Terrestrial Invertebrate Status Review

BRISBANE CITY

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2 March 2005

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FOREWORD

"A national strategy for the conservation of Australia's terrestrial biodiversity was first mooted in a draft discussion paper in 1992. Since that time a number of initiatives have sought to address the issues of biodiversity conservation at National, State and regional levels. Relevant consultative advisory and steering committees have been formed and these have identified key issues, so called biodiversity hotspots and sites of significance that should form the focus of conservation efforts. From a faunal viewpoint I consider that the approach to date has significant shortcomings. Firstly, the basis of much of the discussion is based on vertebrate values. And secondly, if we acknowledge that faunal biodiversity consists chiefly of invertebrates, there appears to be no strategy aimed at filling major gaps in the knowledge base of these animals at either the National, State or regional level".
[Stanisic, 2004: Wildlife, Autumn Edition].

The value of invertebrates in conservation in Australia has received much lip service but little practical attention up to the present time. While it is an inescapable fact that terrestrial "invertebrates" drive ecological processes and functions that maintain forests and their faunas, biodiversity managers still rely heavily on the vertebrate fauna (and vascular flora) for making key management decisions. The blinkered belief that the current system of environmental appraisal is adequate has obvious appeal for environmental managers, consultants and scientists, especially as few of them have more than a scant knowledge of animals other than mammals and other tetrapods (Stanisic and Ponder, 2004).

Filling the 'knowledge gap' about invertebrates is a critical step in raising the profile of 'the little things that run the world' (Wilson, 1987). The Brisbane City Terrestrial Invertebrate Status Review seeks to fill the information void and also contribute significantly to another emerging environmental issue viz. the conservation of urban biodiversity. 'Urban biodiversity' may at first glance appear to be an oxymoron especially in terms of vertebrates, but as the results in this report show, quite the opposite when it comes to invertebrates. Urban invertebrates are alive and well in the Brisbane Bushlands and have much to contribute to their management and continued preservation for the well being of Brisbane residents.

The Brisbane City invertebrate survey is unique in its scope and represents a significant milestone in mapping the city's biodiversity. For supporting this innovative venture the Brisbane City Council needs to be acknowledged as a key proponent of urban biodiversity conservation.

The authors wish to acknowledge the assistance of Stacey McLean, Alan Barton, John Rush, Anne Marie Lindsay (Brisbane City Council, Environment and Parks Branch), Brisbane Water and the Queensland Environmental Protection Agency.

Cover design : Vince Railton (**Nuleaf Creative**).

EXECUTIVE SUMMARY

1. The TISR surveyed the distribution of invertebrates in Brisbane City specifically targetting groups renowned for their use as bio-indicators. These comprised the ants, ground beetles, sucking bugs, spiders and land snails and to a lesser extent the butterflies, dragonflies and damselflies. Ten bushland sites with differing ecological profiles were chosen for the study.

2. Two hundred and fifty-six species of ant, 568 species of spiders, 164 species of beetles, 84 species of sucking bugs, 82 species of butterflies, 34 species of dragon and damselflies, and 43 species of land snails were studied in regard to their distributions and ecological traits. Many more invertebrates were caught and are stored at the Queensland Museum for future study.

3. The ten Brisbane bushland sites chosen for study in the TISR were shown to differ in their invertebrate fauna in both species richness and abundance. These differences in faunal structure indicate that invertebrates could be a useful tool in assessing the health and integrity of these sites. However, for his to happen the results of the TISR need to be verified for fidelity through more rigorous sampling procedures (replication). These follow-up studies should focus on a select subset of the invertebrates included in this report and include some of the TISR sites as well as several other sites in the Brisbane City.

4. The relatively minor component of introduced species recorded across all the sites combined with the rich biodiversity of local species indicates that many of the sites are still in near-pristine condition. Hence, the Brisbane City bushlands also act as reservoirs in sustaining the city's overall biodiversity.

5. The TISR represents the first attempt to document the invertebrates of Brisbane City and adds significantly to the information available on its biodiversity. However, this database must be considered rudimentary given the scope for additions. Nonetheless, even in these early stages of development, the database has a number of potentially important uses:
    - directing additional field studies to improve our understanding of the role of invertebrates in sustaining Brisbane City's greenspace;
    - developing rapid assessment tools for bushland management including the effects of council fire regimes on ecosystem health;
    - taxonomic studies;
    - improving community appreciation of the city's biodiversity; and
    - developing a list of significant invertebrates of Brisbane City

INTRODUCTION

The Brisbane City Council (BCC), through its Environment & Parks Branch engaged the services of the Queensland Museum (QM)'s Centre for Biodiversity (QCB) to undertake a comprehensive Terrestrial Invertebrate Status Review (TISR) in the City of Brisbane as part of the Council's Co-operative Biodiversity Research Program.

Ten sites representing a range of ecosystems from across the BCC conservation reserve network were selected as part of what was a year-long project to determine the composition of the invertebrate fauna of the Brisbane City environs. The QCB commenced this project on 14 April 2003 and the collecting phase of the project was finalised in September 2004. However, sorting of specimens has continued up to the publication date of this report. The results presented in this report are based on a collecting regime chiefly comprising monthly pitfall trapping but also including many other techniques designed to sample invertebrate faunas. The quantity of material collected was extensive and is exemplified by the extraordinary 70,000+ ant specimens examined during the course of the survey and the lengthy list of support staff that helped sort the material. Collecting invertebrate species is not a problem, dealing with the specimens can be.

The work associated with the TISR was primarily performed by key QCB staff viz. Dr Chris Burwell (entomologist), Dr Robert Raven (arachnologist), Dr Geoff Monteith (entomologist) and Dr Barbara Baehr (arachnologist) with support from QCB support staff comprising Susan Wright, Geoff Thompson, Darryl Potter, Owen Seeman, Peter Grimbacher, Eric Volschenk, Doug Cook, Wendy Hebron, Karin Koch, David Fleming, John Purdie, Renee Lewry, Anna Guerney, Terry Carless and affiliated specialists. Dr John Stanisic (malacologist) was Project Leader.

As far as is known this is the first such comprehensive survey of the invertebrate fauna of a major Australian city or town yet undertaken. A somewhat smaller scale project using more restrictive collecting techniques and fewer invertebrate groups was carried out on the coastal plain surrounding Perth some years ago (Harvey *et al*. 1997).

OBJECTIVES OF THE TISR

The primary objectives of the TISR were to:

- identify and assess the key elements of the invertebrate fauna of Brisbane City through the study of selected bushland sites;
- identify the major terrestrial invertebrate faunal habitats within the subset of selected study sites;
- describe key terrestrial invertebrate faunal groups in terms of species richness and abundance, and identify any significant species within these study sites;
- provide data for inclusion in BCC's Wildlife database;
- identify the location of significant terrestrial invertebrate species within the study sites;
- identify management issues for invertebrates in the study sites and make recommendations to address these issues; and
- make recommendations for future surveys and monitoring in Brisbane.

BACKGROUND

South-east Queensland is the fastest growing region in Australia. The pressures of this rapid development are causing local authorities to carefully re-assess the quantity and quality of 'green space' needed for perpetual retention. Environmental levies have been introduced by a number of councils to assist with financing the conservation and management of what green space there is left. In most cases the prioritisation of lands for conservation, often involving buy-back, involves assembling a detailed inventory of the biodiversity values that can be assigned to each patch of bushland. In the past this process has been almost exclusively based on flora and vertebrate fauna. However, many patches are too small to be inhabited by resident numbers of significant vertebrates. In the longer term there is also the need to consider how best to mange this biodiversity through monitoring the well being of the biotic communities that comprise this green space. Again vertebrates are not an ideal group for this process.

Yet the value of remnant bushland patches to the urban domain is rarely beyond dispute. In these instances, invertebrates-the little things that run the world and the other 99% of the Animal Kingdom-can provide very useful information on both the significance and ongoing health of these systems.

Environmental Setting

The Brisbane City bushlands have been identified as home to a range of significant flora and vertebrate fauna species. Geologies and landform range from alluvial floodplains to isolated volcanic mountain-top refugia. This physiographic diversity, combined with extensive floristic diversity, comprises those elements that also lend themselves to the diversification of invertebrates. Diversification that often exhibits local patterns of endemism at both the guild (invertebrate community) and individual species levels. But almost nothing is known of this diversity and its status in regard to the overall health of the bushlands.

SCOPE OF THE TISR

The TISR was not intended to be a comprehensive survey of all the invertebrates within Brisbane City. Nor was it meant to be a survey of all the invertebrates collected within the selected study sites. Such projects would take many more episodes of collecting to complete and many more hours of sorting and identification. The focus of this study was on assessing biodiversity, rare species and key ecological processes with a forward view to monitoring fluctuations both across the study sites and possibly within these sites, as they respond to urban environmental impacts such as development, pollution and fire.

Major Issues

The use of invertebrates in environmental survey has yet to receive universal acceptance among land and conservation managers. Invertebrates do present a number of logistic problems when compared with vertebrates. Both the collection and analysis of invertebrate data are an order of magnitude removed from that associated with vertebrates.

In the first instance, the remarkable quantity of specimens that can be collected in a relatively short time presents a hurdle in regard to processing. Hundreds of species of any single group of insect (e.g. beetles, moths, ants) can be readily collected by applying the simplest of techniques. The application of substantial resources to sorting this material is a necessary and unavoidable ingredient in the process.

Secondly, identification, even to morphospecies, can be an impediment not readily overcome. So called parataxonomy still requires a knowledge base about a group of species that is not always available. Pictorial or written keys simply do not exist for most invertebrates. Hence, the involvement of relevant skilled specialists is essential and to some extent will determine the composition of target groups.

Thirdly, data analyses and interpretation of results need to be treated cautiously if their significance are not to be subsumed by the sheer volume of ‘information’ that can be gathered (compared to vertebrates) from any particular sample site. Baseline data (spatial and temporal), particularly for comparative studies of invertebrates in most Australian environments, is nearly always lacking. Therefore contextualising the fauna in terms of taxonomic or geographic importance may have little meaning. New species are not an oddity and lack of information on the distribution and habitats of many species of invertebrates in Australia makes terms such as local endemic, rare, endangered or vulnerable almost inapplicable. The absence of such a contextual framework necessitates a slightly different approach to that used with vertebrates. Species richness and local community composition rather than individual species seem more useful means of interpreting the significance of local and regional invertebrate biodiversity.

In essence, a practical approach using surrogate groups that are recognised bio-indicators, and for which associated collections and expertise are available, is required.

The value of any animal in environmental assessment is dependent on the quality of data about its distribution, biology and ecology. But, in the case of invertebrates even basic presence/absence records are lacking for most areas of Australia, not to mention urban areas which typically are not often the focus of biodiversity scientists. Invertebrate surveys of the scope needed to produce this data for urban areas have rarely been conducted, even at the global scale. Unfortunately then it would seem that invertebrates, while having great potential to tell us important things about our natural environment, are restricted in their use by a human knowledge gap. Yet there exists within museums and similar taxonomic institutions, a great deal of unpublished data on the distribution of invertebrates that can assist with their use in environmental management (Ponder 1999). More importantly museums also house the custodians of this data (curator/scientists) who in themselves possess a great deal of unpublished information on these animals.

The partnership between the QCB and BCC is therefore an important and seminal link in bridging the ‘knowledge gap’ about urban invertebrates and also ensuring a positive outcome in managing the biodiversity of Brisbane City. The BCC has provided the financial resource to support the project whilst the QCB has contributed a significant knowledge base.

METHODS

TARGET GROUP SELECTION CRITERIA

The criteria for using surrogate species in biodiversity assessment depends on their ease of identification to morphospecies (Cranston & Hillman 1992; New 1995; Hinkley & New 1997), their functional role in the ecosystem (Churchill 1997), their predictive and monitoring value (Halffter & Favila 1993) and their ability to demonstrate the presence of unusual communities (New 1995). Cranston & Trueman (1997) encapsulated the key attributes of indicator species by defining the role for such species as both environmental indicators and biodiversity predictors.

In this study, ants, spiders, ground beetles, sucking bugs, dragonflies, butterflies and land snails were chosen as surrogates for both total invertebrate biodiversity and as indicators of total environmental health. These groups of invertebrates have been shown to be cost effective 'tools' for rapid biodiversity assessment (Oliver & Beattie 1993, 1996); indicators of ecosystem function and key ecological processes such as decomposition, pollination and predation; and effective bio-predictors (Majer 1983; Halffter & Favila 1993; Majer & Beetson 1996; Andersen 1997a; Churchill 1997; Moritz *et al*. 2001). Ants in particular have been prominent in studies of the impacts of mining on the environment (Andersen 1990, 1993, 1997a,b; Majer 1984a,b, 1992; Majer *et al*. 1982; Majer and de Kock 1992).

The key ecological functions and processes that can be ascribed to the target groups can be summarised as follows:

- herbivory: *beetles, sucking bugs, butterflies*.
- propagule dispersal: *ants*.
- predation: *beetles, spiders, land snails, sucking bugs, dragonflies, ants*.
- pedogenesis: *ants, beetles*.
- decomposition: *land snails, sucking bugs, dung beetles*.
- food-sourcing: *all of the above*.

Due to the non-selective nature of some of the sampling methodology employed, a range of 'non-target' species was also collected. This 'collateral' material is held and maintained in the Queensland Museum and consequently, can also be studied in the future.

TARGET GROUPS

Order Araneida (Spiders)

Spiders are a very diverse (potentially around 400 species per site) and environmentally informative group that are easily sampled and identified. Three groups are highly informative. The first group comprises the Mygalomorphae which includes the burrowing Trapdoor and Funnel-web spiders. These spiders may live for up to 20-25 years and hence are sound indicators of the long term environmental health of an area. They are present in all seasons and adults can usually be located. Mygalomorphs also show high degrees of local endemicity and hence are highly informative about recent vegetation history, disjunctions and connections. The second group are the Ant spiders (Zodariidae) which also have been found to be highly useful in identifying regional significance. And the third group comprises litter spiders which are minute and tend also to be endemic to small areas. The QM, through past collecting programs, has significant collections of spiders from Daisy Hill State Forest, Upper Brookfield, Gold Creek Reservoir and Karawatha Forest. These collections provide an additional basis for placing the BCC survey material into local context.

Order Hymenoptera: Family Formicidae (Ants)

Ants are ubiquitous, abundant and diverse. They are active to some extent in all seasons, allowing regular sampling throughout the year. Most species forage on the ground and can be easily and quantitatively sampled using pitfall traps. Excellent identification keys are available to the generic level. Species identifications are, by necessity, "parataxonomic" for many genera. However in some groups, such as *Polyrhachis*, species identifications are possible.

