Composition and functional groups of ants at the Fiona Stanley Hospital and Beeliar Regional Park, Western Australia

Report for the Fiona Stanley Hospital Project

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Abstract

Ants have been widely adopted as indicators in environmental assessment in Australia due to their abundance, functional importance and sensitivity to environmental change. A functional group model has been developed for ants in Australia which classifies taxa at genus and species-group levels according to their continental-scale responses to environmental stress and disturbance. This study describes ant species richness and functional group composition at the Fiona Stanley Hospital (FSH) site, Perth, Western Australia, and compares them with those at various locations throughout Beeliar Regional Park (BRP). 74 morpho-species from 21 genera were recorded in the study. 5 species were identified as being potential indicators for select areas in BRP. 17 species were found to be unique to the FSH site, 11 of which were only found in areas scheduled for clearing. The FSH site contained communities which were distinct from those at BRP in both species and functional group composition which suggests the site is biologically unique. The findings may serve as a comparative reference to aid future studies whilst also providing a framework for estimating the biodiversity impacts of the Fiona Stanley Hospital project.

Introduction

The process of ecological restoration necessitates monitoring restoration projects against ecological criteria, with rigorous sampling designs and analytical methods (Jackson *et al*. 2005). The limitation imposed by time and money make it virtually impossible to monitor all aspects of the ecological health of a site, thus some ecologists have adopted the use of indicator species to gain an overview of the health of an ecosystem (Palmer *et al*. 2005). Indicator species or groups of species are those which readily reflect the abiotic and biotic state of an environment, represent the impact of environmental change, or are indicative of the diversity of a subset of taxa within an area (Jackson *et al*. 2005).

Invertebrates carry out numerous roles in ecosystems such as facilitating soil drainage, litter decomposition and nutrient cycling (Bisevac & Majer 1999). They may reflect ecological conditions and be potential candidates as indicators due to their abundance, diversity, functional importance and sensitivity to environmental change. Additionally, many are relatively easily sampled (Disney 1986), although identification can be difficult, particularly as the number of practicing taxonomists is small (Andersen *et al.* 2004).

In Australia, ants are the dominant invertebrate group. The Australian ant fauna is extremely diverse due to considerably high *alpha*- and *beta*- diversity, with the greatest diversity found in arid and semi-arid regions (Andersen 1991), although current taxoniomic revision of the *Melophurus* genus suggests their diversity may be overestimated (B. Heterick, Curtin University, pers. comm.). Ant species richness and composition show predictable colonization patterns at sites undergoing rehabilitation which reflect those of other invertebrate groups (Andersen *et al.* 2002), whilst also reflecting key ecosystem processes (Andersen & Sparling 1997) and as such ants are commonly suggested as biological indicators in land management (Majer 1983; Andersen 1997a; Andersen *et al.* 2002). The monitoring of ant communities has proven to be a useful tool when determining management strategies or while evaluating the recovery of areas after severe disturbance. For example, inventories of the ants present in a minesite before disturbance have proved to be very useful in establishing the baseline conditions for successful restoration (Majer 1990) and the predictable re-colonisation pattern of ants can provide some degree of indication of re-establishment of ecosystem functioning.

The relative abundance and composition of ant species is strongly influenced by climate, vegetation structure and competitive interactions. For example, in Australia species of *Iridomyrmex* are particularly abundant in areas of high temperatures and open vegetation. *Camponotus* and *Melophorus* are also extremely common in arid regions and are well adapted to coexist with *Iridomyrmex* – many *Camponotus* species reduce interaction by foraging at night and exhibiting submissive behaviour. The three genera collectively contribute over half the total species at most arid sites (Andersen 1991).

Environmental stress and disturbance are also key factors in determining ant community composition and previous research suggests that ant communities respond predictably to disturbance (Majer 1983; Andersen 1990, 1997a, b; Majer & Nichols 1998; Bisevac & Majer 1999). For example species of the opportunistic *Rhytidoponera* species, particularly *R. metallica* and allies, often increase in areas of disturbance such as following fire, grazing, mining and intensive recreation (Majer 2005).

Functional Groups

Rather than focusing on entire assemblages in a study, an alternative approach is to monitor groups that reflect broader ecological patterns (Lassau 2004). A functional group model has been developed which classifies ant taxa at genus and species-group levels according to their continental-scale responses to environmental stress and disturbance (Andersen 1995). Studies can use functional group composition as an indication of habitat stress and disturbance. Undisturbed temperate woodlands in Australia tend to support competitive, stress tolerant ant communities which have moderate diversity and a moderate representation of competitive taxa (Andersen 1995). The characteristics of the functional groups and their responses to disturbance are summarized in Table 1.

Table 1: Summary of functional groups of Australian ants, based on continental-scale responses to environmental stress and disturbance (adapted from Hoffman & Andersen, 2003).

Group and major taxa	Code	Characteristics
Dominant Dolichoderines *Iridomyrmex, Anonychomyrma*	DD	Abundant, highly active and aggressive species that favour hot and open habitats, and exert a strong competitive influence on other ants.
Subordinate Camponotini *Camponotus, Polyrhachis, Opisthopsis*	SC	Co-occurring with and behaviourally submissive to Dominant Dolichoderines. Large body size and often nocturnal foraging.
Hot Climate Specialists *Melophorus, Meranoplus, Monomorium* (part)	HCS	Arid-adapted taxa with morphological, physiological or behavioural specializations that reduce their interaction with Dominant Dolichoderines.
Cold Climate Specialists *Prolasius, Notoncus, Monomorium* (part)	CCS	Distribution centred on the cool-temperate zone. Most abundant in habitats where Dominant Dolichoderines are generally not abundant.
Tropical Climate Specialists *Oecophylla, Tetraponera*, many other tropical taxa	TCS	Distribution centred on the humid tropics. Occur in habitats where Dominant Dolichoderines are generally not abundant.
Cryptic Species *Solenopsis, Hypoponera*, many other small ponerines and myrmicines.	CR	Forage predominantly within soil and litter, having relatively little interaction with epigaeic ants.
Opportunists *Rhytidoponera, Paratrechina, Aphaenogaster, Tetramorium*	OP	Unspecialised, 'weedy' species characteristic of disturbed sites, or other habitats supporting low ant diversity.
Generalized Myrmicinae *Pheidole, Monomorium* (part), *Crematogaster*	GM	Cosmopolitan genera occurring in most habitats. Rapid recruitment to, and successful defence of, clumped food resources.
Specialist Predators *Myrmecia, Cerapachys*, large ponerines	SP	Relatively little interaction with other ants due to specialist diet, large body size, and small colony size.

