22
LARVAE	1.15	0.35	1.30	0.48	1.00	0.30	0.61	0.27	3.16	1.75	1.15	0.25	1.35	0.47	2.00	0.67	1.28	0.27	2.31	0.79	0.42	0.16	1.00	0.33
BLATTODEA	0.65	0.17	0.60	0.21	0.65	0.25	0.61	0.22	0.74	0.23	0.40	0.13	0.25	0.12	0.94	0.22	0.22	0.10	0.88	0.31	0.58	0.16	0.70	0.21
DIPLOPODA	0.10	0.13	0.20	0.12	0.25	0.14	0.17	0.12	0.53	0.38	0.10	0.07	0.15	0.08	0.33	0.14	0.17	0.09	0.25	0.11	0.00	0.00	0.05	0.05
ISOPODA	0.30	0.05	0.15	0.08	0.10	0.07	0.61	0.26	0.32	0.15	0.20	0.09	0.25	0.16	0.50	0.17	0.28	0.14	0.56	0.26	0.00	0.00	0.05	0.05
MANTODEA	0.05	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00
CHILOPODA	0.00	0.00	0.05	0.05	0.15	0.08	0.11	0.08	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NEUROPTERA	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.00	0.00	0.00	0.00	0.00	0.00
ISOPTERA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
THYSANURA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.17	0.00	0.00	0.00	0.00	0.00	0.00
DIPLURA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PSEUDOSCORPION	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.11	0.08	0.06	0.06	0.00	0.00	0.00	0.00
AMPHIPODA	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix 2. Total Abundance of Ant Species Classified into Functional Groups in Temperate Stringybark Forest in December 1993.

Dec-93 SPECIES	site a total	site b total	site c total	site d total	site e total	site f total	site g total	site h total	site i total	site j total	site k total	site l total	total	SE
1. Dominant dolichoderinae														
Iridomyrmex (discors gp.) sp. N1	80	48	93	3	17	34	15	14	4	29	1	89		
Ochetellus sp. N46	19		3		5				16	6		5		
Iridomyrmex sp. N60		74	50	63	81	340	521	170	815	136	524	223		
total abundance	99	122	146	66	103	374	536	184	835	171	525	317	290	68
no of species	2	2	3	2	3	2	2	2	3	3	2	3	2	
2. Subordinate formicinae														
Camponotus sp. N7	19	8	2	3	5	2	3	3	2		7	8		
Camponotus sp. N44					9	7	1	1		6	1	1		
Camponotus sp. N54	1		1				3		12	8	1			
Camponotus sp. N75					2		7	8	3	4	29			
Camponotus sp. N76						2		1	1					
Camponotus sp. N92										7				
Polyrhachis sp. N45	1													
Polyrhachis sp. N77							1							
Polyrhachis sp. N80							1							
Polyrhachis sp. N83							1							
total abundance	21	8	3	3	16	11	17	13	18	25	38	9	15	3
no of species	3	1	2	1	3	3	7	4	4	4	4	2	3	
3. Climatic/Soil Specialists														
Aphaenogaster sp. N26	203	165	279	58	385	92	601	187	261	234	85	560		
Leptomyrmex sp. N12				2	2		2	3	1		2	1		
Dolichoderus sp. N 55	3									2	2			
Dolichoderus sp. N 57	1			5					8					
Melophorus sp. N64	4					12	11			6	6	45		
Melophorus sp. N65			9	2	1	1	1							
Melophorus sp. N66			7		3		12		4	2		20		
Meranoplus sp. N10	3	6		1	11	16	17	12	5	5	25	38		
Notoncus sp. N43	33		78	8	8		9	18	6	8	21	7		
Notoncus sp. N58		10							1			10		
Prolasius sp. N59	4	13	21	9	13	11	7	17	11	6	2	16		
total abundance	251	194	394	85	423	132	660	237	297	263	143	697	315	57
no of species	7	4	5	7	7	5	8	5	8	7	7	8	7	
4. Cryptic Species														
Amblypone sp. N74					1		1							
Brachyponera sp.N53	2			1						1		4		
Sphinctomyrmex sp. N71					6	3	3				1			
Sphinctomyrmex sp. N73					4	13	14		4			94		
Stigmacros sp. N91											1			
total abundance	2	0	0	1	11	16	18	0	4	1	2	98	13	8
no of species	1	0	0	1	3	2	3	0	1	1	2	2	1	

Appendix 2 Continued

Dec-93 SPECIES	site a total	site b total	site c total	site d total	site e total	site f total	site g total	site h total	site i total	site j total	site k total	site l total	total	SE
5. Opportunists														
Paratrechina sp. N42	15	92	7		30	18	11		1		156	41		
Paratrechina sp. N62			2											
Rhytidoponera sp. N15	4	24	2	1		12			2		13			
Rhytidoponera sp. N4	13	39	32	26	29	10		17	36	33	57	30		
Rhytidoponera sp. N23											1			
Rhytidoponera sp. N50	8		5	12	4	2		1	4	7	2			
Rhytidoponera sp. N61		6												
Tapinoma sp. N20		5	2		70	25	6		61	58	46			
Tetramorium sp. N18		2			2						6	2		
total abundance	**40**	**168**	**50**	**39**	**135**	**67**	**17**	18	**104**	**98**	**281**	**73**	91	22
no of species	**4**	**6**	**6**	**3**	**5**	**5**	**2**	**2**	**5**	**3**	**7**	**3**	4	
6. Generalised myrmicines														
Crematogaster sp. N72					12	5		38		30	25			
Solenopsis sp. N3	2			3	8	64	25	17	21		10			
Monomorium sp. N16	52	7				10	6			4	4			
Monomorium sp. N85								2						
Monomorium sp. N90											4	5		
Pheidole sp. N2	420	82	246	38	63	445	29	42	135	28	112	39		
Pheidole sp. N69				34	42	225	57	131	17	17	33	29		
Pheidole sp. N81							10							
total abundance	**474**	89	**246**	**75**	**125**	**749**	**127**	**230**	**173**	**79**	188	**73**	219	58
no of species	**3**	**2**	**1**	**3**	**4**	**5**	**5**	**5**	**3**	**4**	**6**	**3**	4	
7. Specialist predators														
Cerapachys sp. N84								2						
Myrmecia sp. N70				1	5									
Myrmecia sp. N88									2			1		
Myrmecia mandibularis								1						
total abundance	**0**	**0**	**0**	**1**	**5**	**0**	**0**	**1**	**2**	**0**	**0**	**1**	1	0.40
no of species	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**2**	**1**	**0**	**0**	**1**	1	
total abundance	**887**	**581**	839	**270**	818	**1349**	**1375**	683	**1433**	**637**	**1177**	1268	943	107
total no of species	20	15	17	18	26	22	27	20	25	22	28	22	22	