Surveying ants may provide insight into the negative impacts of introduced species. This is particularly relevant given the recent introduction of the Red Imported Fire Ant, *Solenopsis invicta*, which if not eradicated, is likely to have negative impacts on native invertebrates. Other introduced, tramp species of ants, e.g. the Coastal Brown Ant, *Pheidole megacephala*, have also been implicated in the exclusion of native species. The presence of introduced tramp species of ants can indicate levels of disturbance. Ant communities have been demonstrated to change significantly when environmental conditions are altered and monitoring ants is widely used to assist in developing natural resource management strategies. A substantial collection of named ants of the genus *Polyrhachis* is available for the Brisbane City area at the QM. Databased survey collections of ants from Karawatha Forest Park and the Doolandella area are also available.

Order Coleoptera: Scarabaeinae (Dung Beetles)

The dung beetles have been chosen as a global biodiversity survey group and have been targetted under the Australian Biological Resources Study's OZCAM project for national databasing in Australia. They are easy to survey and identify. The different species are segregated according to soils and vegetation type. They are linked to vertebrate faunas by virtue of their diet of vertebrate dung and thus have potential as surrogates for the vertebrate fauna. Substantial collections for the Brisbane City area are already available at the QM. An extensive database of about 50,000 specimens of Queensland dung beetles is maintained and this allows the Brisbane fauna to be placed into regional context.

Order Coleoptera (Ground Beetles)

The beetles comprise the most diverse group of insects and a large proportion of this fauna lives in the litter and upper soil layers. Much of this fauna is flightless and thus tends to show small distributions and relict patterns due to low dispersal powers. The QM holds large collections of ground beetles. Certain components of these, such as groups of darkling beetles (F. Tenebrionidae) and predatory ground beetles (F. Carabidae) are databased, providing some preliminary context for the Brisbane City survey.

Order Hemiptera (Sucking Bugs)

The sucking bugs are a diverse group of insects, most of which feed by sucking plant sap, both from the green, above-ground parts of plants and from roots and seeds in the soil/litter layer. Most sucking bugs are reasonably host specific regarding the plant species utilised and thus they have potential as vegetation surrogates. The QM already holds a substantial collection of sucking bugs from the Brisbane area. One family, the fungus-feeding Aradidae, has been specialist sorted and databased, and is available to place the Brisbane survey collections in regional context.

Order Lepidoptera: Papilionoidea & Hesperioidea (Butterflies)

Because of their conspicuous behaviour and attractive colours the butterflies are a high profile group with the public and there have been various campaigns aimed at encouraging the public to modify their gardens to attract and breed butterflies. The butterflies are also very well studied and easy to identify. Most species breed on a limited range of food-plant species and thus the butterflies are linked to characteristics of the overall vegetation. For these reasons the butterflies are a desirable survey target group. The QM holds a moderate collection of butterflies and there is also a large amount of published literature which deals with local butterflies.

Order Odonata (Dragonflies and damselflies)

The taxonomy of Australian dragonflies is well known and the species are easily identified. Their immature stages are aquatic predators and dragonflies have proven to be useful indicators of the health of freshwater habitats. However, an effective survey of the dragonfly fauna of a site is difficult given that many species are rapid, agile fliers and difficult to capture and other species may not fly far from their aquatic larval habitats. The QM holds a small collection of dragonflies with limited numbers of specimens from the Brisbane area.

Class Gastropoda (Land Snails)

Land snails are significant indicators of both environmental health and biodiversity hotspots. The QM has the largest Australian database of this terrestrial invertebrate group. Brisbane City has a number of land snail species (approx 25-30) associated in various combinations with specific habitat types. The QM database of land snails (approx 180 000 specimen records) includes many records from the Brisbane area. In addition the collection comprises material from most parts of Australia, but in particular, the east coast region.

All eastern Australian land snails in the QM collections are databased and identified to putative species. All undescribed species have been assigned to a family and given an alpha-numeric descriptor eg. Helicarionidae SQ 5. This code number refers to undescribed species but identified as such in the QM collections. These collections are based on material from more than 2500 sample sites in eastern Australia and comprise approximately 180,000 specimens representing more than 1200 species (about 900 undescribed) from coastal and subcoastal eastern Australia. While this probably does not represent the total fauna in this region the comprehensive coverage allows almost all east coast species to be readily placed in local, state and national context. This provides a strong context against which to compare the BCC survey results.

Other Invertebrate Groups

Material representing invertebrate groups other than those outlined above will be stored and maintained in the QM collections pending the future availability of resources for their study. These resources include both financial assistance and available expertise. Groups such as isopods (slaters) and myriapods (millipedes and centipedes) featured strongly in the survey 'catch' but currently lack the available local expertise necessary for their study.

STUDY SITES

Ten sites, covering a broad range of environments were selected for survey in this study. Choice of sites was made by BCC staff following advice from QCB scientific personnel. Because of the lack of any prior surveys, and in order to contextualise the local significance of the invertebrate fauna, site selection aimed specifically at incorporating a broad range of native vegetation communities. The sites surveyed and the location of collecting areas within these sites is provided in Table 1. Some sites e.g. Belmont Hills were floristically diverse but care was taken to ensure that collecting was confined, as much as possible, to a specific ecosystem within each site. Invertebrates show extremely localised distribution patterns compared with vertebrates and the integrity of data, especially for comparisons between broadly similar sites, can be compromised by ignoring dramatic small scale changes in ecosystem structure.

Locality Descriptions

The relative locations of the TISR study sites are shown in Map 1.

Karawatha Forest Park

Karawatha Forest is a large area of 642.5 hectares of bushland located at the southern boundary of the City of Brisbane. The forest is one of the last remaining remnants of what was once a large and continuous tract of 'green belt' and is one of the most biodiverse areas in the City. The forest forms an important buffer between Brisbane and other local authorities.

Karawatha Forest is both geologically and biologically significant and supports a unique combination of habitats within Brisbane City. Rocky sandstone outcrops overlaying Triassic coal measures that form part of the Ipswich coalfields. Floristically the forest contains communities once more widespread in the sub-coastal hills of southern Brisbane. Of particular significance are the *Eucalyptus planchoniana* and *E. baileyana* associations of the sandstone ridges, the heath communities with emergent *E. carnea* and the *E. seeana* dominated communities.

The unusual combination of habitats supports many native vertebrate animals that were once also common in the Brisbane City area. This fauna has been identified as significant in both a local and regional context (EDAW 1996a).


Karawatha Forest Park


Illaweena Street, Karawatha Forest Park

Two study sites, Karawatha Forest Park and Illaweena Street, were located within this bushland reserve.

North East Wetlands

The North East Wetlands represent approximately 1700 hectares of freshwater wetlands, tidal wetlands and low lying terrestrial lands on the north-eastern boundary of Brisbane City. The wetlands comprises four core areas consisting of the Tinchi Tamba Wetlands, the Deagon Wetlands, the Boondall Wetlands and the Kedron Brook Wetlands.

The Boondall Wetlands is an area comprising approximately 655 hectares bounded roughly by Cabbage Tree Creek in the north, the Gateway Motorway and Nudgee Road in the south. It is contiguous with the Kedron Brook Wetlands. The Boondall Wetlands comprises a mosaic of vegetation types ranging from eucalypt and *Melaleuca* woodlands to grasslands and tidal flats. The area is seasonally inundated (Wood *et al*. 1991; WBM 1999a, b).

One study site was located within the Boondall Wetlands.

Boondall Wetlands

Belmont Hills Bushland Reserve

Belmont Hills is located in the urban-dominated, middle and lower reaches of the Bulimba Creek Catchment, which runs in a generally northerly direction through the southern and eastern suburbs of Brisbane. The Belmont Hills Bushland Reserve plays an important role in the natural headwaters draining into Bulimba Creek. The Belmont Hills are elevated ranging to a height of 105m AHD. The geology includes metamorphosed sedimentary rocks.

Belmont Hills Bushland Reserve

Vegetation communities within the area are diverse and include heath, rainforest, eucalypt open forest and woodland, and riparian communities. The area also supports dry rainforest and is typical of some of the original lowland vegetation found throughout south-east Queensland.

The existing Belmont Scrub has been identified as hickory wattle woodland. A number of locally significant plant species have been found within the area. Eleven fauna species (vertebrates) have been identified as significant or noteworthy at local, State or national levels (BCC 2003).

Bulimba Creek

Two study sites were located within the area. One in the woodland communities of Belmont Hills and another along Bulimba Creek adjacent to Old Cleveland Road. The

Bulimba Creek site comprised true riparian vegetation including Flooded Gums (*Eucalyptus grandis*) and an adjacent low ridge of eucalypt woodland with *Alloasuarina littoralis*. A number of introduced plant and tree species were also present.

Brisbane Koala Bushlands

The Brisbane Koala Bushlands (BKB) are located about 20km south of Brisbane and comprise a mosaic of 800 hectares of council managed lands supporting a diverse range of landforms and biotic habitats. These bushlands are part of a larger regional area of significant habitat which includes an additional 2000 hectares stretching across three local jurisdictions. The majority of the BKB is underlain by lithic sandstones and the carbonaceous deposits of the Tingalpa Formation. The soils of the area are largely infertile with exception of the alluvial soils of the waterway margins (BCC 2000).

The vegetation of the BKB has particular regional significance as containing remnants of communities once more widespread in southeast Queensland. Floristically the BKB is comparatively megadiverse with 25 vegetation communities recognised containing more than 200 plant and tree species. Five core bushland areas have been identified within the BKB and these have high conservation significance. They comprise Mt Petrie Section, J.C. Trotter Memorial Park, Tingalpa Creek, Buhot Creek and Priests Gully. Six major vegetation alliances have been mapped within the BKB and comprise Scribbly Gum open forest and woodland; mixed eucalypt; Melaleuca open forest; Brush Box open forest, Riparian and regrowth (BCC 2000).

The BKB were mainly established as Koala habitat but contain a diverse vertebrate fauna. Of the approximately 618 species recorded for Brisbane City, 279 occur in the BKB.

Buhot Creek

One study site situated along Buhot Creek was located within the BKB.

Bayside Parklands

The Bayside Parklands are located 16 km east of the Brisbane CBD immediately south of the Brisbane River. They are a ribbon of natural area reserves situated along the foreshores of Moreton Bay and stretch from Whyte Island in the north to Lota and Tingalpa Creeks in the south.

The southern precinct is situated south of Lota and mainly to the west of Tingalpa Creek and contains a number of bushland, wetland and tidal ecosystems. Among the bushland systems are included the Chelsea Road and Ransome Reserves situated in Ransome. These are both areas of native woodland that exhibit a small degree of human disturbance. They are important elements in the parklands corridor and are home to significant vertebrate species including the Koala and Powerful Owl (EDAW 1996b).

Chelsea Road Reserve

Chelsea Road is largely *Eucalypus tereticornis* woodland with grass understorey in the lower portions giving rise to ironbark woodland on the ridges. Ransome Reserve exhibits an ecotone of *Casuarina glauca* giving rise to stands of *Corymbia tessellaris*. *Melaleuca* swamps inhabit the lowlands (EDAW 1996b).

Two study sites were located in the Bayside Parklands, one in each of the Chelsea Road and Ransome Reserves.

Brisbane Forest Park

The Brisbane Forest Park (BFP) is the largest protected area adjacent to a capital city in Australia and features a wide range of landforms (foothills to mountain tops), geologies (floodplains to volcanic rocks), vegetation (open woodland, through tall open forest to closed subtropical rainforest) and significant fauna (e.g. Tiger Quoll, Mount Glorious Torrent Frog, Platypus, Mt Glorious Spiny Crayfish). Much of the area has suffered from major disturbance in the past including logging and bushfires.

Gold Creek

Boombana National Park

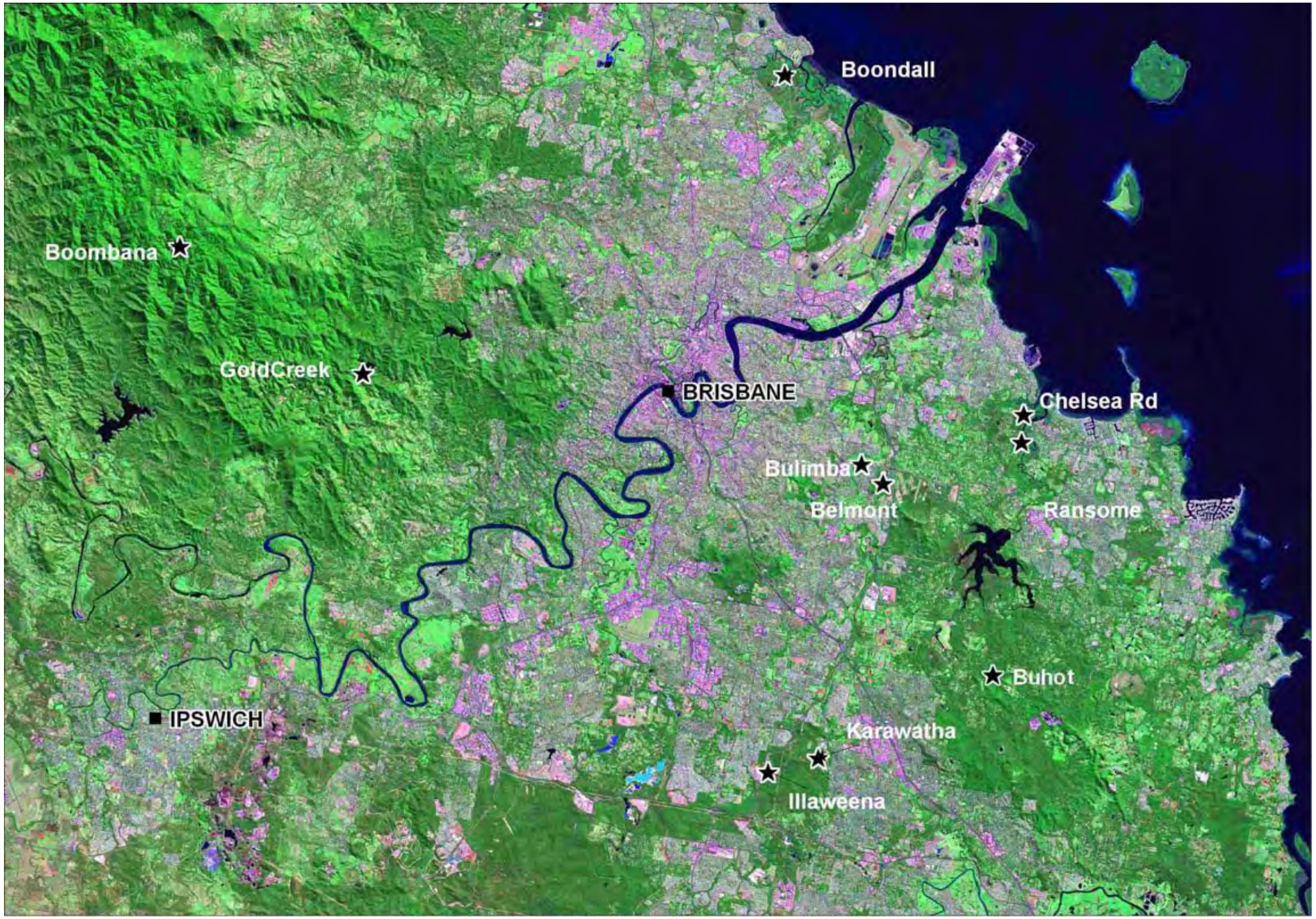
Two study sites were located within the BFP, one in the Gold Creek Reservoir Reserve while the other was situated in Boombana National Park (now part of the larger D'Aguilar Range National Park).