Fiona Stanley Hospital Project

The Fiona Stanley Hospital will operate as the major tertiary health facility in the south metropolitan area. Construction of the hospital on South Street, Murdoch began, in December 2009 with the opening scheduled for 2014. The hospital site originally included two natural bushland areas to be protected into the future. These were approximately 3 ha each and included high quality Jarrah, Banksia and Marri woodlands. Most of these areas have been cleared for construction, with only a small area remaining (Appendix 1).

Due to obligations under Australia's *Environmental Protection & Biodiversity Conservation Act 1999*, the FSH Project is undertaking rehabilitation of Jarrah-Banksia woodland at several sites across BRP. Grass trees and Zamias were removed from the hospital site prior to clearing, and topsoil rich in seeds was stripped and relocated across rehabilitation sites in Beeliar Regional Park. Approximately 50 ha of land within Beeliar Regional Park (BRP) is to be rehabilitated over five years as part of the Fiona Stanley Hospital Project's environmental program. $1.1 million will be invested over five years to restore and revegetate approximately 75 ha of land within and around BRP. $50 000 has been committed to research into critical rehabilitation success factors for woodlands on the Swan Coastal Plain (Department of Health 2010) with one such success factor being the use of indicator species sampled from reference bushland at the FSH site and across relevant locations within the restoration areas.

A Conservation Agreement will be entered into with the Commonwealth Department of Environment, Water, Heritage and the Arts for the area of land located between the Fiona Stanley Hospital site and Farrington Road, which will reserve 2.5 ha of bushland for conservation purposes (Department of Health, 2010). The land consists mostly of Jarrah-Banksia woodland in good condition except for some degraded areas.

Aims of Study

In this study I assess ant species richness, species composition and functional group composition in areas of Beeliar Regional Park undergoing rehabilitation to examine the extent to which these communities resemble those in the adjacent bushland and the Fiona Stanley Hospital site. In doing so I aim to inventory a reference list of ant species for the areas; identify species which are exclusive to the FSH site, which of those are found in the reserved area and any that may be eliminated in the hospital developments. Indicator species are also identified for FSH and the Beeliar Regional Park sites. The findings of this study and the ant species list may serve as a comparative reference to aid future studies whilst also providing a framework for estimating the biodiversity impacts of the Fiona Stanley Hospital project.

Methods & Study Regions

Study Regions

The Fiona Stanley Hospital site is 32.4 ha in size and is bounded generally by South Street, Murdoch Drive, Kwinana Freeway, St John of God Hospital and the Murdoch Campus of Challenger TAFE. It is located within the City of Melville and bordered by the residential suburbs of Bateman, Murdoch, Leeming and North Lake (Appendix 1).

Beeliar Regional Park is Located in the South West of the Perth metropolitan area and extends approximately 23 km from its northernmost and southernmost areas. The Park contains both Bassendean and Spearwood Dune Systems, the soils of which are considered to be infertile. BRP has a high nature conservation value due to rich diversity and complexity of ecosystems. These ecosystems are far from their pristine states due to subjection to a range of pressures from increasing suburban growth in surrounding areas. Nonetheless, vegetation communities represent communities once widespread on the Swan Coastal Plain (Dooley *et al.* 2006).

For this study plots were selected from previously established vegetation transects which were created in relation to the Fiona Stanley Hospital rehabilitation projects. FSH Plots were positioned on land behind the Fiona Stanley Hospital which is reserved for conservation (FSH 1 – 4); on land originally to be preserved but which is now part of the hospital developments (FSH 5 – 10)(Department of Health 2010); and on land which was cleared for development soon after sampling (11 & 12).

Three sites in Beeliar Regional Park were sampled. Site 1, situated off Hodges Drive in Beeliar, was one of the locations of the top soil transfer. Plots 101-103 were based around the topsoil vegetation transects and 104 - 106 in the reference bushland. Site 2 was established on land cleared for the installation of a water pipeline, and rehabilitated except for a service vehicle track which was void of vegetation. Plots 201 and 202 were established over the track, and Plots 203 and 204 were located in the rehabilitated adjacent bushland. Topsoil transfer had also taken place at Site 3; 301 was established at the topsoil vegetation plot and 302 in the adjacent bushland. Following trap setting, this area was affected by arson, with fire trucks accessing the flames via the cleared topsoil area - consequently plot 301 was significantly damaged and had to be reset. In addition, two new plots in the burnt zone were installed (303 & 304).

Survey Design

Ant sampling was conducted from 12th to 22nd January 2010. Four traps were set at each corner of 10 m by 10 m plots at each site and left open for ten days. Each trap consisted of 45 mm diameter pitfall traps partially filled with 10 ml/L ethylene glycol as a preservative, which has been shown not to impact 'trappability' of ants (Korczyński 2006). Two traps were covered with mesh to limit interference by fauna. Traps at five plots were reset from 22nd January to 1st February due to disturbance. Perth daytime temperatures during these periods were extremely high, averaging 31.2°C and exceeding 40°C on three occasions (Bureau of Meteorology 2010).

Sorting

A reference collection was established from the collected specimens. Ants were sorted to genus level in all but one case, and species level in several instances. Each species was then assigned a name (or a reference number where species-level identification was not achieved) and a functional group according to the classification of Andersen (1995) (Table 1).

Data Analysis

An ordination of the plots based on log ant abundance was conducted using Non-metric Multidimensional Scaling (NMS) in *PC-Ord*. Abundance data was transformed to log 10 to reduce the impact of very abundant species on the results. An additional ordination using Detrended Correspondence Analysis (DCA) was run with data converted to presence-absence of species within plots. Ordinations arrange quadrants along axes based on taxon composition and do not force association among groups (Harris *et al.* 2010).

ANOVA and t-tests in Microsoft Excel were used to compare mean species richness between sites. Pearson's Correlation Coefficient was used to test if relationships between the abundance of Dominant Dolichoderines and Subordinate Camponotines fit the functional group model. This method was repeated to test the relationship between Dominant Dolichoderines and species richness at sites.

Indicator species analysis was performed on all but two plots using *PC-Ord*; Site 3 Bush and Site 3 Restored were omitted as they consisted of just one plot each. Indicator species analysis identifies taxa of particular community types and Indicator Values (IV) ranging from zero (no indication) to 100 (perfect indication) for each species in each group. Statistical significance of IVs is then given and species with an IV > 30 and a P-value < 0.05 are selected as indicator species.

Results

A total of 5494 individual ants were sampled representing 74 morpho-species from 21 genera and 6 sub-families (Appendix 2). *Camponotus* (11), *Melophorus* (10), *Monomorium* (10) and *Iridomyrmex* (9) were the most specious genera. *Iridomyrmex chasei* was the most abundant species and numerically dominated many of the traps of Sites 1 – 3 (mean = 223.7) but in comparison was relatively scarce at the FSH site.

Species Composition

An ordination based on the complete data indicated a clear separation between the Beeliar and FSH sites (Figure 1). Within the Beeliar sites the bushland sites (including the burnt bushland sites) fell to the left of the restored sites on axis one. A separate ordination using presence-absence data more clearly separated FSH from Beeliar along axis one, but indicated some overlap between FSH and the Bush plots at Site 1 and 2, with the Restored sites more distinct (Figure 2).

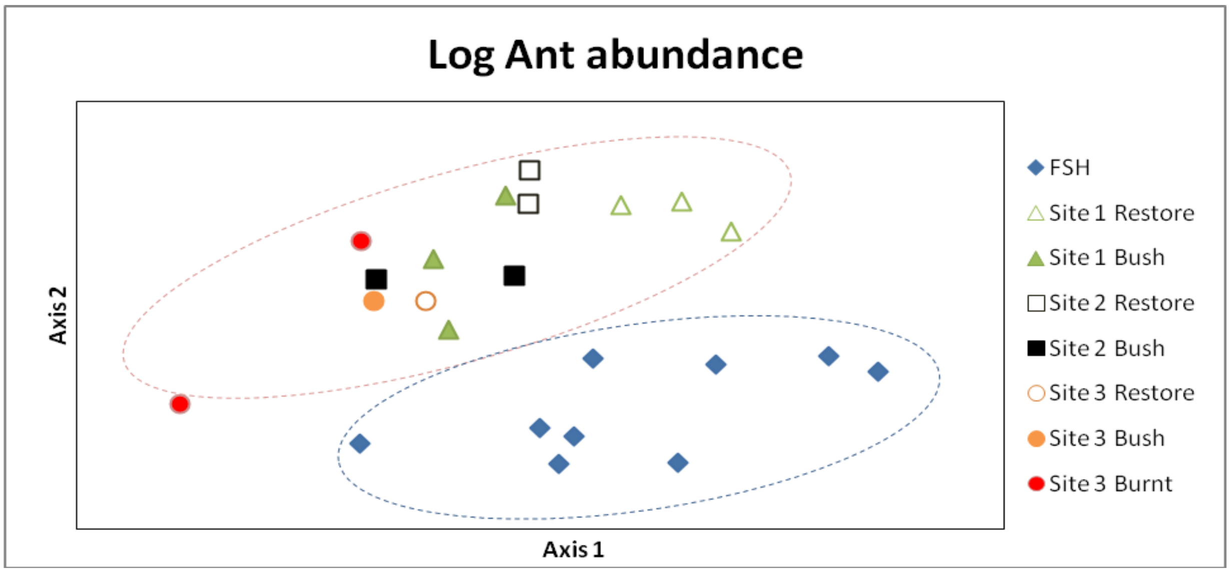

Figure 1: MDS ordination of sites based on log ant abundance.

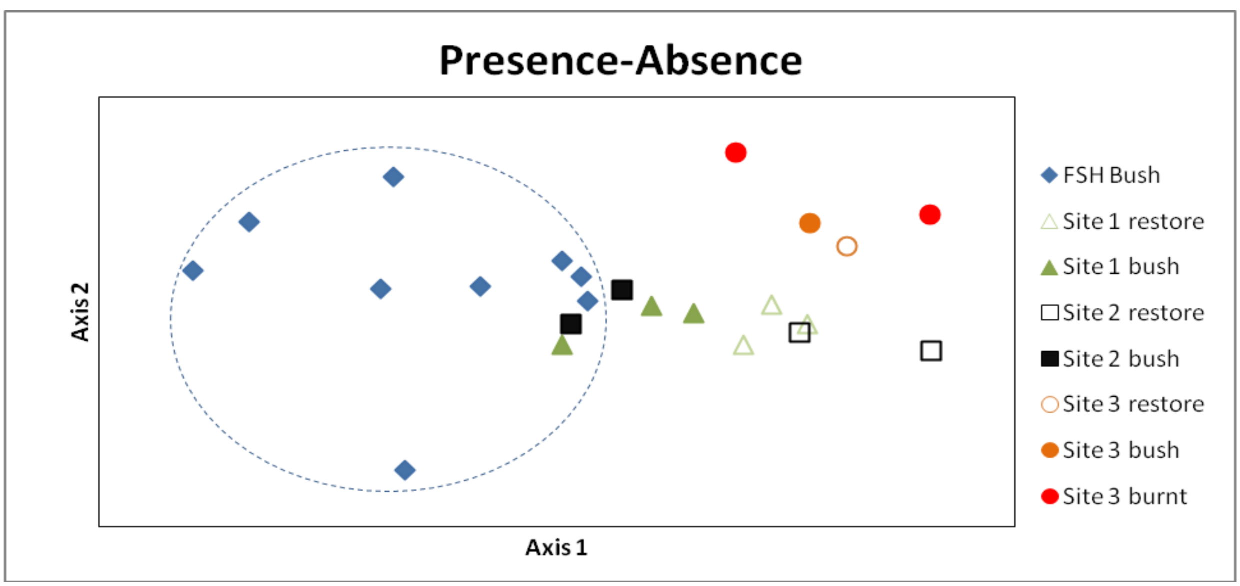

Figure 2: DCA ordination of sites based on presence-absence of species.

Despite similarities in species richness, species composition was markedly different between the sites. 17 species were exclusive to FSH, predominantly climate specialists (Figure 3) and 6 of these unique to the area to be preserved (FSH 1 – 4). *Melophorus* sp. 24 and *Monomorium* sp. 60 were widespread and relatively abundant, while the others appeared in small numbers and in a limited number of plots. 7 species were only recorded in plots which had been cleared or were scheduled for clearing (Table 3).

Thirty four species were not found at FSH (Figure 3); of those species 10 were common across Sites 1 - 3 and the remainders were exclusive to their respective sites. Site 3 contained a high number which were common to all but also had 10 which were exclusive to its zone. 7 species were found at all three sites – *Rhytidoponera violacea, Melophorus* sp. 9*, M. perthenis, M. insularis, Tetramorium impressum* and *Meranoplus* sp. 40.