Site Descriptions

Within each site a polygon was selected to represent a particular vegetation community (regional ecosystem) for survey. Pitfall trapping and other survey work was carried out only within this area. Table 1 lists the location of the sites chosen for the study together with a general vegetation descriptor of the polygon in which the site was located. Aerial photographs of all sites are presented in Appendix 1.

TABLE 1. BCC study sites and selected vegetation communities. (Datum: AGD 66).

Survey Site	Vegetation Community	Co-ordinates
1. Buhot Creek	Riparian	27º 35' 27"S, 153º 10' 19"E
2. Boombana National Park	Subtropical rainforest	27º 24' 07"S, 152º 47' 23"E
3. Boondall Wetlands	Melaleuca woodlands	27º 20' 21"S, 153º 04' 27"E
4. Gold Creek Reservoir	Mixed dry eucalypt open forest	27º 27' 53"S, 152º 52' 32"E
5. Illaweena Street	Scribbly Gum dry woodland with grass/heath understorey	27º 38' 39"S, 153º 03' 47"E
6. Karawatha Forest Park	Mixed dry eucalypt woodlands	27º 37' 33"S, 153º 05' 24"E
7. Ransome Bushland Reserves	*Casuarina glauca* ecotone	27º 29' 34"S, 153º 11' 05"E
8. Chelsea Road Bushland Reserve	Coastal ironbark open forest	27º 28' 58"S, 153º 11' 15"E
9. Bulimba Creek	Forest Red Gum on river flats	27º 30' 09"S, 153º 06' 34"E
10. Belmont Hills Bushland Reserve	Mixed dry eucalypt woodland	27º 30' 47"S, 153º 07' 05"E



Map 1. The location of the TISR study sites in relation to the Brisbane 'urban footprint'. [Map: Geoscience Australia © Commonwealth of Australia (Geoscience Australia) 2004].

SURVEY

Timing

The field survey was begun in April 2003. Collecting at Boombana National Park was delayed until September 2003 because of entry issues. Weather conditions during the year of the survey were typical with a hot mainly dry summer and cooler, dry winter. Summer rains occurred intermittently in January, 2004 otherwise rainfall was light and sporadic. The summer rains caused the pitfall traps in the seasonally inundated Boondall Wetlands to be relocated due to area flooding. The collection and trapping details of the survey are summarised in Table 2.

TABLE 2. Summary of sampling techniques and effort as carried out on the BCC sites in the current study.

	SITE[1]									
SAMPLING METHOD	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**
Pitfall traps (trap days)	1890	1670	1865	1885	1890	1890	1895	1895	1895	1895
Dung-baited pitfall traps (trap days)	6	6	6	6	6	6	6	6	6	6
Day hand-collecting (person hours)	9	9	9	9	9	9	9	9	9	9
Night hand-collecting (person hours)	6	6	6	6	6	6	6	6	6	6
Sweeping (person hours)	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Pyrethrum knockdowns (samples)	4	4	4	4	4	4	4	4	4	4
Hand-netting (person hours)	6	6	6	6	6	6	6	6	6	6
Litter berlesate (litres per site)	9	9	9	9	9	9	9	9	9	9
Land snail collecting (person hours)	9	9	9	9	9	9	9	9	9	9
Litter for snail sorting (litres per site)	6	6	6	6	6	6	6	6	6	6

[1] Site numbers refer to site list in Table 1.

Methodology

As with vertebrates, invertebrates require the application of a number of different techniques for sampling. None of these techniques involve any major expenditure of resources. These techniques are varied but can be tailored to meet specific collecting outcomes given knowledge of the local invertebrate fauna and expectations in regard to the groups that are to be sampled. In the case of the current survey, the major objective was to gain a representation of the targeted groups and hence, a broad, though not exhaustive range of techniques was applied. Pitfall traps formed the mainstay of the survey and were cleared on a monthly basis. These targeted ants and spiders but also captured a range of other ground dwelling arthropods. Hand-collecting, sweeping, pyrethrum knockdown and leaf litter extraction were employed to broaden the range of microhabitats sampled. Two additional techniques (dung traps and netting) specific to particular insect groups were also applied. An outline of these procedures is given below.

Pitfall traps

The following pitfall trap methodology was employed to sample ground active invertebrates, particularly ants, ground beetles and spiders. At each site, five pitfall traps were installed in a more or less straight transect line with each trap approximately 5m apart. At most sites the first trap of the line was situated at least 10m from the road in order to reduce edge effects.

Each pitfall trap consisted of a two litre plastic ice-cream container 9cm deep, with an attached lid that had an approximately 11x11cm square hole cut in the top. Each trap was sunk into the ground so that the surface of the lid was flush with the soil surface. Propylene glycol (a non-evaporative preservative and low in toxicity to mammals) was poured into each trap to an approximate depth of 1cm. The propylene glycol contained a bittering agent, Bitrex®, which makes it distasteful to vertebrates. Each trap was covered by a rectangular, fibreglass 'roof', 30cm long x 18cm wide and approximately 3cm high. This 'roof' excludes rain, preventing dilution of the preservative, and also prevents certain vertebrates, such as larger frogs and reptiles, from falling into the traps. Pitfall traps were cleared on a monthly basis.


Pitfall Trap


Dung-baited Pitfall Trap

Dung-baited pitfall traps

Dung-baited pitfall traps were specifically employed to sample dung beetles at each site. However, these traps also operated as short-term pitfall traps and did catch some ground active invertebrates. Two traps were employed at each site for 24 hours on three separate occasions.

The dung traps consisted of the same container and lids used for the pitfall traps. Water, with a small amount of detergent added, was poured into the container to a depth of approximately 2cm. The bait consisted of a ball of frozen wallaby dung, approximately 4cm in diameter, wrapped in a layer of kitchen cloth. The bait was suspended on the end of a twig, over the mouth of the container. As the bait thawed, the odour produced by the dung, attracted dung beetles which fell into the fluid. Traps were installed in mid to late afternoon and emptied mid to late morning the following day, ensuring that diurnal, nocturnal and crepuscular dung beetles were sampled.

Day hand-collecting

Hand collecting of insects and spiders was carried out for three person hours per site within a 100m radius of the pitfall trap transect. Of this time, 30 minutes was particularly concentrated on collecting ants by turning logs and looking for nesting sites and by scanning tree trunks for foraging workers. Day hand collecting was carried out at each site in April, November 2003 and February, 2004.


Day hand collecting at Karawatha Forest

Night hand-collecting

Night hand collecting of insects and spiders was carried out for three person hours per site within 100m radius of the pitfall trap transect, on two occasions in November and December 2003.

Pyrethrum knockdown

Pyrethrum knockdown samples (whereby insect spray is used to dislocate invertebrates from vegetation) were rtaken from all sites. Four knockdown samples were taken per site.

Sweeping

At each site, vegetation of low and medium heights was swept for 15 minutes with a fine mesh (silk screen printing material) hand net with a handle length of 75cm and an internal hoop diameter of 36.5cm. The products of sweeping were preserved in 70% ethanol and all the arthropods from each sample were later separated from the swept vegetative material. Sweeping samples were taken from each site in April, November 2003 and February, 2004.

Hand Netting

At each site, insects, particularly flying insects, were hand collected for two person hours, using an approximately 1mm square mesh net with a handle length of 120cm and an internal hoop diameter of 43.5cm. Particular groups of insects targeted included butterflies and dragonflies. Hand netting was carried out at each site in April, November 2003 and February, 2004.


Hand Netting

Leaf Litter Berleseates

Approximately three litres of sieved leaf litter were collected from each site. Litter was not collected at random. Areas with a thick layer of litter were targeted. In these areas, leaf litter was moister and more likely to contain greater numbers of invertebrates. Each leaf litter sample was treated in a Berlese Funnel where light and heat were used for about eight hours to drive invertebrates into a collecting jar filled with 70 % ethanol. Leaf litter was collected from each site in April, November 2003 and February, 2004.

Land Snail collecting

Most of the techniques outlined above are particularly useful for arthropods but not land snails for which a slightly different approach is required. In contrast to the comparatively active and swift moving arthropods, land snails tend to be less active and largely nocturnal. Trapping is not possible without the use of toxic baits. Sampling is focussed on searching the preferred habitats of snails (chiefly under logs, fallen bark, rocks and other debris (rarely arboreal). Land snails can also be sampled *post mortem* because their shells (as an indication of presence) remain intact in the litter long after their death. Hence, litter sorting for shells is an effective and largely non-destructive technique for gaining an insight into local snail diversity.

Typical land snail microhabitat

Collecting techniques for land snails comprised searching known microhabitats eg. under logs, rocks and other forest debris, for approximately three person hours per site. Both live snails and dead shells were collected. At each site, approximately three litres of litter were collected from around the base of trees where bark accumulation was greatest and from around the base of fallen logs where forest debris accumulates over time. Two lots of searching and litter collections were conducted per site.

RESULTS

ANTS OF BRISBANE CITY

To summarise the sampling program for ants, 27 samples were collected at each of the 10 sites over the course of a year: 12 monthly pitfall trap samples; 3 day hand collections; 2 night hand collections; 3 sweeping samples; 4 pyrethrum knockdowns and 3 berleseate leaf litter extractions. All 270 samples contained ants.

Ants from all samples were processed and identified to species. Where possible, taxa were identified as described species using the published literature. However, modern taxonomic revisions are unavailable for numerous Australian ant genera and though many of the taxa collected during this survey are probably described, it was difficult to associate them with their correct identities. Consequently, these taxa were assigned species codes, for example *Pheidole* QM.1, *Pheidole* QM.2 etc. In general species limits were conservatively interpreted and some are probably comprised of two or more species, particularly in genera such as *Hypoponera*, *Pheidole*, *Solenopsis*, *Crematogaster* and *Iridomyrmex*. Future collections, targeting large nest series may help to resolve the species limits in these intractable genera. A voucher collection of more than 5000 pinned and databased ants, representing all species collected during the survey, is housed in the Queensland Museum. The generic classification used here largely follows Shattuck (1999) with some modifications (see Bolton 2000, Fernandez 2004), while subfamily classification follows Bolton (2003).

Pitfall trap, pyrethrum knockdown, berleseate and sweeping samples were treated quantitatively, i.e. the numbers of specimens of each ant species in each sample were recorded. Day and night hand collecting samples were treated qualitatively, i.e. only the presence of each species in a sample was recorded. Numbers of specimens collected during bouts of hand collecting were not considered useful because ant nests or foraging trails were targeted and large numbers of specimens of a particular species could be collected in a short time. Consequently, numbers of specimens taken during hand collecting were not an effective measure of relative abundance.

Ant data was converted to presence/absence to enable all species counts from all methods to be pooled. Species richness counts for site comparisons were based on this pooled data. Ant assemblages were compared amongst sites using multidimensional scaling ordination (MDS) with the PRIMER computer package (Plymouth Marine Laboratory 2002).

Figure 1. Live representatives of ants from the subfamilies Myrmeciinae (a, b); Ponerinae (c); Pseudomyrmecinae (d) and Myrmicinae (e). **a.** Jumper Ant, *Myrmecia nigrocincta* worker. **b.** Giant Bull Ant, *Myrmecia brevinoda* worker. **c.** Green Head Ant, *Rhytidoponera metallica*. **d.** *Tetraponera punctulata* workers with caterpillar. **e.** *Podomyrma* QM.3 worker. [not to scale].

Figure 2. Live representatives of *Camponotus* ants (Formicinae), the second most diverse genus recorded in the survey. **a.** *Camponotus consobrinus* major worker. **b.** *Camponotus consobrinus* minor and major workers. **c.** *Camponotus eastwoodi* major worker. **d.** *Camponotus eastwoodi* minor workers with brood. **e.** *Camponotus nigriceps* major worker. **f.** *Camponotus nigriceps* minor worker. **g.** *Camponotus* nr *novaehollandiae* minor worker. **h.** *Camponotus* nr *novaehollandiae* minor workers with brood. [not to scale].

Figure 3. Live representatives of *Polyrhachis* ants (Formicinae), the most diverse genus recorded in the survey. **a.** *Polyrhachis ammon*. **b.** *Polyrhachis (Hagiomyrma)* QM. 1. **c.** *Polyrhachis euterpe*. **d.** *Polyrhachis rufifemur*. **e.** *Polyrhachis aurea*. **f.** *Polyrhachis australis*. [not to scale].

Figure 4. Live representatives of ants from the subfamily Dolichoderinae. **a.** Southern Meat Ant *Iridomyrmex purpureus*. **b.** *Dolichoderus extensispinus* worker. **c.** *Leptomyrmex varians rufipes*. **d.** *Technomyrmex* QM.1. **e.** *Ochtellus* QM.1 worker. [not to scale].

Overall species richness

Across all ten sites, the four quantitative sampling methods (pitfall, sweeping, pyrethrum knockdowns and berleseates) yielded 65910 ant specimens. If we conservatively estimate that each of the qualitative day and night hand collecting samples yielded an average of 100 ants, another 5000 specimens were collected, bringing the total number of ants examined during the survey to more than 70,000.

A total of 256 species of ants were recorded from 12 of the 13 subfamilies of Australian ants (Table 3, Figs 1-4). Only the Leptanillinae were not collected which are represented in Australia only by the genus *Leptanilla* (Shattuck 1999). The distribution of the 256 ant species across the ten sites is summarised in Appendix 2.

Myrmicinae and Formicinae were the most diverse subfamilies with 88 and 83 species respectively (Fig. 5). Dolichoderinae and Ponerinae were considerably less diverse with 33 and 19 species respectively. Other subfamilies were represented by a few species, Cerapachyinae 10, Ectatomminae 8, Myrmeciinae 6, Proceratiinae 4, Ambyloponinae 2 and Aenictinae, Heteroponerinae and Pseudomyrmecinae each with a single species.

A total of 65 ant genera were recorded (Table 3). The Myrmicinae was clearly the most diverse subfamily at the generic level with 26 genera (Fig. 6). Formicinae, Dolichoderinae and Ponerinae were also diverse with 10, 9 and 8 genera respectively. The other subfamilies were represented by one, two or three genera.

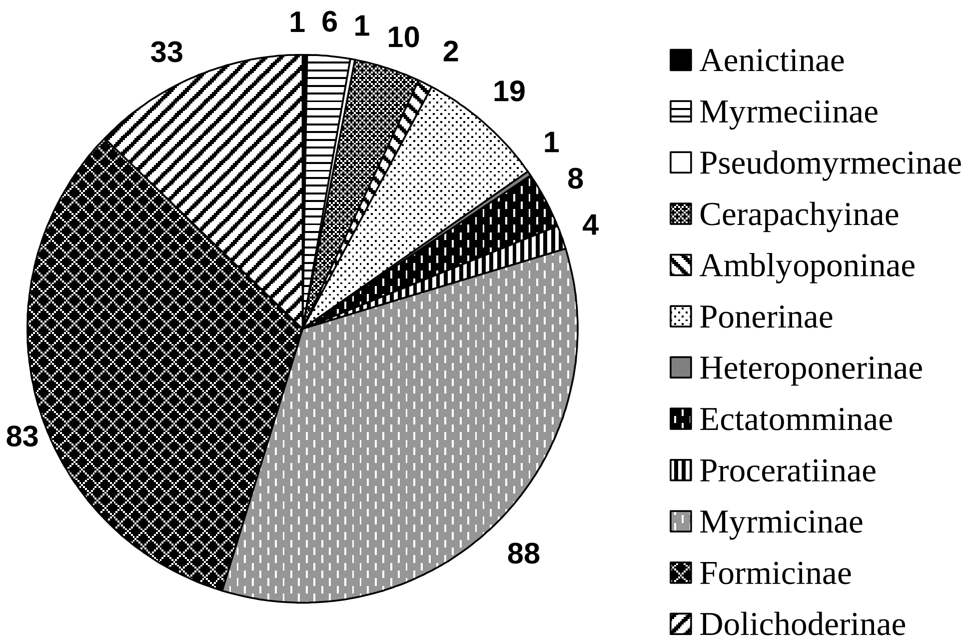


Figure 5. Subfamily composition of the 256 ant taxa recorded across all 10 sites.

According to the distribution maps of Shattuck (1999), 76 genera have previously been recorded from the extreme south-east corner of Queensland. Fourteen of these were not collected during the survey: *Doleromyrma*, *Turneria*, and *Froggatella* (Dolichoderinae); *Calomyrmex*, *Myrmecorhynchus*, *Pseudonotoncus*, *Notostigma*, and *Teratomyrmex* (Formicinae); *Leptanilla* (Leptanillinae); *Mesostruma*, *Metapone* and unnamed genus #3 (Myrmicinae); *Odontomachus* (Ponerinae); and *Onychomyrmex* (Amblyoponinae). However, three myrmicine genera not previously known from south-east Queensland were collected, *Calyptomyrmex*, *Peronomyrmex* and *Rhopalomastix*. Two other myrmicine genera, *Anisopheidole* and *Pyramica*, have also recently been found in south-east Queensland but were not collected during the survey. Therefore, a total of 81 genera of ants are known to occur in the south-east corner of Queensland and 80% of these were collected during the survey.

The majority of genera were represented by only one or a handful of species (Table 3). Only 13 genera were represented by five or more species, but together, they accounted for more than 65% of the total species collected. By far the most speciose genera were *Polyrhachis* (Fig. 3) and *Camponotus* (Fig. 2) (Formicinae) with 29 and 19 species respectively. Other diverse formicine genera included *Paratrechina* (8 spp.), *Stigmacros* (8 spp.) and *Melophorus* (7 spp.). Amongst the ponerines, *Leptogenys* and *Pachycondyla* were most diverse each with 5 species. *Podomyrma* (15 spp., Fig. 1e), *Pheidole* (10 spp.), *Monomorium* (13 spp.), *Crematogaster* (6 spp.) and *Strumigenys* (6 spp.) were the most speciose genera of Myrmicinae while *Iridomyrmex* (9 spp., Fig. 4a) and *Leptomyrmex* (6 species, Fig. 4c) were the most diverse Dolichoderinae. *Rhytidoponera* (8 spp. Fig. 1c), *Cerapachys* (8 spp.) and *Myrmecia* (6 spp., Figs 1a,b) were the most diverse genera amongst the smaller subfamilies.

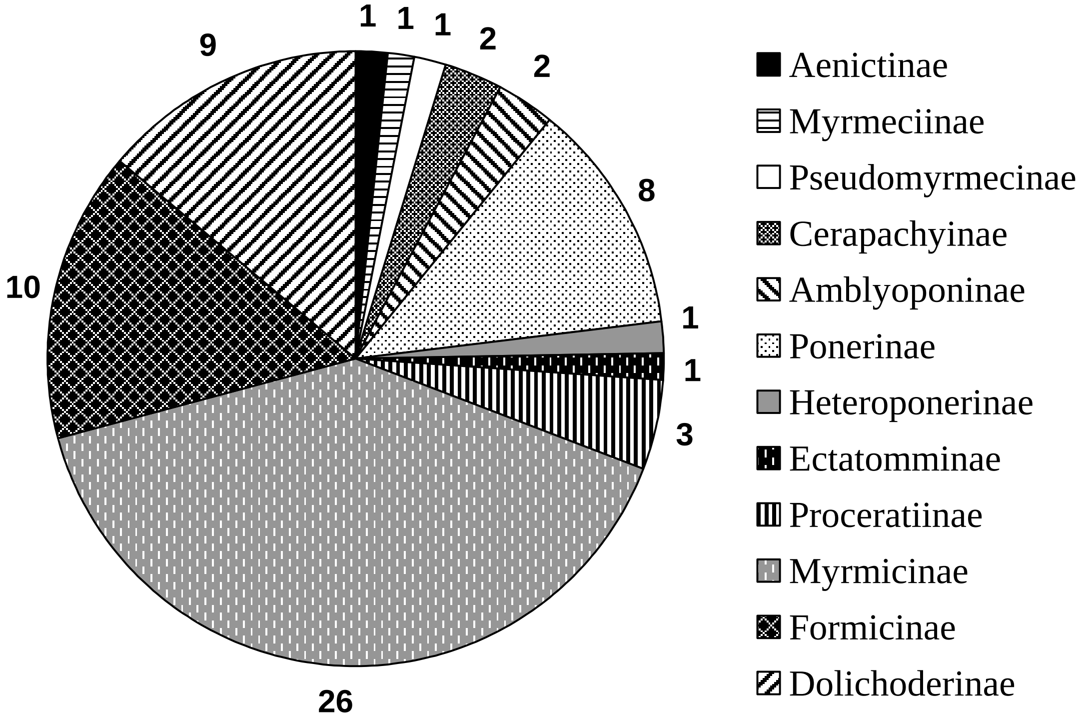


Figure 6. Subfamily composition of the 65 ant genera recorded across all 10 sites.

A particularly diverse ant fauna was found to inhabit bushland reserves within Brisbane City with 256 species recorded from 65 genera. At least another 25 ant species not recorded during this study are known to occur within the region, either in natural or highly disturbed habitats. Additional surveys, particularly of other rainforest sites, will undoubtedly increase the species inventory, and the true number of ant species in Brisbane is likely to exceed 300 and possibly 350. Estimates of the ant faunas of Australian metropolitan centres are mostly unavailable, but around 200 to 210 species are thought to occur in metropolitan Perth (Brian Heterick pers. comm.). A comparable number of species to that found by this survey, has been recorded from Danggali Conservation Park in eastern South Australia, where 248 species were collected in pitfall traps in eighteen 1km^2 plots covering a broad range of habitats (Anderson & Clay 1996). Arid and semi-arid Australia is known to support a very diverse fauna of ant species (Anderson 2003a), but its generic diversity is much lower compared to more mesic habitats. Only 32 genera were recorded from Danggali Conservation Park, less than half the number found in Brisbane.

Table 3. Number of species recorded from each of the 65 ant genera collected during the survey. Genera containing five or more species indicated in bold.

Genus	# spp.
AENICTINAE	
Aenictus	1
MYRMECIINAE	
Myrmecia	**6**
PSEUDOMYRMECINAE	
Tetraponera	1
CERAPACHYINAE	
Cerapachys	**8**
Sphinctomyrmex	2
AMBLYOPONINAE	
Amblyopone	1
Prionopelta	1
PONERINAE	
Anochetus	1
Cryptopone	1
Hypoponera	4
Leptogenys	**5**
Myopias	1
Pachycondyla	**5**
Platythyrea	1
Ponera	1
PROCERATIINAE	
Discothyrea	2
Probolomyrmex	1
Proceratium	1

Genus	# spp.
HETEROPONERINAE	
Heteroponera	1
ECTATOMMINAE	
Rhytidoponera	**8**
MYRMICINAE	
Adlerzia	1
Anillomyrma	1
Aphaenogaster	1
Calyptomyrmex	1
Cardiocondyla	2
Carebara	3
Colobostruma	4
Crematogaster	**6**
Epopostruma	3
Eurhopalothrix	1
Lordomyrma	2
Machomyrma	1
Mayriella	1
Meranoplus	4
Monomorium	**13**
Myrmecina	1
Orectognathus	2
Peronomyrmex	1
Pheidole	**11**
Podomyrma	**15**
Pristomyrmex	1
Rhopalomastix	1

Genus	# spp.
Rhopalothrix	1
Solenopsis	1
Strumigenys	**6**
Tetramorium	4
FORMICINAE	
Acropyga	2
Camponotus	**19**
Melophorus	**7**
Notoncus	3
Opisthopsis	2
Paratrechina	**8**
Plagiolepis	2
Polyrhachis	**29**
Prolasius	3
Stigmacros	**8**
DOLICHODERINAE	
Anonychomyrma	2
Bothriomyrmex	4
Dolichoderus	2
Iridomyrmex	**9**
Leptomyrmex	**6**
Ochetellus	2
Papyrius	1
Tapinoma	4
Technomyrmex	3
TOTAL GENERA	65
TOTAL SPECIES	256

Species of special significance

A number of native ant species recorded during the survey were notable because of their rarity in collections or because they represented substantial range extensions.

Probolomyrmex greavesi (Proceratiinae) [Fig. 7a,b]
The single Australian species of *Probolomyrmex*, *P. greavesi*, has been collected fewer than 10 times (Shattuck 1999). It has been recorded from rainforests in far northern Queensland and drier habitats in south-eastern Queensland and the ACT (Shattuck 1999). Recently *P. greavesi* was first recorded from the Northern Territory, from a single collection from open forest near Darwin (Anderson 2003b). A single dealate queen of *P. greavesi* was hand collected from leaf litter at Bulimba Creek in November.

Peronomyrmex overbecki (Myrmicinae) [Fig. 7c,d]
The endemic *Peronomyrmex* is one of the rarest genera of Australian ants. Until recently it was represented in collections by a single specimen, the holotype of *Peronomyrmex overbecki* from Trial Bay in northern New South Wales. Six specimens of an apparently new species were collected from the Clohesey River near Mareeba in north Queensland, but these were subsequently lost (Taylor 1991). In 1995 two specimens were collected from pitfall traps in Victoria and these were described as a second species *Peronomyrmex bartoni* (Shattuck and Hinkley 2002). A single *Peronomyrmex* worker that was hand collected at night from Ransome Reserve in November 2003, proved to be the second specimen of *P. overbecki* ever collected. This is the first record of the genus from south-east Queensland.

Rhopalomastix QM.1 (Myrmicinae) [Fig. 7e,f]
This rarely collected genus has been previously recorded in Australia from the Top End of the Northern Territory, the Wet Tropics in northern Queensland and once from near Yeppoon (Taylor 1991, Shattuck 1999). A single worker of *Rhopalomastix* was collected in a pitfall trap from Ransome Reserve in September 2003, and represents a significant southern extension of the range of the genus in Australia.

Rhopalothrix orbis (Myrmicinae) [Fig. 7g,h]
A single species of *Rhopalothrix* is known from Australia and is restricted to rainforests in the extreme south-east corner of Queensland and northern New South Wales (Shattuck 1999). *Rhopalothrix orbis* has been collected only a handful of times (Shattuck 1999). Ten specimens were extracted from leaf litter collected at Boombana NP in February and April 2004.

Calyptomyrmex QM.1 (Myrmicinae) [Fig. 8a,b]
Within Australia, ants of the genus *Calyptomyrmex* are rarely collected and are limited to rainforests in Queensland (Shattuck 1999). Taylor (1991) noted that there were at least eight Australian species, only one of which is described. Published collection records for Australian *Calyptomyrmex* are from northern Queensland, the most southerly from the vicinity of Mackay (Taylor 1991, Shattuck 1999). A single alate queen of *Calyptomyrmex* was hand collected during the day in November 2003 from Boombana NP. This represents a significant southern extension of the range of the genus in Australia.

?*Lordomyrma* QM.2 (Myrmicinae) [Fig. 8c,d]
A single specimen of this species was hand-collected at Boombana NP in November 2003. It runs to couplet 41 of Shattuck's (1999) key to the Australian genera of Myrmicinae, separating *Lordomyrma* from his 'unnamed genus #2'. However, the specimen from Boombana shares characters from each couplet. It has mandibles with 9 teeth or denticles, as in *Lordomyrma*, but it also has a flattened and spatulate apex to the sting as in 'unnamed genus #2'. The precise generic placement of this specimen is problematic but I have tentatively placed it within *Lordomyrma* for the present.

Stumigenys xenos (Myrmicinae) [Fig. 8e,f]
Two dealate queens of *Strumigenys xenos* were collected in pitfall traps, one from Illaweena Street in November 2003 and another from Bulimba Creek in January 2004. *Strumigenys xenos* lacks a worker caste and has previously been found only as an inquiline within the nests of *Strumigenys perplexa* in Victoria and New South Wales (Brown 1955, Bolton 2000). Both species have also been found in New Zealand where they are believed to be introduced (Taylor 1968). This is the first record of *S. xenos* from Queensland. Given that *S. perplexa* was not found at Illaweena Street or Bulimba Creek, it is possible that *S. xenos* may also live within the nests of the closely related *S. deuteras* that is present at both sites.

Polyrhachis euterpe (Formicinae) [Fig. 9a,b]
All species of *Polyrhachis* recorded during the survey were known from the Brisbane area except the rare *Polyrhachis euterpe* (R.J. Kohout pers. comm). Several specimens of *P. euterpe* were taken on the trunk of an ironbark tree at Karawatha Forest in April and November 2003 by day hand collecting and pyrethrum knockdowns. Previously *Polyrhachis euterpe* was known from a total of eight specimens from west of Mackay, west of Charters Towers, Marlborough and Jandowae, Queensland (R.J. Kohout pers. comm.).

Camponotus macrocephalus-group species (Formicinae) [Fig. 9c-h]
Several species belonging to the *macrocephalus* species-group of *Camponotus* were collected during the survey. The group contains arboreal species that are generally lignicolous, nesting in hollows in twigs and branches. The Australian species of the group were recently revised by Macarthur & Shattuck (2001).

Three species collected during the survey, *C. macrocephalus*, *C. gasseri* and *C. sanguinfrons*, are known from south-eastern Queensland (McArthur & Shattuck 2001). Another, *C. mackayensis* has been recorded only from the 'Top End' of the northern Territory and northern Queensland as far south as Mingela near Townsville (McArthur and Shattuck 2001). Several specimens of *C. mackayensis* were collected at Buhot Ck and Boombana NP, by hand during the day, sweep-netting and pyrethrum knockdowns. These are the first records of *C. mackayensis* from south-eastern Queensland and represent a significant southern extension of the range of the species.