Figure 3: Number of species exclusive to FSH or other sites.

Table 2: Species which were exclusive to FSH and their likelihood of remaining (based on this survey) pending future developments for the Fiona Stanley Hospital.

RTU #	Species	Functional Group	Land conservation status		
			Conserved (FSH 1 - 4)	Cleared (FSH 11-12)	To be cleared (FSH 5 – 10)
24	*Melophorus* sp. 24	HCS	x		
54	*Notocus gilberti*	CCS	x		
57	*Dolichoderus ypsilon*	CCS	x		
60	*Melophorus* sp. 60	HCS	x		
65	*Monomorium* sp. 65	HCS	x		
84	*Camponotus* sp. 84	SC	x		
48	*Melophorus* sp. 48	HCS		x	
56	*Tetramorium simillimum*	OP		x	
59	*Crematogaster dispar*	GM		x	
26	*Camponotus ceriseipes*	SC			x
27	*Myrmecia* sp. 27	SP			x
30	*Stigmacros pilosella*	CCS			x
33	*Stigmacros* sp. 33	CCS			x
37	*Monomorium longinode*	HCS			x
58	*Crematogaster queenslandica*	GM			x
61	*Iridomyrmex ?notialis*	DD			x
64	*Monomorium* sp. 64	HCS			x

Species Richness

Species richness varied from 5 to 19 species (both extremities were from FSH plots) and total species richness was overall highest at FSH, although this is to be expected as more plots were established (Figure 4). The mean species richness of the FSH site (12.22) was lower than all other sites except the restored zones at Site 1 (7.33) and Site 3 (12.00) (Figure 4). Species richness was similar between sites ($P > 0.05$) and between bush and restored sites ($P > 0.05$) but the bush plots tended to have greater numbers. There was a weak positive linear relationship between abundance of Dominant Dolichoderines and total species richness at sites (Table 3, $r = 0.21$, n.s.), however the Restored sites had a high abundance of Dominant Dolichoderines corresponding to low total species richness. A weak negative linear relationship between abundance of Dominant Dolichoderines and Subordinate Camponitines across all sites (Table 3, $r = -0.28$, n.s.). A similar trend was also apparent with Generalised Myrmicines (Table 3, $r = -0.37$, n.s.).

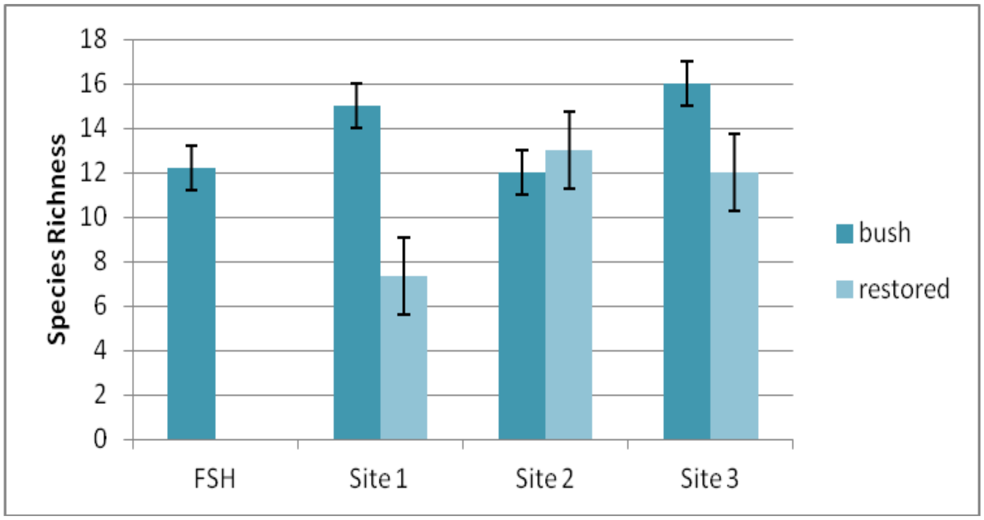

Figure 4: Mean species richness by site, differentiating 'bush' and 'restored' plots from Beeliar Regional Park samples.

Table 3: Abundance of *Iridomyrmex chasei*; species richness of Dominant Dolichoderines & Subordinate Camponotines; and total species richness of plots.

Trap	***I. chasei***	**DD**	**SC**	**Total S.R.**
FSH1	31	1	2	8
FSH2	0	0	1	14
FSH3	0	0	2	14
FSH4	194	1	3	19
FSH5	2	3	1	17
FSH6	0	1	1	7
FSH7	0	0	0	5
FSH8	0	0	2	13
FSH11	1	2	1	13
101	1	4	0	8
102	41	2	0	7
103	139	2	1	7
104	11	2	0	17
105	781	2	1	8
106	301	3	1	13
201	187	4	0	14
202	344	2	0	12

203	98	4	1	12
204	484	3	0	12
301	40	2	2	12
302	19	3	5	16
303	798	3	5	12
304	336	2	4	11

Functional Groups

The most abundant and specious functional groups across all sites were Hot Climate Specialists and Dominant Dolichoderines, with Opportunists also featuring relatively strongly at most sites (Figure 5). Species richness of functional groups was relatively uniform across all sites, and in particular between the Bush plots (Figure 5(a)). Overall the Bush plots at Site 101 maintained high species richness despite the markedly high abundance of Dominant Dolichoderines, in particular *Iridomyrmex chasei*.

All functional groups were sampled within the FSH site. Cold Climate Specialists were rarely found in the restored zones but featured in the adjacent reference Bush plots. Functional groups were most poorly represented in the Site 1 Restored plots which only contained Specialist Predators, Opportunists, Hot Climate Specialists and Dominant Dolichoderines.

The uniformity of species richness did not extend to the abundance of species within functional groups, as shown in Figure 5(b). Subordinate Camponotines formed the majority of individuals sampled at FSH, accounting for only 11% of species richness but more than 50% of total abundance. FSH also had a relatively low portion of Dominant Dolichoderines.

There was a high diversity of Hot Climate Specialists (HCS) across FSH – they accounted for more than half of the total species richness, and 5 of the 17 species exclusive to FSH were Hot Climate Specialists - and the bush plots at Sites 1 and 3. Cold Climate Specialists (CCS) were most abundant in the restored plots at all sites and were comparatively void in all other plots, although FSH contained 5 CCS, 4 of which were exclusive to the site. Of the restored zones, Site 1 contained the most CCS (25, SR = 4). Notably, *Dolichoderus ypsilon* and *Stigmacros* spp. 15 and 19 all appeared in each restored plot and were almost exclusive to these plots (only *Stigmacros* sp. 15 was recorded once outside of them). HCS, on the other hand were consistent with the functional group model, faring well where Dolichoderines were abundant.

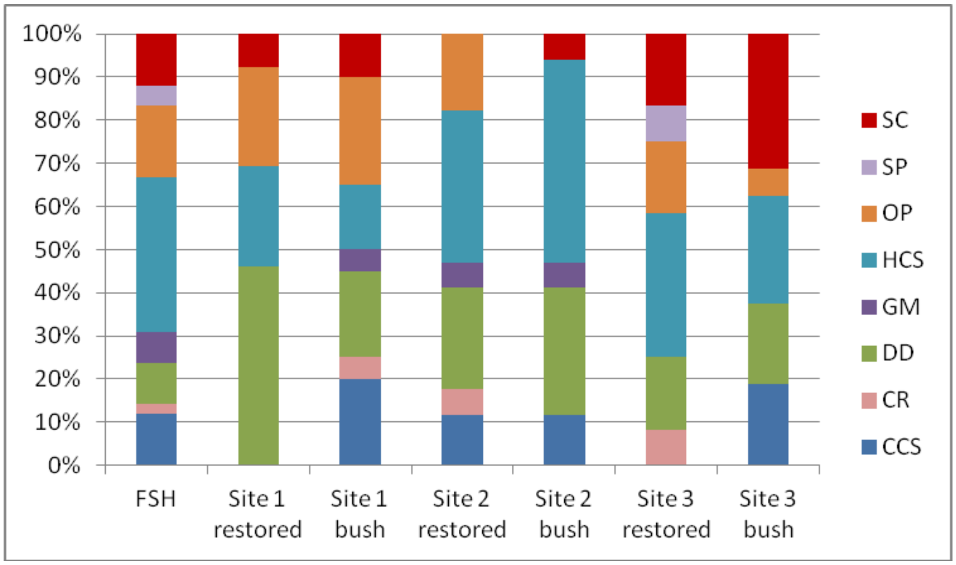

Figure 5(a): Percentage species richness within functional groups at each site from 'bush' and 'restored' plots.

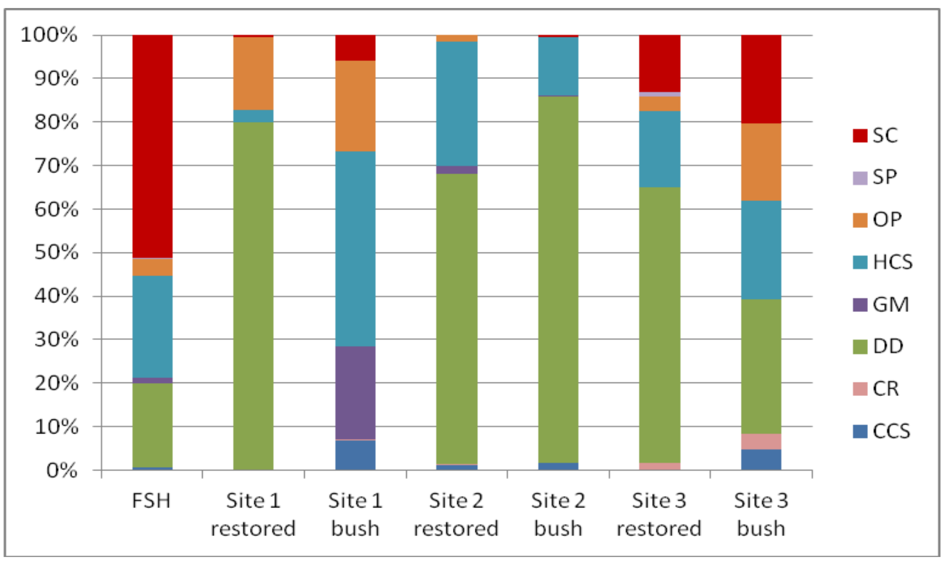

Figure 5(b): Percentage species abundance within functional groups at each site from 'bush' and 'restored' plots.

Dominant Dolichoderines were richest at Site 1 in the Restored zones, and most abundant at Site 2 Bush. These plots were established in dense, shaded understory with patches of sandy soil. Despite the high abundance of Dominant Dolichoderines at both the Bush and Restored plots at Site 2, species richness within most other functional groups remained high.

The fire-affected Site 3 had low species richness and was dominated numerically by Dominant Dolichoderines (73.2%), the most abundant of which was *Iridomyrmex chasei*. Hot Climate Specialists and Opportunists contributed the most species at these plots with 4 and 3 respectively.

Indicator Species

Five species were identified as being significant indicators for the six habitat types assessed. Site 2 Restored contained 2 indicator species and 3 were identified for Site 3 Burnt (Table 3). *Melophorus* sp. 9 occurred in all bush but two Bush plots.

Table 4: Indicator species identified by *PC-Ord* (where P = <0.05). Site 3 Bush & Site 3 Restored were eliminated from the analysis as they only contained one plot each.

Site	**RTU#**	**Species**	**Functional Group**
Site 2 Restored	5	*Melophorus tuneri*	HCS
	50	*Iridomyrmex bicknelli*	DD
Site 3 Burnt	40	*Meranoplus* sp. 40	HCS
	68	*Pachycondyla lutea*	CR
	82	*Camponotus capito ebenithorax*	SC

Discussion

Distinct differences in community composition were seen across the sites and also between Bush and Restored zones. A clear separation is apparent for the assemblages from the FSH sites, indicating that there are consistent differences in species composition between FSH and Beeliar Regional Park. Functional group composition for FSH was distinct, with notably high numbers and species richness of both Subordinate Camponotines and Hot Climate Specialists and a correspondingly low abundance of Dominant Dolichoderines. Seventeen species sampled were found exclusively at the FSH sites and 33 species were absent. These exclusions may be partially attributed to geographical isolation and limited sampling efforts.

Plots which experienced the highest degree of disturbance differed in composition from the other categories. The Restored sites generally exhibited lower richness than their Bush equivalents, despite close proximity, and tended to support large numbers of Dominant Dolichoderines. Areas of topsoil transfer still exhibited relatively diverse community structure which suggests that the 'disturbance' caused by the topsoil did not have immediate detrimental effects on ant communities, or they have re-colonised. A succession of species across revegetated sites has been observed in various studies across Australia, with initial colonisation by species of *Iridomyrmex* succeeded by broadly adapted, opportunistic species as vegetation cover increases (Andersen 1993; Majer & Nichols 1998).