Camponotus QM.7 (Fig 9c,d) belongs to the *macrocephalus*-group but does correspond with any of the species treated by McArthur & Shattuck (2001). It is either an undescribed species or a described species that has not been recorded from Australia. Four specimens of *Camponotus* QM.7 were collected in a pyrethrum knockdown at Gold Creek Reservoir in April 2003and a single specimen in a pitall trap in January 2004 from Karawatha Forest Park.

Two other 'species' of the *macrocephalus*-group were hand collected at night from rainforest at Boombana NP, *Camponotus* QM.14 (Fig. 9e,f) and QM.15 (Fig. 9g,h). Both run to *C. macrocephalus* in the key in McArthur & Shattuck (2001), however, they are quite different in appearance to other *C. macrocephalus* specimens collected during the survey. They may represent undescribed species.

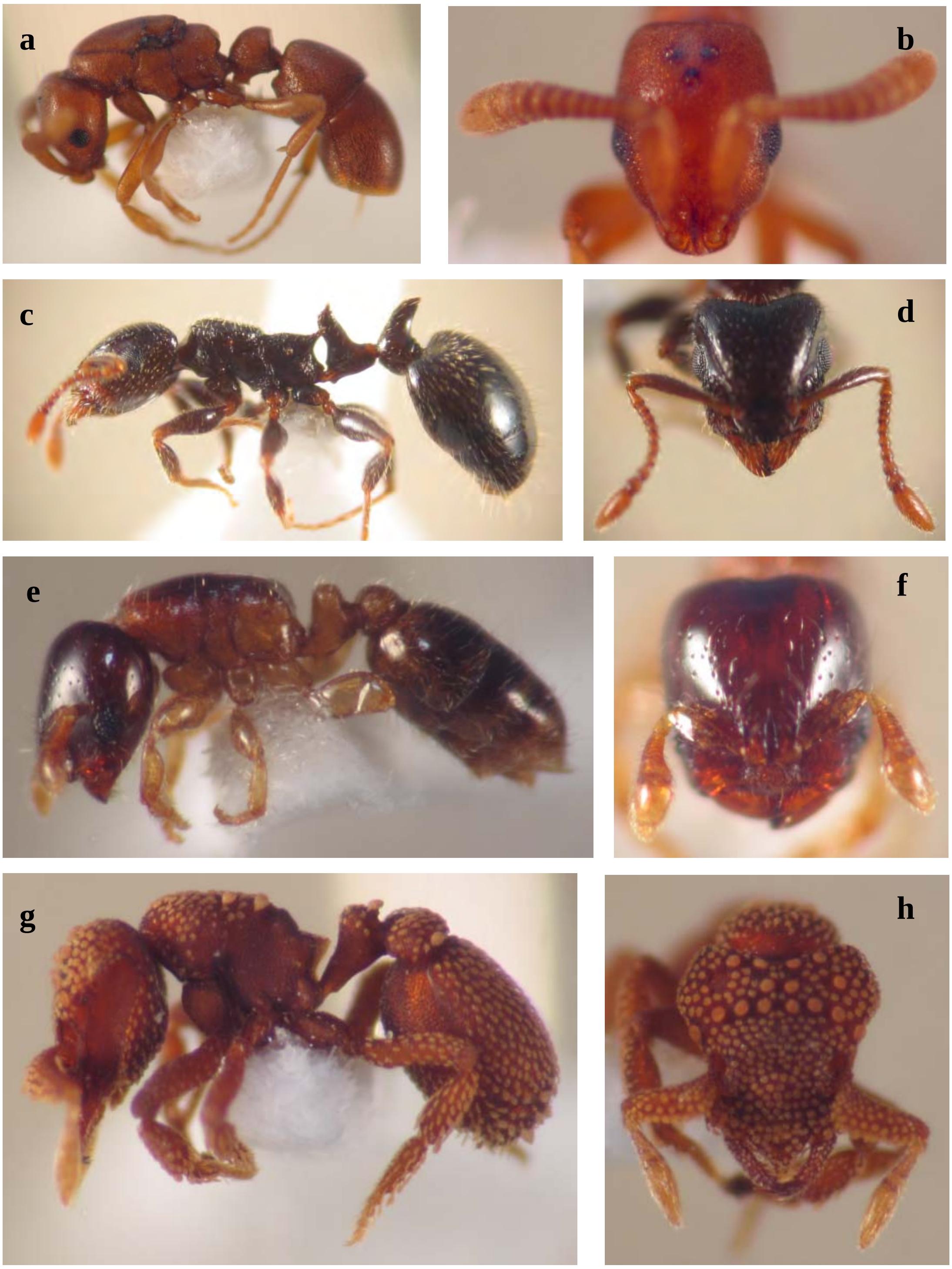


Figure 7. Species of special significance collected during the survey. **a, b.** *Probolomyrmex overbecki*. **c, d.** *Peronomyrmex overbecki*. **e, f.** *Rhopalmastix* QM.1. **g, h.** *Rhopalothrix orbis*.

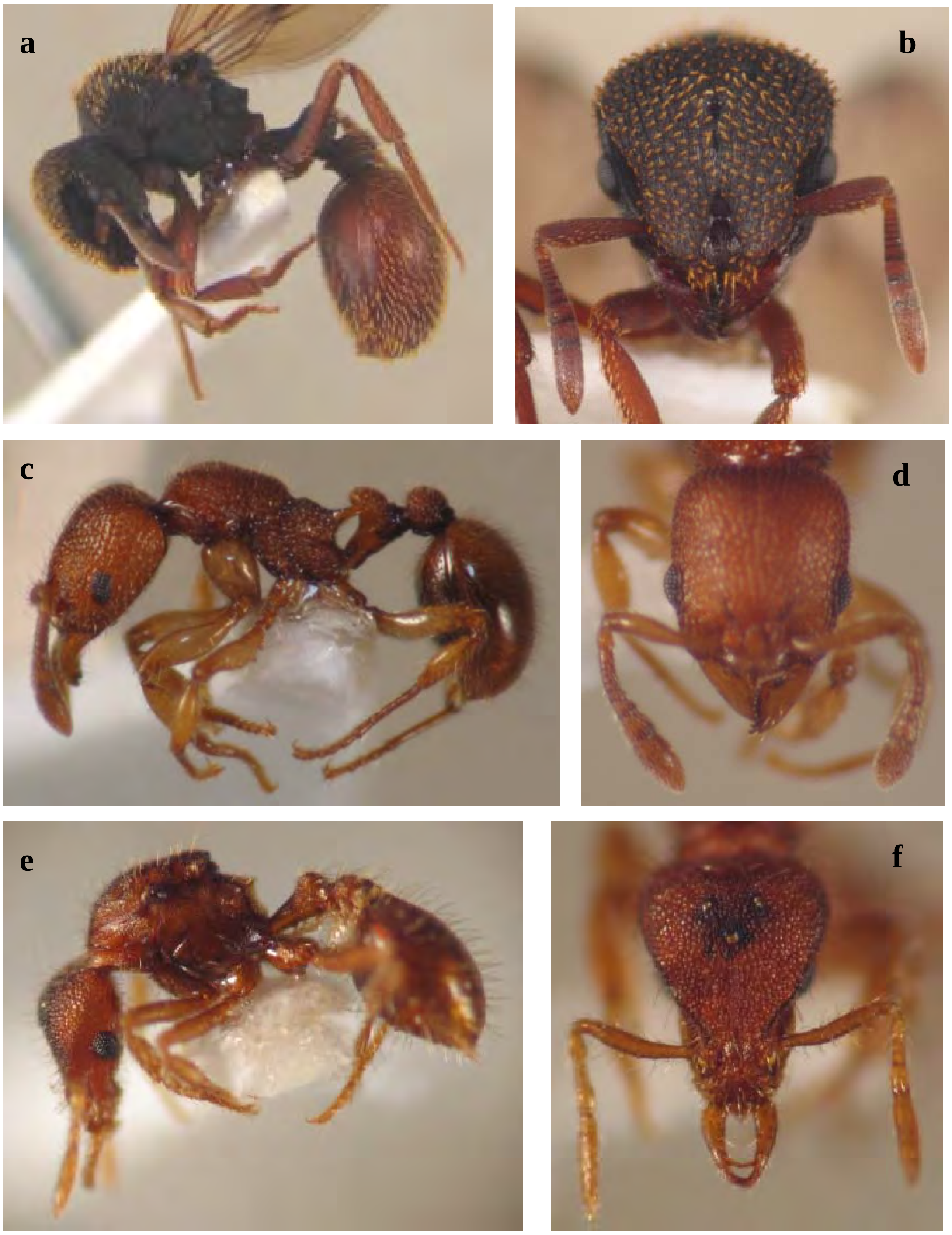


Figure 8. Species of special significance collected during the survey. **a, b.** *Calyptomyrmex* QM.1. **c, d.** ?*Lordomyrma* QM.2. **e, f.** *Stumigenys xenos*

Figure 9. Species of special significance collected during the survey. **a, b.** *Polyrhachis euterpe*. **c, d.** *Camponotus* QM.7. **e, f.** *Camponotus* QM.14. **g, h.** *Camponotus* QM.15.

Introduced species

Four species recorded during the survey, *Pheidole megacephala*, *Tetramorium simillimum*, *Paratrechina longicornis* and *Cardiocondyla wroughtoni*, are undoubtedly exotic (Taylor 1987). In the past, *Cardiocondyla nuda* has generally been regarded as introduced (Taylor 1987, Heterick *et al*. 2000). However it may be an Australian native as Seifert (2003) considered *C. nuda* restricted to Australasia and Polynesia. It is possible that other introduced species were recorded during the survey, but they could not be identified with confidence. We did not record the Red Imported Fire Ant, *Solenopsis invicta* from any sites, nor *Tetramorium bicarinatum*, a common introduced species in urban environments in Brisbane.

The distribution and relative abundance in pitfall traps of the four introduced species and *C. nuda* across the ten sites are presented in Table 4. Introduced species were present in low abundances (contributing less than 5% of the individuals collected in pitfall traps) at nine of the sites. The clear exception was Gold Creek Reservoir where introduced species made up more than 90% of the ants collected in the pitfall traps. The Coastal brown ant, *Pheidole megacephala* dominated the ant fauna at this site and was represented in all samples from all collecting methods. At Gold Creek Reservoir *P. megacephala* was ubiquitous, foraging during the day and night, in leaf litter, on tree trunks and on vegetation It was the dominant ground active species, making up more than 87.7% of the total ants collected in pitfall traps.

Paratrechina longicornis (Fig. 10d)

The precise native range of *Paratrechina longicornis* is uncertain but it probably originated in the Old World tropics, perhaps in south-eastern Asia or Melanesia (Wilson and Taylor 1967). It is now a widespread pantropical tramp species that is usually associated with disturbed environments and is a particularly successful coloniser of urban areas (Trager 1984). In some situations *P. longicornis* penetrates into rainforest in areas with depauperate native ant faunas (Wilson and Taylor 1967). In Brisbane it is a common ant in disturbed, urban areas, but it appears unable to colonise more natural habitats. It was recorded only from Karawatha Forest, where it occurred in very low numbers. Single specimens were collected in two pitfall trap samples, two specimens were collected in a pyrethrum knockdown and a few specimens were hand collected at night in February.

Cardiocondyla wroughtoni

Cardiocondyla wroughtoni is a widespread tramp species that probably originated in south-east Asia (Bolton 1982). In Asia it has been recorded from India, Sri Lanka, Nepal, Taiwan, Japan, Thailand, Singapore, West Malaysia, Brunei and Indonesia (Seifert 2003). It is also known to occur in Hawaii, Papua New Guinea, Australia, USA and Africa (Bolton 1982, Seifert 2003). In Brisbane it appears uncommon (*pers. obs.*) and probably has no appreciable effect on native ant species. Only a single worker of *C. wroughtoni* was collected during the survey, a hand collected specimen from Bulimba Creek.

Tetramorium similimum (Fig. 10c)

Tetramorium simillimum is a common pantropical tramp species of African origin. It is also found in temperate regions, living within glasshouses and zoological gardens (Bolton 1977). In south-east Queensland *Tetramorium simillimum* is common in urban areas, but has also colonised more open natural habitats. It was recorded from eight of the 10 sites and was absent only from Buhot Creek and Boombana Nat. Pk. It was relatively commonly collected in pitfall traps from Belmont Hills, Chelsea Rd and Gold Creek reservoir where it comprised 4.0, 2.31 and 2.64 percent respectively of the total numbers of ants in the traps at each site.

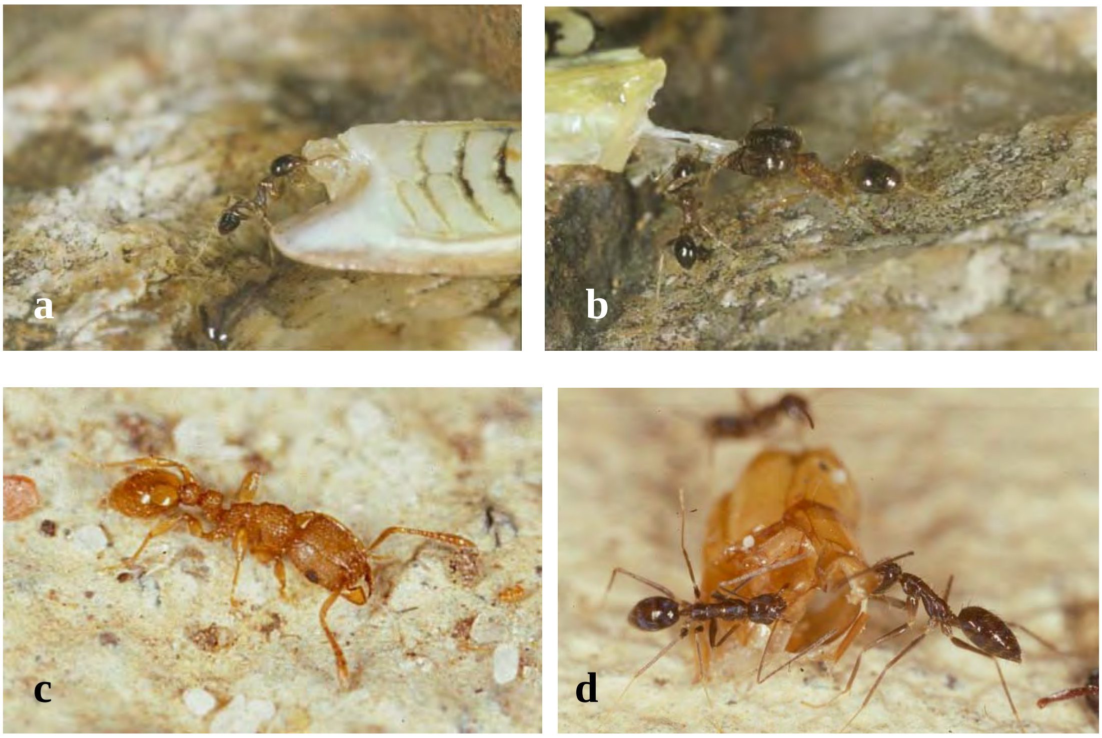


Figure 10. Live representatives of introduced ant species recorded during the survey. **a.** Coastal Brown Ant, *Pheidole megacephala* (Myrmicinae), minor worker. **b.** Coastal Brown Ant, *P. megacephala* minor and major workers. **c.** *Tetramorium simillimum* (Myrmicinae), worker. **d.** *Paratrechina longicornis* (Formicinae), workers. [not to scale].