In fire-affected areas an important factor in species composition is time since disturbance, because an immediate response incorporating direct mortality may differ from long term response. Studies of ant assemblages following fire have shown ant richness to be lower in recently burnt sites than burnt sites (Andersen 1997b; Gunawardene & Majer 2005; Sackman & Farji-Brener 2006). Dominant Dolichoderines and Generalist Myrmicines have been found to re-colonise recently burnt sites (Gunawardene & Majer, 2005). These findings were based on sampling carried out 1 – 5 years after fire - given that Plot 301 was subjected to very recent arson it is reasonable to assume a high mortality rate of any species which occurred, but that those present survived the fire rather than recolonised.

A negative correlation between the abundance of Dominant Dolichoderines and Subordinate Camponotines was observed. Stress, such as disturbance or fire, is a key factor in regulating ant community structure, particularly as it controls the abundance of Dominant Dolichoderines and therefore largely determines competitive dynamics within community (Andersen 1995). As a functional group Dominant Dolichoderines have a strong effect on Subordinate Camponotines and Generalized Myrmicines and in the absence of Dominant Dolichoderines, Subordinate Camponotines are known to be competitively dominant (Andersen & Patel 1994; Majer & Brown 1986), a trend which is prevalent across our data.

Hot Climate Specialists dominated the FSH plots in terms of species richness, and also featured strongly in abundance. This is consistent with the functional group model which states that Hot Climate Specialists prefer open environments and tend to be favoured by low levels of disturbance in well-forested habitats (Majer & Brown, 1986).

Opportunists, which are comprised of broadly adapted taxa with wide habitat tolerances, were not as well represented as expected in disturbed sites given their dominance in other studies (for example, the group forms 80 - 95% of total ants in traps at disturbed sites in King *et al*. (1998)). Two species of the opportunistic *Rhytidoponera* were recorded*,* a genus which is regarded as an increaser following disturbance (Andersen 1990; Hoffman & Andersen 2003) with *Rhytidoponera ignorant* appearing at all sites. As there was no data on the sites prior to this study no conclusions can be drawn on whether either of these species has increased over time, although their presence indicates some degree of disturbance at all sites. *R. ignorant* was present in FSH plots 3 - 6 which may relate to their proximity to fire breaks. Based on other studies it was expected that Opportunists would feature more strongly, particularly in the restored zones. Their relative absence may be due to the abundance of Dominant Dolichoderines at these sites – whilst Opportunists may be characteristic of sites where stress or disturbance severely limits productivity they are particularly sensitive to competitive interactions such that their responses oppose those of Dominant Dolichoderines (Andersen 1995; 1997a). In relation to re-colonisation patterns, as vegetation cover increases it is expected that more Opportunists and specialist species will replace these initial colonisers. Ant colonisation at the Restored sites suggests, at least from an ant's perspective, that the areas might not be as disturbed as they appear.

Specialist Predators, which have highly specialized requirements that make them particularly sensitive to disturbance, were only present in single units across all plots, contributing a negligible amount to overall data and showing no particular trend or habitat preference from species to species. A more intense study may reveal some to be of use as site-specific indicators, but for this study they were not informative.

Indicator Species

Melophorus species #9 (Western Australian Institute of Technology sp. JDM 176) was present in all but two Bush plots including FSH and was absent from Restored plots. As such it is a species which might be useful as a key indicator of bushland recovery in the Restored sites. *Melophorus tuneri* (Hot Climate Specialist) and *Iridomyrmex bicknelli* (Dominant Dolichoderine) were identified as indicators for Restored plots at Site 2, which were characterized by a high abundance of Dominant Dolichoderines and a lack of Subordinate Camponotines. These indicator species might be predicted to decrease or disappear from the Restored sites if vegetation cover increases. Although many species occurred exclusively in some sites they did not occur in multiple sites and as such were not statistically significant.

No indicator species were identified for the FSH site as numbers of individuals were generally low and their presence restricted to one or two plots. Nonetheless, a suite of species unique to FSH were identified, most of which were climate specialists. Six species were present in the area of bushland reserved for conservation and 3 were identified in areas which have since been cleared. It is uncertain whether the remaining 11 species would be found in the reserved area so it cannot be said for certain that they will be eliminated during future clearing. The clearing of vegetation around the reserved area is likely to have a significant impact on the ant species present. Edge effects are known to have 'ecotonal' effects on ant species (their relative abundance either increases or decreases) due to the interactions between the adjacent habitat types and the increase in disturbance (Dauber & Wolters 2004) and may facilitate changes in species richness, community composition and ecosystem processes (Murcia 1995). The small area of land reserved for conservation is unlikely to retain its current characteristics once the surrounding vegetation is removed. Future sampling of the site could consider these 17 species to determine if they have remained or been lost from the site as the habitat available has declined.

Summary

The distinct differences between FSH and Beeliar Regional Park in regards to both species and functional group abundance and composition indicate varying ecological states across the sites, although the relatively small, unrepeated and uneven sampling efforts of this study were somewhat limiting. Despite high levels of disturbance at several sites the ant communities remained relatively diverse, particularly where topsoil transfer had occurred, indicative of reasonable ecological health despite the appearance of degradation. As vegetation cover increases, ant re-colonisation should see a shift in community composition away from the dominant species – not necessarily in abundance, but certainly in species richness of functional groups.

Future studies within the restored areas of Beeliar Regional Park should find this data very useful, particularly as it was collected only a short time after the transfer or topsoil (and an unexpected fire) which would not have allowed sufficient time for ant communities to reform. Data from the FSH plots may serve as a useful reference for future studies as it was obtained from relatively undisturbed bushland in the area. Such studies may also reveal if those species unique to the area are still present.

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Appendices

Appendix 1: Location of sampling plots at FSH and across Beeliar Regional Park.

Appendix 2: Species inventory for the study.

Fiona Stanley Project Ant Reference Collection			
RTU #	**Subfamily**	**Genus**	**Species**
1	Ectatomminae	*Rhytidoponera*	*violacea* (Forel)
2	Dolichoderines	*Iridomyrmex*	? *chasei concolor* Forel
3	Dolichoderines	*Iridomyrmex*	*chasei* Forel
4	Myrmicinae	*Tetramorium*	? impressum (Viehmeyer)
5	Formicinae	*Melophorus*	*? turneri perthensis* Wheeler
6	=RTU9		
7	=RTU68	(queen)	
8	Myrmicinae	*Tetramorium*	? sp. JDM 1007
9	Formicinae	*Melophorus*	? sp. JDM 176
10	Dolichoderines	*Dolichoderus*	*ypsilon* Forel
11	Ectatomminae	*Rhytidoponera*	? *ignorant* Crawley
12	Myrmicinae	*Monomorium*	sp.
13	Formicinae	*Melophorus*	? *turneri* Forel
14	= RTU9		
15	Formicinae	*Stigmacros*	sp.
16	Myrmicinae	*Monomorium*	sp.
17	Dolichoderines	*Iridomyrmex*	*? rufoniger suchieri* Forel (pop. 1)
18	Formicinae	*Melophorus*	sp. JDM 230
19	Formicinae	*Stigmacros*	*aemula* Forel
20	=RTU15		
21	Myrmicinae	*Crematogaster*	? *laeviceps* group JDM 858
22	Formicinae	*Melophorus*	*insularis* Wheeler
23	=RTU16		
24	Myrmicinae	*Melophorus*	sp.
25	Dolichoderines	Tapinoma	sp. JDM 78
26	Formicinae	*Camponotus*	? *ceriseipes* complex sp. JDM 105
27	Myrmecinae	*Myrmecia*	sp.
28	Formicinae	*Camponotus*	? *claripes* gp JDM 63
29	=RTU22		
30	Formicinae	*Stigmacros*	? *pilosella* (Viehmeyer)

31	Myrmicinae	*Meranoplus*	? sp. JDM 968
32	Myrmicinae	*Monomorium*	
33	Formicinae	*Stigmacros*	sp. JDM 1050
34	Dolichoderines	*Doleromyrma*	*rottnestensis* (Wheeler)
35	Formicinae	*Camponotus*	? *terebrans* (Lowne)
36	Myrmicinae	*Tetramorium*	? *striolatum* Viehmeyer
37	Myrmicinae	*Monomorium*	*longinode* Heterick
38	Dolichoderines	*Anonychomyrma*	sp.
39	Dolichoderines	*Dolichoderus*	*clusor* Forel
40	Myrmicinae	*Meranoplus*	? sp. JDM 423
41	Myrmicinae	*Monomorium*	sp.
42	=RTU21		
43	=RTU21		
44	Myrmicinae	*Pheidole*	? *ampla perthensis* Crawley
45	Myrmicinae	*Cardiocondyla*	'*nuda*' (Mayr)
46	Myrmicinae	*Monomorium*	sp.
47	Formicinae	*Melophorus*	sp.
48	Formicinae	*Melophorus*	sp.
49	Formicinae	*Stigmacros*	? *pusilla* McAreavey
50	Dolichoderines	*Iridomyrmex*	? *bicknelli* Emery
51	Formicinae	*Camponotus*	sp.
52	Formicinae	*Camponotus*	sp.
53	Formicinae	*Polyrhachis*	sp. JDM 118
54	Formicinae	*Notoncus*	*gilberti* Forel
55	Myrmecinae	*Myrmecia*	? *swalei Crawley*
55a	?Formicinae	*??Camponotus*	*chalceus* Crawley
56	Myrmicinae	*Tetramorium*	*simillimum* (F. Smith)
57	Formicinae	*Dolichoderus*	*ypsilon niger* Forel
58	Myrmicinae	*Crematogaster*	*queenslandica* group JDM 428
59	Myrmicinae	*Crematogaster*	*dispar* Forel
60	Formicinae	*Melophorus*	sp. JDM 500
61	Dolichoderines	*Iridomyrmex*	*conifer* Forel
62	=RTU58		
63	Myrmicinae	*Monomorium*	sp.

64	Myrmicinae	*? Monomorium*	sp.
65	Myrmicinae	*Monomorium*	sp.
66	Myrmicinae	*Monomorium*	*sydneyense* Forel
67	Cerapachyinae	*Cerapachys*	sp.
68	Ponerinae	*Pachycondyla*	*lutea* (Mayr)
69	Dolichoderines	*Iridomyrmex*	? notialis *Shattuck*
70	=RTU50		
71	Dolichoderines	*Anonychomyrma*	*? itinerans perthensis* Forel
72	Dolichoderines	*Iridomyrmex*	*chasei concolor* Forel
73	Dolichoderines	*Papyrius*	*nitidus* (Mayr)
74	Dolichoderines	*? Ochetellus*	*glaber* gp. sp. JDM 19
75	Dolichoderines	*? Iridomyrmex*	sp.
76	Dolichoderines	*Iridomyrmex*	? *dromus* Clark
77	Formicinae	*Camponotus*	*? walkeri* Forel
78	Formicinae	*?Paratrechina*	minutula (Forel)
79	Formicinae	*??*	
80	Formicinae	*Camponotus*	*gasseri* (Forel)
81	Formicinae	*Camponotus*	sp.
82	Formicinae	*Camponotus*	? *capito ebenithorax* Forel
83	Formicinae	*Camponotus*	? *johnclarki* Taylor
84	Formicinae	*Camponotus*	sp.
85	Formicinae	*Melophorus*	??*mjobergi* Forel

Appendix 3: Indicator species analysis results.