Pheidole megacephala (Fig. 10a,b)
The Coastal brown ant or Big-headed ant, *P. megacephala* is possibly originally from Africa, but is now found across all of the humid tropics (McGlynn 1999). In Australia is has become established along the eastern seaboard and in urban areas of Darwin and Perth. It has also been recorded from the inland towns of Mt Isa (Queensland) and Katherine (Northern Territory) (Hoffman 1998). In Australia, *P. megacephala* is most commonly associated with highly disturbed environments such as urban areas and regenerated coastal dunes following sand mining (Majer 1985, Vanderwoude *et al*. 2000, Heterick *et al*. 2000). In Brisbane it is a very common ant in urban areas and was first recorded in Brisbane a few years prior to 1912 by Tryon (1912).

Pheidole megacephala was recorded from half of the sites surveyed, from Bulimba Creek, Belmont Hills Bushlands, Chelsea Road Bushlands, Gold Creek Reservoir and Boombana Nat. Pk. At Boombana Nat. Pk only a single worker of *P. megacephala* was collected from leaf litter collected in rainforest but within the vicinity of the Mt

Nebo-Mt Glorious road. Almost certainly this specimen originated from a roadside nest of this species. At most of the other sites, the abundance of *P. megacephala* was low, contributing less than 0.5% of the total ants collected in the pitfall traps (Table 4). This was even the case at Bulimba Creek, a very small bushland remnant completely surrounded by development. Nests of *P. megacephala* were common at the edges of the remnant but the species had not invaded the forest in any great numbers.

However, there are an increasing number of examples of *P. megacephala* invading and dominating relatively undisturbed habitats dramatically altering native ant communities (Heterick 1997, Hofmann *et al*. 1999, Vanderwoude *et al.* 2000). This appears to be the situation at the Gold Creek Reservoir site where *P. megacephala* dominated the ant fauna making up more than 87% of the total ants collected in the pitfall traps (Table 4). Heterick (1997) examined the effects of *P. megacephala* on the invertebrate fauna at J.C. Slaughter Falls at Mt Coot-tha Brisbane. In infested areas, *P. megacephala* was the dominant ant species representing 89% of the ants collected in pitfall traps. The overall abundance of invertebrates did not significantly vary between infested and uninfested plots but their ants faunas were markedly different. Medium-sized to large, aggressive ponerine and dolichoderine species were absent from plots infested with *P. megacephala* as were some myrmicines including other species of *Pheidole* (Heterick 1997).

Vanderwoude *et al.* (2000) examined the impact on native ants of an extensive colony of *P. megacephala* established within long undisturbed open forest near Maryborough. In heavily infested sites over 94% of the ants recorded in pitfall traps were *P. megacephala*. The ant faunas of heavily infested and unifested sites were dramatically different with dominant dolichoderines (species of *Iridomyrmex*), subordinate Camponotini (species of *Camponotus*, *Opisthopsis* and *Polyrhachis*) and other species of *Pheidole* completely displaced from infested sites.

Hoffman *et al.* (1999) investigated the effects on invertebrates of a heavy infestation of *P. megacephala* in a monsoonal patch of rainforest in the Northern Territory. In the most heavily infested areas the abundance of *P. megacephala* collected in pitfall traps was 37-110 times greater than that of native ant species in uninfested areas. Both the abundance and species richness of native ants and other invertebrates were significantly reduced in areas where *P. megacephala* was present. In the most heavily infested plot only two individuals of a single native ant species were found, while at the least infested plot, native ant species richness was reduced by about one half.

It is difficult to assess the effect of the infestation of *P. megacephala* at Gold Creek Reservoir as uninfested sites were not sampled in the same region. However, the abundance of *P. megacephala* approaches that observed in the above studies and it is very likely that it has appreciable effects on native ants. Other species of *Pheidole* were effectively excluded from the site, with only two species of *Pheidole* QM.3 recorded from the pitfall traps over the year, compared with 10 613 specimens of *P. megacephala*. A number of other *Pheidole* species were common at most of the other sites surveyed.

Table 4. The distribution of introduced ants and the possibly exotic *Cardiocondyla nuda* across the 10 sites. The upper value in each cell is the number of individual samples in which the species was collected (maximum of 27) followed in parentheses by the number of pitfall trap samples in which it was collected (maximum 12). The lower value in each cell is the percentage contribution of the species to the total number of ants collected in pitfall traps over the course of the survey (1 year for all sites). "Total species" is the number of introduced species recorded for a site using all collection methods followed, in parentheses, by the total number collected in pitfall traps. "Total % introduced" is the percentage contribution of all introduced species at a site to the total numbers of ants collected in pitfall traps.

Species	**Buhot Ck**	**Boon. Wet.**	**Ransome**	**Illaweena**	**Karawath.**	**Boom. NP**	**Bulimba**	**Chelsea**	**Gold Ck**	**Belmont**
Paratrechina longicornis					4 (2) 0.03%					
Cardiocondyla nuda	1 (0) 0%	9 (7) 1.21%	1 (0) 0%	10 (8) 0.25%		1 (0) 0%	2 (0) 0%	1 (0) 0%	13 (11) 1.21%	
C. wroughtonii							1 (0) 0%			
Pheidole megacephala						1 (0) 0%	8 (3) 0.45%	1 (0) 0%	27 (12) **87.67%**	2 (2) 0.17%
Tetramorium simillimum		4 (0) 0%	3 (0) 0%	2 (1) 0.01%	17 (11) 0.72%		19 (9) 0.82%	16 (10) 2.31%	20 (12) 2.64%	17 (9) 4.0%
Total Species	1 (0)	2 (1)	2 (0)	2 (2)	2 (2)	1 (0)	4 (2)	3 (1)	2 (2)	2 (2)
Total % introduced	**0**	**1.21**	**0**	**0.26**	**0.75**	**0**	**1.27**	**2.31**	**91.52**	**4.17**

Comparison of the ant faunas of different sites

COMPARISONS BASED ON PRESENCE/ABSENCE DATA

Overall species richness

The overall ant species richness values at each site (in descending order) were: Buhot Creek **101** species; Boondall Wetlands **89**; Ransome Reserve **86**; Illaweena Street **86**; Karawatha Forest **85**; Boombana Nat. Pk **84**; Bulimba Creek **81**; Chelsea Road Bushlands Reserve **81**; Gold Creek Reservoir **72**; Belmont Hills Bushlands **62** (Figure 11, Table 5). The assemblages of ant species represented at each site and the methods employed to collect each species are summarised in Appendices 3-12.

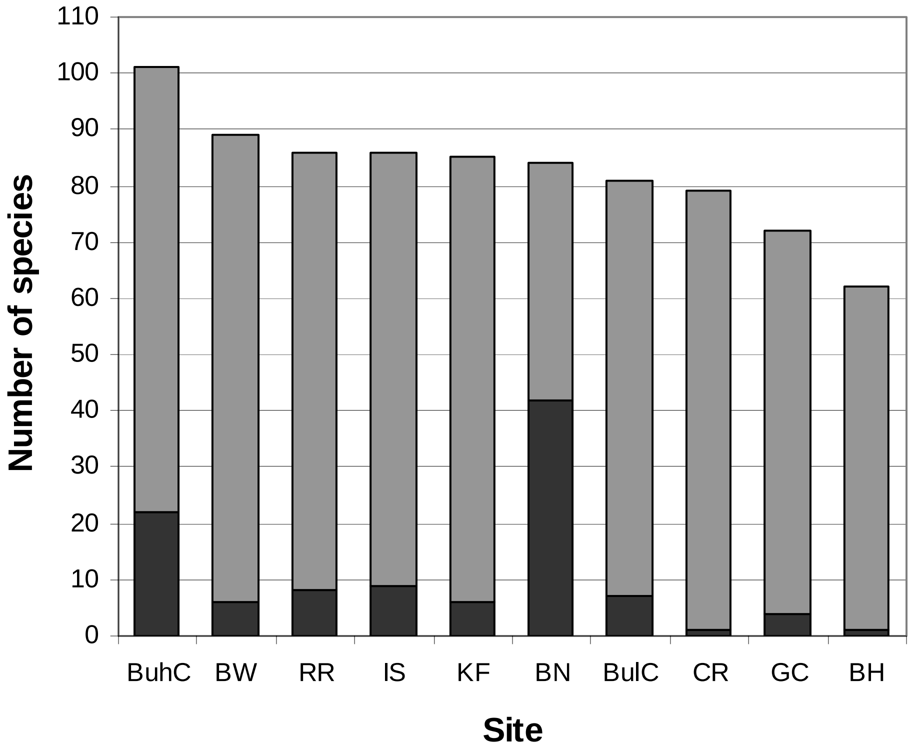


Figure 11. Overall ant species richness across the 10 survey sites. Data for all six sampling methods pooled. The black area at the base of each bar is the number of species unique to that particular site. BuhC – Buhot Creek, Burbank; BW – Boondall Wetlands; RR – Ransome Reserve; IS – Illaweena St, Drewvale; KF – Karawatha Forest; BN – Boombana NP; BulC – Bulimba Creek, Carindale; CR – Chelsea Road Bushlands; GC - Gold Creek Reservoir; BH – Belmont Hills Bushland Reserve.

Buhot Creek was clearly the most species rich site and this is probably due in part to its heterogeneous nature. The site contains relatively intact forest, on a rocky substrate, in which the pitfall traps were situated. However, other parts of the site are highly disturbed and consist of open weedy areas or *Acacia* regrowth. This site contained a rich fauna of ants within the undisturbed forest and a different suite of ant species associated with the more disturbed areas, resulting in very high overall species richness. The majority of the other sites displayed similar richness values except for two sites that had a noticeably lower compliment of ant species, Gold Creek Reservoir and particularly Belmont Hills. Both sites are somewhat disturbed and many of their species are known to occur in suburban gardens. Invasive ant species may also be contributing to the lower species richness observed at Gold Creek.

Unique species at each site

Despite the relatively similar species richness values of each site, the assemblages of species at each site were markedly different. Boombana NP, the only rainforest site sampled, had a particularly distinct ant fauna with 50% of its species not recorded from any other site. Similarly, Buhot Creek, was relatively distinct with 22% of its species unique to the site (Table 5). The proportion of unique species present at the other eight sites ranged from a little over 1% (Chelsea Road Bushlands and Belmont Hills Bushlands) to around 10% (Bulimba Creek, Ransome Reserve and Illaweena Street). When examining ant species unique to particular sites, it can be instructive to examine the impact of singletons. In this context, singletons are species that are represented by a single specimen, or were collected on only a single sampling occasion. Singletons are necessarily unique to a particular site, but without additional collecting, it is difficult to determine whether they are restricted to that site or are just rare and have not yet been recorded from other sites. Even when singletons are removed, the ant faunas of Buhot Creek and especially Boombana NP are still distinct (10.9% and 36.1% respectively of their species unique) (Table 5). In addition, Illaweena had a relatively distinct fauna, with 8.1% of its species found nowhere else. Five of the species restricted to Illaweena Street, belonging to the genera *Melophorus* (2 spp.) and *Iridomyrmex* (3 spp.) are thermophilic (heat-loving) species associated with the open sandy areas found at that site.

Table 5. Overall ant species richness and the number and percentage of species restricted to each of the 10 sites. The unique species are further divided into singletons, those collected on only one sampling occasion, and non-singletons, those collected on two or more sampling occasions. The final column is the number of unique non-singletons at each site expressed as a percentage of the total number of species occurring at that site.

Site	Total species	Unique species	% unique species	Singletons	Non-singletons	% non-singletons
Buhot Creek	101	22	**21.6%**	11	11	**10.9%**
Boondall Wetlands	89	6	6.7%	1	5	5.6%
Ransome Reserve	86	8	9.3%	5	3	3.5%
Illaweena Street	86	9	10.5%	2	7	**8.1%**
Karawatha Forest	85	6	7.1%	2	4	4.7%
Boombana NP	84	42	**50%**	11	30	**36.1%**
Bulimba Creek	81	7	8.6%	4	3	3.7%
Chelsea Road Bushlds	79	1	1.3%	1	0	0%
Gold Creek Reservoir	72	4	5.6%	2	2	2.8%
Belmont Hills Bushlds	62	1	1.6%	1	0	0%

Table 6. Jaccard similarity matrix for all possible pair-wise comparisons of the 10 surveyed sites. The values in the uncoloured cells are the number of species shared by two compared sites followed by the total number of species at each site. The values in the coloured cells are the Jaccard similarity indices obtained by dividing the shared species by the total species and then multiplying by 100. The Jaccard indices are coloured coded to allow easier comparisons of the relative similarities of sites: yellow – 10.01-20; blue – 20.01-30; green – 30.1-40; orange – 40.1-50; pink – 50.1-60; purple 60.1-70.

SITE	Boondall	Bulimba	Belmont	Ransome	Chelsea	Buhot Ck	Karawatha	Illaweena	Gold Ck	Boombana
Boondall		49/121	40/111	50/125	51/117	47/141	51/123	53/122	44/117	24/149
Bulimba	40.50		53/90	48/119	59/101	44/138	46/120	45/122	44/109	24/141
Belmont Hills	36.04	58.89		43/105	53/88	41/122	43/104	40/108	40/94	24/122
Ransome Res	40.00	40.34	40.95		53/112	47/140	51/120	47/125	42/116	22/148
Chelsea Rd	43.59	58.42	60.23	47.32		47/133	53/111	52/113	47/104	24/139
Buhot Ck	34.75	31.88	33.61	33.57	35.34		43/143	41/146	37/136	33/152
Karawatha	41.46	38.33	41.35	42.50	47.75	30.07		61/110	48/109	17/152
Illaweena	43.44	36.89	37.04	37.60	46.02	28.08	55.45		47/111	20/150
Gold Ck	37.61	40.37	42.55	36.21	45.19	27.21	44.04	42.34		17/139
Boombana	16.11	17.02	19.67	14.86	17.27	21.71	11.18	13.33	12.23	

Pairwise comparisons using Jaccard similarity indices

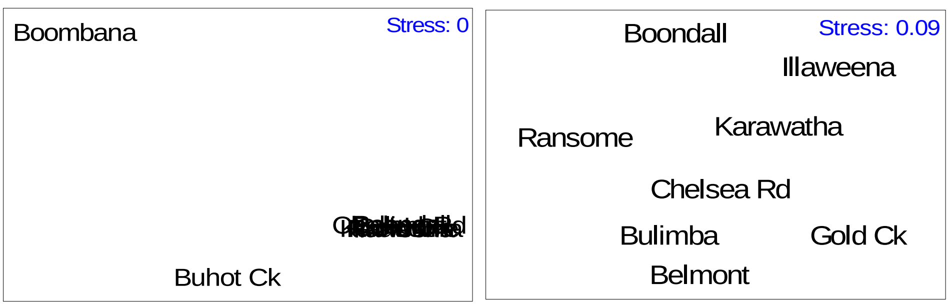
Pairwise comparisons between all of the ten sites using a modified Jaccard similarity index are presented in Table 6. Any two given sites were compared by counting the total number of species occurring at both sites and the number of species that are shared by both of the sites. A similarity index was calculated by dividing the number of shared species by the total number of species found at the two sites and then multiplying the result by 100. The higher the similarity index the more similar are the two sites. A similarity index of 100 indicates that the two sites have exactly the same compliment of ant species.