		Site:	FSH	S1-R	S1-B	S2-R	S2-B	Burnt	Indicator Value	
		No. of plots	12	3	3	2	2	2		
RTU#	**Subfamily**	**Genus**							**(IV)**	***P*-value**
FSH										
12	Myrmicinae	*Monomorium*	**8**	0	0	0	0	0	8.3	0
24	Myrmicinae	*Melophorus*	**42**	0	0	0	0	0	41.7	0.1872
26	Formicinae	*Camponotus*	**8**	0	0	0	0	0	8.3	0
27	Myrmicinae	*Myrmecia*	**8**	0	0	0	0	0	8.3	0
28	Formicinae	*Camponotus*	**36**	0	4	0	1	0	35.7	0.4811
30	Formicinae	*Stigmacros*	**8**	0	0	0	0	0	8.3	0
32	Myrmicinae	*Monomorium*	**23**	0	0	20	7	0	22.7	0.6441
33	Formicinae	*Stigmacros*	**8**	0	0	0	0	0	8.3	0
37	Myrmicinae	*Monomorium*	**8**	0	0	0	0	0	8.3	0
41	Myrmicinae	*Monomorium*	**8**	0	0	0	0	0	8.3	0
48	Formicinae	*Melophorus*	**8**	0	0	0	0	0	8.3	0
54	Formicinae	*Notoncus*	**17**	0	0	0	0	0	16.7	0
56	Myrmicinae	*Tetramorium*	**8**	0	0	0	0	0	8.3	0
57	Formicinae	*Dolichoderus*	**17**	0	0	0	0	0	16.7	0
58	Myrmicinae	*Crematogaster*	**8**	0	0	0	0	0	8.3	0
59	Myrmicinae	*Crematogaster*	**8**	0	0	0	0	0	8.3	0
60	Formicinae	*Melophorus*	**8**	0	0	0	0	0	8.3	0
61	Dolichoderines	*Iridomyrmex*	**8**	0	0	0	0	0	8.3	0
64	Myrmicinae	*? Monomorium*	**8**	0	0	0	0	0	8.3	0
65	Myrmicinae	*Monomorium*	**42**	0	0	0	0	0	41.7	0.198
84	Formicinae	*Camponotus*	**8**	0	0	0	0	0	8.3	0
Site 1 Restored										
4	Myrmicinae	*Tetramorium*	2	**30**	0	7	0	14	30.3	0.3397
47	Formicinae	*Melophorus*	0	**33**	0	0	0	0	33.3	0.5133
72	Dolichoderines	*Iridomyrmex*	0	**30**	0	0	0	4	30.5	0.4871
83	Formicinae	*Camponotus*	0	**33**	0	0	0	0	33.3	0.4871
Site 1 Bush										
1	Ectatomminae	*Rhytidoponera*	1	30	**33**	8	0	5	33	0.5753
2	Dolichoderines	*Iridomyrmex*	0	1	**33**	0	0	0	32.8	0.4351
3	Dolichoderines	*Iridomyrmex*	0	5	**28**	21	23	22	28.4	0.7031
7	Ponerinae	*Pachycondyla*	0	0	**33**	0	0	0	33.3	0.4989
8	Myrmicinae	*Tetramorium*	0	0	**33**	0	0	0	33.3	0.4989

10	Dolichoderines	*Dolichoderus*	0	0	**32**	0	0	0	31.7	0.4051
14	Formicinae	*Melophorus*	17	0	**50**	0	0	0	49.6	0.1308
19	Formicinae	*Stigmacros*	0	0	**53**	0	7	17	53.3	0.0926
21	Myrmicinae	*Crematogaster*	1	0	**32**	0	1	0	32.1	0.5209
29	Formicinae	*Melophorus*	4	6	**12**	0	0	0	11.6	0
34	Dolichoderines	*Doleromyrma*	7	0	**19**	0	0	0	19	0.9584
36	Myrmicinae	*Tetramorium*	13	0	**25**	0	0	0	24.9	0.5741
38	Dolichoderines	*Anonychomyrma*	0	0	**33**	0	0	0	33.3	0.5007
63	Myrmicinae	*Monomorium*	0	0	**33**	0	0	0	33.3	0.4989
80	Formicinae	*Camponotus*	0	0	**33**	0	0	0	33.3	0.4989
Site 2 Restored										
5	Formicinae	*Melophorus*	0	4	5	**80**	0	0	79.9	0.0398
45	Myrmicinae	*Crematogaster*	0	35	0	**65**	0	0	65.2	0.0538
46	Myrmicinae	*Monomorium*	0	0	0	**50**	0	0	50	0.2627
49	Formicinae	*Stigmacros*	0	0	0	**50**	0	0	50	0.2498
50	Dolichoderines	*Iridomyrmex*	0	5	0	**64**	11	0	64.3	0.0492
66	Myrmicinae	*Monomorium*	0	0	17	**25**	0	0	25	0.5963
70	Dolichoderines	*Iridomyrmex*	0	0	0	**52**	0	24	52.2	0.0888
76	Dolichoderines	*Iridomyrmex*	0	6	0	**27**	0	14	27.3	0.4535
Site 2 Bush										
9	Formicinae	*Melophorus*	19	0	22	1	**32**	0	32.1	0.4283
13	Formicinae	*Melophorus*	0	0	8	0	**38**	0	37.5	0.3619
15	Formicinae	*Stigmacros*	0	0	22	18	**37**	2	37	0.2597
16	Myrmicinae	*Monomorium*	0	0	46	2	**51**	0	50.9	0.112
17	Dolichoderines	*Iridomyrmex*	0	19	2	4	**26**	0	25.7	0.5257
18	Formicinae	*Melophorus*	1	0	2	0	**90**	0	90	0.0036
22	Formicinae	*Melophorus*	18	0	9	0	**21**	14	21.2	0.8496
31	Myrmicinae	*Meranoplus*	2	0	7	0	**33**	0	33.3	0.2941
71	Dolichoderines	*Anonychomyrma*	8	0	0	0	**27**	0	27.3	0.4861
73	Dolichoderines	*Papyrius*	0	0	0	0	**50**	0	50	0.2559
Site 3 Burnt										
11	Ectatomminae	*Rhytidoponera*	5	0	15	0	0	**21**	20.8	0.7127
25	Dolichoderines	Tapinoma	4	0	0	0	0	**38**	37.5	0.2915
35	Formicinae	*Camponotus*	3	0	0	0	0	**94**	93.7	0.0012
39	Dolichoderines	*Dolichoderus*	0	0	13	0	0	**30**	30	0.4173
40	Myrmicinae	*Meranoplus*	0	0	0	0	2	**94**	94.1	0.026
44	Myrmicinae	*Pheidole*	0	0	0	19	0	**31**	30.8	0.4011
51	Formicinae	*Camponotus*	1	0	0	0	0	**43**	42.9	0.2853

62	Myrmicinae	*Crematogaster*	5	0	0	0	0	**21**	21.4	0.6275
67	Cerapachyinae	*Cerapachys*	1	0	0	0	0	**43**	42.9	0.2853
68	Ponerinae	*Pachycondyla*	0	0	0	6	0	**84**	84	0.0128
69	Dolichoderines	*Iridomyrmex*	0	0	0	0	0	**50**	50	0.244
75	Dolichoderines	*? Iridomyrmex*	0	0	0	0	0	**50**	50	0.244
77	Formicinae	*Camponotus*	0	0	0	0	0	**50**	50	0.244
78	Formicinae	*?Paratrechina*	0	0	0	0	0	**50**	50	0.2438
82	Formicinae	*Camponotus*	0	0	0	0	0	**100**	100	0.0098