Jaccard indices (JI's) for the majority of site comparisons were similar, generally ranging between 35 and 45 (Table 6). Comparisons involving two of the sites were consistently lower, indicating that the ant faunas of these sites were relatively distinct. Comparisons involving Buhot Creek generally ranged between 25 and 35, while those involving Boombana Nat. Pk were even lower, mostly between 10 and 20. The sites with the most similar ant faunas were Karawatha Forest and Illaweena Street (JI = 55.45) as well as a group of three sites, Bulimba Creek, Chelsea Road Bushlands and Belmont Hills Bushlands (JI's between 58.42 and 60.23).

MDS ordinations based on presence/absence

Although pairwise site comparisons are no doubt useful, they sometimes fail to fully represent ecological patterns that are apparent amongst all the faunal assemblages. Multivariate statistical techniques such as MDS ordination, take all species and sites into consideration simultaneously. This is a computationally demanding task however, but when the results are presented as two-dimensional ordinational plots, they are easy to interpret. Sites spaced closer together in ordinational space have more similar assemblages, conversely those spaced further apart are less similar.

The MDS ordination (Fig. 12a), clearly shows that the ant assemblages at Buhot Creek and particularly Boombana NP, differ dramatically from those at all other sites (tightly compressed in ordination). When the ant assemblages in these other sites were examined independently of the Boombana NP and Buhot Creek sites (Fig. 12b), no clear patterns emerged. The spacing of sites apart from one another indicates that each of the eight sites contained slightly different ant assemblages.



(a) (b)

Figure 12. Multidimensional scaling ordinations of ant assemblages (based on presence/absence data) for (a) all ten sites, and (b) sites excluding Boombana NP and Buhot Creek.

COMPARISONS INCORPORATING ABUNDANCE DATA (PITFALL TRAPS)

Further comparisons between the ant faunas of the 10 sites can be made using the quantitative data obtained from pitfall traps. This data includes both information on the ant species present at each site and information on their relative abundance. However, it is important to remember that pitfall traps sample only a subset of the ants present at a site, specifically the ground active species. Pitfall traps undersample cryptic and subterranean species that are closely associated with the soil and leaf litter layers, and arboreal foraging and nesting species. This is less of a problem in relatively open habitats but becomes more pronounced as habitat complexity increases (see "Comparison of sampling methodologies").

Most common ground active species

The five most common ant species in the pitfall traps and their percentage contribution to the total pitfall catch from each site is presented in Table 7. All 10 sites showed a unique combination of common species. However, the common species were drawn from a relatively limited suite of genera. Thermophilic species of *Iridomyrmex* were common in relatively open habitats such as Illaweena Street, Chelsea Road Bushlands and Karawatha Forest. In more shaded sites, such as Buhot Creek, Ransome Reserve and Boombana Nat. Pk, species of *Pheidole* were usually common. Species of *Paratrechina*, *Rhytidoponera* and to a lesser extent *Tetramorium* were often common at a number of sites. At two sites, Illaweena Street (*Iridomyrmex* QM.2) and Gold Creek Reservoir (*Pheidole megacephala*), a single ant species dominated the pitfall trap catches, making up more than 85% of the individual ants collected over a year. At most other sites there were two or more relatively common ant species.

MDS ordinations based on pitfall abundance data

Incorporation of both abundance and species richness data from the pitfall trapping into a MDS ordination (Fig. 13) produced a different pattern of relationships between the sites compared to that produced using presence/absence data obtained from all the collecting methods. Pifall traps survey a subset of the total ant fauna at a site and these results relate primarily to ground active ants. Once again, the fauna of Boombana NP was dramatically different to the more open habitats while Buhot Creek was closely clustered with the other sites (Fig. 13a). When the pitfall trap assemblages were examined independently of the Boombana Nat. site (Fig. 13b), again no clear patterns emerged. However, the composition of the ground active ant faunas of the Karawatha Forest and Chelsea Road Bushlands sites were most similar.

Table 7. Relative abundances of the five commonest ant species collected in pitfall traps from each site. Values are the percentage contribution of individuals of that species to the total pitfall trap catch at each site. Number in parenthesis after each value are the ranking of species within the site from 1 (most common) to 5 (5th most common). Species from different functional groups (see text for explanation) are colour coded: pink – dominant dolichoderines; yellow – generalised myrmicines; blue – opportunists; green – cryptic species; orange – climate specialists.

Species	Buhot Ck	Boondall	Ransome	Illaweena	Karawatha	Boombana	Bulimba	Chelsea	Gold Ck	Belmont
Iridomyrmex QM.1					**9.3 (3)**			**39.3 (1)**		
Iridomyrmex QM.2		**12.0 (3)**		**86.2 (1)**	**37.6 (1)**					
Iridomyrmex QM.3		**15.3 (1)**		**1.7 (5)**	**17.5 (2)**			**6.3 (5)**	**2.7 (2)**	
Pheidole megacephala									**87.7 (1)**	
Pheidole QM.1	**9.1 (4)**					**36.2 (1)**				
Pheidole QM.2	**6.7 (5)**									
Pheidole QM.3							**7.0 (4)**	**7.1 (4)**		
Pheidole QM.4	**11.8 (2)**		**24.3 (1)**			**26.7 (2)**				**7.1 (5)**
Pheidole QM.5		**8.5 (5)**	**12.4 (3)**				**13.7 (2)**			
Pheidole QM.6			**20.7 (2)**							
Pheidole QM.10						**11.2 (3)**				
Monomorium leave			**5.5 (4)**							
Cardiocondyla nuda									**1.2 (5)**	
Ochetellus QM.1		**11.9 (4)**								**15.3 (3)**
Paratrechina QM.1				**2.2 (3)**	**5.4 (5)**		**11.9 (3)**	**9.0 (3)**	**1.9 (4)**	**21.1 (1)**
Paratrechina QM.2				**2.3 (2)**						
Paratrechina QM.3		**14.3 (2)**								
Paratrechina QM.4										**7.7 (4)**
Rhytidoponera metallica							**19.3 (1)**			
Rhytidoponera victoriae							**7.0 (5)**			
Rhytidoponera chalybea						**4.3 (5)**				
Tapinoma QM.1					**6.5 (4)**			**12.6 (2)**		**16.3 (2)**
Tetramorium ?impressum				**1.8 (4)**						
Tetramorium simillimum									**2.6 (3)**	
Solenopsis QM.1						**5.2 (4)**				
Melophorus QM.1			**5.3(5)**							
Meranoplus QM.3	**13.7 (1)**									
Leptomyrmex varians rufipes	**10.1 (3)**									

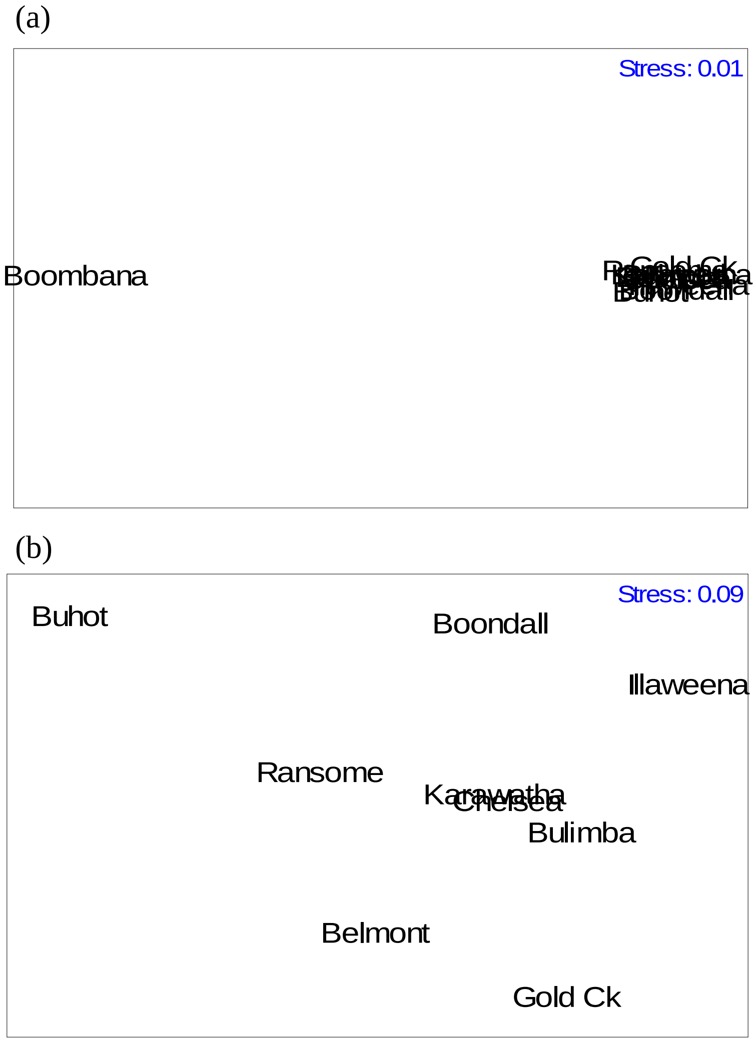


Figure 13. Multidimensional scaling ordinations of ground active ant assemblages (based on species richness and abundance data from pitfall traps) for (a) all ten sites, and (b) sites excluding Boombana NP.

Functional Group Profiles

Ants can be divided into functional groups based on their competitive interactions, habitat requirements and their role in community dynamics. These functional groups in turn can be related to basic ecological processes and hence indicate a community's responses to stress and disturbance (Anderson 1995). The scheme was based on a system in use for plants, but in the case of ants it has been found that they respond to stress and disturbance quite differently to plants. Hence, they may provide an alternative measure of environmental health to that based on the well-being of plant communities at any site. An outline of ant functional groups (after Hoffman and Anderson 2003) is presented below.

Dominant Dolichoderinae: abundant, highly active and aggressive ants favouring hot, open habitats; exert a strong competitive influence over other ants; include the ubiquitous *Iridomyrmex*.

Subordinate Camponotini: co-occurring with, and behaviourally submissive to dominant dolichoderines, but comparatively dominant in their absence; relative abundance is usually low; includes the ubiquitous *Camponotus*.
Climate specialists: ants are centred on three distinct climatic zones; the arid zone (hot climate specialists), the humid tropics (tropical climate specialists) and the cool temperate areas (cold climate specialists). Tropical climate specialists are characteristic of areas where dominant dolichoderine groups are low in numbers. In hotter areas some ants in this group are exceptionally thermophilic, foraging when few other species are active.
Cryptic species: small to minute ants; forage mostly within soil and litter; have little interaction with ground active ants; mostly in subfamilies Myrmicinae and Ponerinae.
Opportunists: unspecialised, 'weedy' species characteristic of disturbed sites, or other habitats supporting low diversity; suffer from competitive interaction with other ants.
Generalised Myrmicinae: cosmopolitan genera occurring in most habitats; not highly active and aggressive, depending on rapid recruitment and mass mobilisation to defend clumped resources; include *Pheidole*, *Monomorium* and *Crematogaster*.
Specialist predators: medium to large-sized species; specialised predators of other arthropods; include group raiders and solitary foragers such as *Myrmecia*; have little interaction with other ants and typically have low population densities.

In Australia, a functional group approach has been widely utilised to analyse the effects of environmental disturbance on ant communities. Functional groups have been used to examine the effects of fire, mining, grazing, clearing and urbanisation (see Hoffman and Anderson 2003 for a review). In the context of this study, sites were not selected to examine the effects of environmental disturbance. However, an examination of the functional group profile of ants collected in the pitfall traps from each site reveals dramatic difference in their ant community structures (Fig. 14).

Dominant dolichoderines (principally species of *Iridomyrmex*) were most prevalent in open habitats such as those at Illaweena Street, Karawatha Forest and Chelsea Road Bushlands, while generalised myrmicines dominated in shaded habitats at Boombana NP, Ransome Reserve and to a lesser degree Buhot Creek. The dominance of generalised myrmicines at Gold Creek Reservoir, an open habitat, is due entirely to the prevalence of *Pheidole megacephala*, at this site. Also of interest in the functional group profiles, are the proportions of opportunists. Opportunists are unspecialised, weedy species that are often characteristic of disturbed sites, or other habitats supporting low ant diversity. Throughout higher rainfall areas of eastern and southern Australia, severe disturbance (involving extensive vegetation clearing) typically leads to a proliferation of opportunists, especially smaller species of *Rhytidoponera* (Hoffman & Anderson 2003). Opportunists were most abundant at four sites, Boondall Wetlands, Chelsea Road Bushlands, Bulimba Creek and Belmont Hills Bushlands. This may be indicative of some level of disturbance at these sites, particularly at Belmont Hills Bushlands where opportunists made up more than 70% of the total pitfall trap catch. This combined with its low species richness suggests this site is quite degraded.

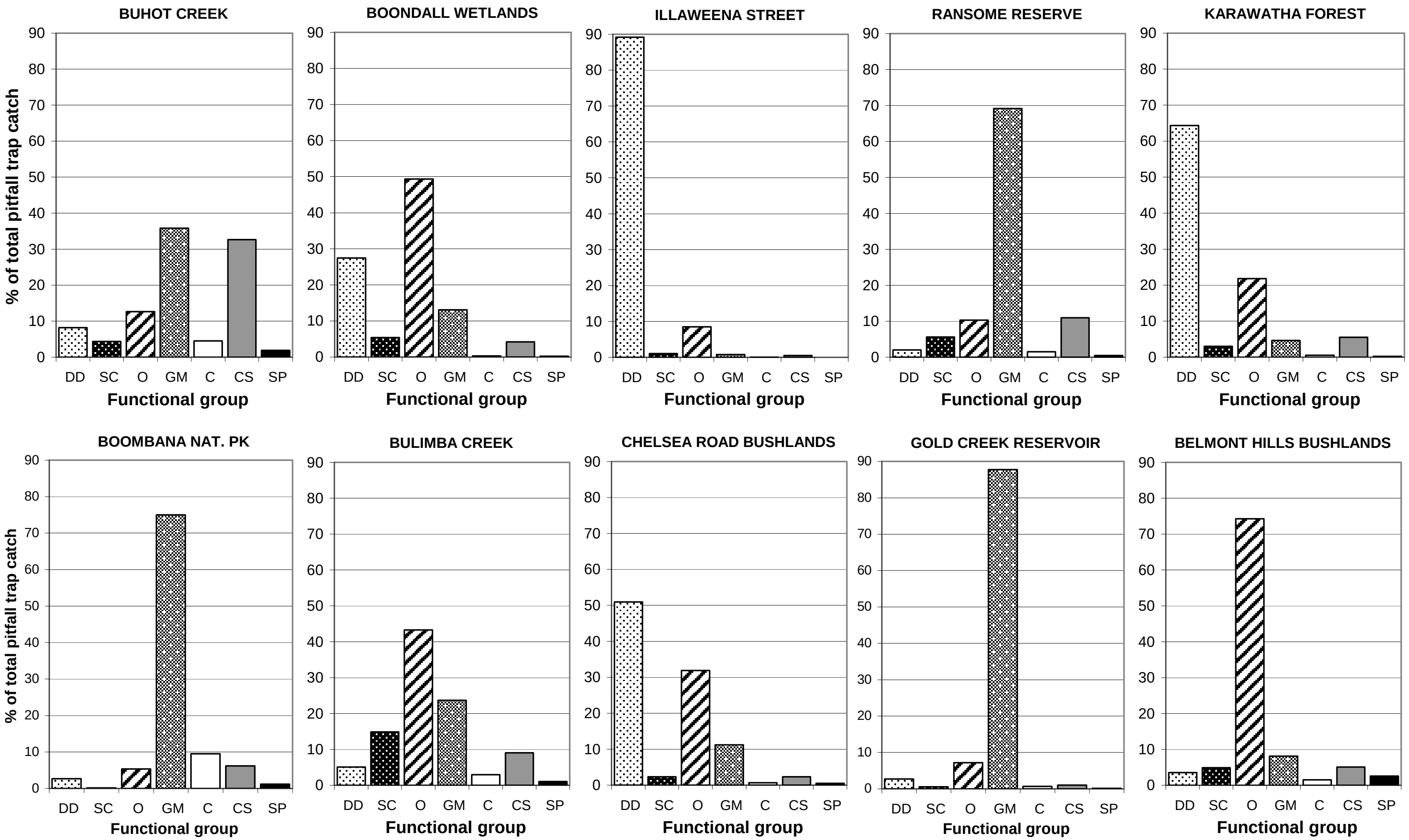


Figure 14. Relative abundance of ant functional groups in total pitfall trap catch across the 10 sites surveyed. DD – Dominant Dolichoderinae; SC – Subordinate Camponotini; O – Opportunists; GM – Generalised Myrmicinae; C – Cryptic species; CS – Climate Specialists; SP – Specialist Predators.

Comparison of sampling methodologies

Overall, day hand collecting was the most productive sampling method, yielding 193 species, 76% of the total ant fauna recorded during the survey (Fig. 15). Pitfall trapping was also very productive, yielding 158 species, 62% of the total ant fauna. A little over half of the total species recorded were hand collected at night (130 spp., 51%) and around one third were collected by each of the other methods; 92 spp. (36%) from Berlese leaf litter extracts, 91 spp. (36%) from pyrethrum knockdowns and 82 spp. (32%) by sweeping vegetation. Information on which sampling methods collected each of the 256 ant species is summarised in Appendix 13.

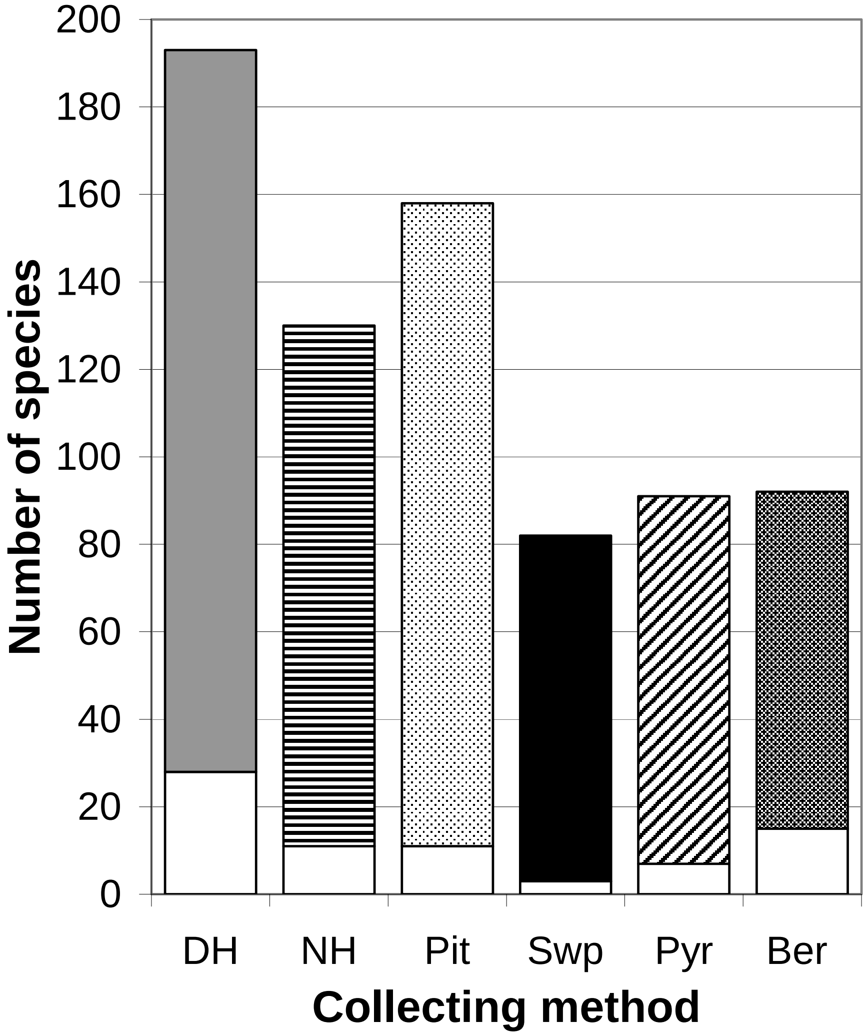


Figure 15. Overall number of ant species collected by each of the six sampling methods employed during the survey. Data from all 10 sites combined. The white area at the base of each bar is the number of species collected only by that particular sampling method. DH – day hand collecting; NH – night hand collecting; Pit – pitfall traps; Swp – sweeping low vegetation; Pyr – pyrethrum knockdowns; Ber – Berlese leaf litter extracts.

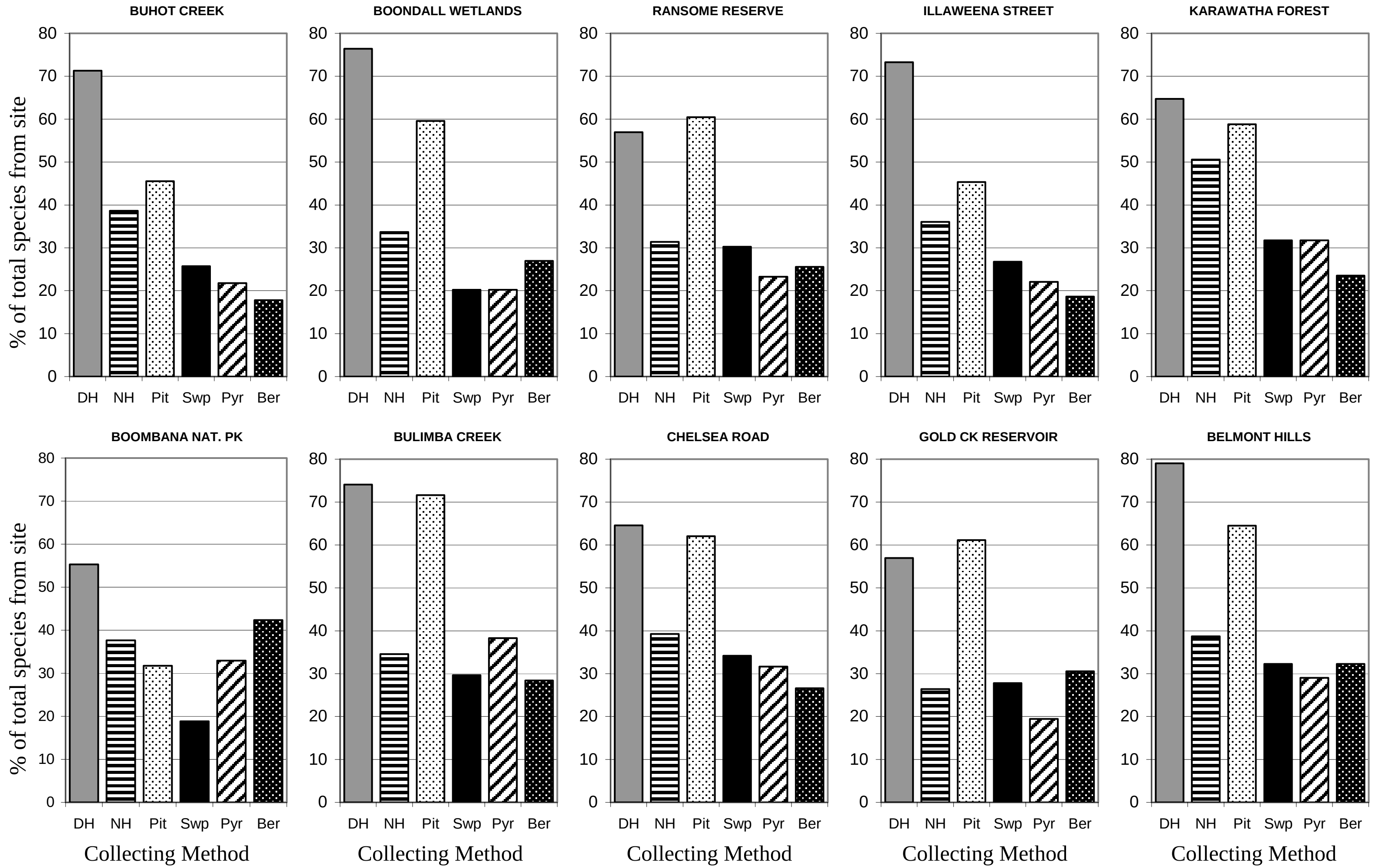


Figure 16. Relative efficacy of different collecting methods in sampling the ant fauna of 10 sites surveyed, expressed as a percentage of the total number of species recorded from the particular site. DH – Day hand collecting; NH – Night hand collecting; Pit – Pitfall traps; Swp – Sweep netting; Pyr – Pyrethrum knockdowns; Ber – Berlese leaf litter extracts.

A similar pattern was found at most of the individual sites where day hand collecting and pitfall trapping yielded the greatest percentage of the species recorded at each site (Fig. 16). Generally day hand collecting produced more species than pitfall trapping as both ground active and arboreal species were sampled. Hand collecting was also conducted over a wider area, sometimes encompassing more than one vegetation type at the more heterogeneous sites. To some extent this explains the more pronounced discrepancy between day hand collecting and pitfall trapping found at Buhot Creek and Illaweena Street (Fig. 16). Conversely, the year long duration of pitfall trapping increased the number of rare species collected at some sites. At Ransome Reserve and Gold Creek Reservoir pitfall traps yielded slightly more species than hand collecting (Fig. 16). In general the four other sampling methods yielded fewer species across most sites, although night hand collecting was particularly effective at Karawatha Forest. The one exception was Boombana Nat. Pk, the only rainforest site. Although day hand collecting still produced the most species, pitfall trapping was relatively unproductive, yielding only about one third of the total ant fauna (Fig. 16). On the other hand, berleseate leaf litter extracts, were second only to hand collecting in species richness, yielding a number of cryptic myrmicine and “ponerines” that were not taken by other sampling methods. These results parallel those of Majer (1997) who found that pitfall traps undersample the complete ant community, especially in complex habitats such as rainforest.

Each of the six collecting techniques used in this study sampled some ant species that were not obtained with any other technique (Fig. 15). In particular day hand collecting and berleseate leaf litter extracts yielded the greatest numbers of unique species which made up 15% and 16% of the total species collected by each method respectively. Night hand collecting, pitfall traps and pyrethrum knockdowns produced similar proportions of unique species ranging from 7-9% of the total species collected by each method. Vegetation sweeps produced the least distinctive assemblage of ants with only 4% of its species unique.

An MDS ordination comparing the assemblages of species collected using each sampling technique shows that hand collecting during the day, hand collecting during the night and pitfall trapping produced the most similar suites of species (Fig. 17). This is most probably because all three techniques collected many of the same ground active species. Thus these techniques cluster together because of numerous shared species, somewhat masking the many unique species collected by each method. Berleseate extracts collected a very distinct suite of species that included many cryptic leaf litter inhabiting species (many from Boombana NP) that did not fall into the pitfall traps. Sweeping and pyrethrum knockdowns also collected quite distinct groups of species that, not surprisingly, were most different from those extracted from leaf litter. Both techniques collected many arboreal foraging species, though pyrethrum knockdowns collected a greater number of arboreal nesting species. About one quarter of the species collected by sweeping are strictly arboreal nesters versus about one third of the species collected by pyrethrum knockdowns. Large trees, that had probably developed dead, hollow branches and twigs providing nesting sites for lignicolous ants, were specifically targeted for pyrethrum knockdowns.

Figure 17. Multidimensional scaling ordination of ant assemblages (based on presence/ absence data) obtained from all five collecting methods.

Seasonality

At all sites there was a marked seasonality in overall ant abundance (Fig. 18). Numbers of ants falling into the pitfall traps were generally lowest during May to August, and highest in the warmer months of October 2003 to February 2004. There was also a strong positive correlation between overall ant abundance and species richness so that at most sites many more species were captured in the pitfall traps in late spring and summer compared to late autumn and winter.

There were two anomalous results that deserve some explanation. At Boondall Wetlands, overall ant abundance and species richness responded in similar ways throughout much of the year, but showed quite a different pattern in February to April 2004. This was almost certainly the result of most of the traps at this site being shifted to new positions at the beginning of February 2004. Heavy rainfall in January 2004 caused 4 of the 5 pitfall traps at Boondall Wetlands to be completely inundated and their catches lost. This accounts for the dramatic drop in both species and numbers of specimens observed in January 2004, the results based on the single unflooded trap. This area remained inundated with water until the end of the survey and 4 of the traps were relocated to slightly higher ground on the opposite side of the road to the sewage treatment plant. It appears that this new site had somewhat lower ant abundance but greater diversity, probably due its higher elevation allowing a greater range of ground nesting ants. This result is interesting because it suggests that ants have the potential to detect very fine scale changes in the environment.

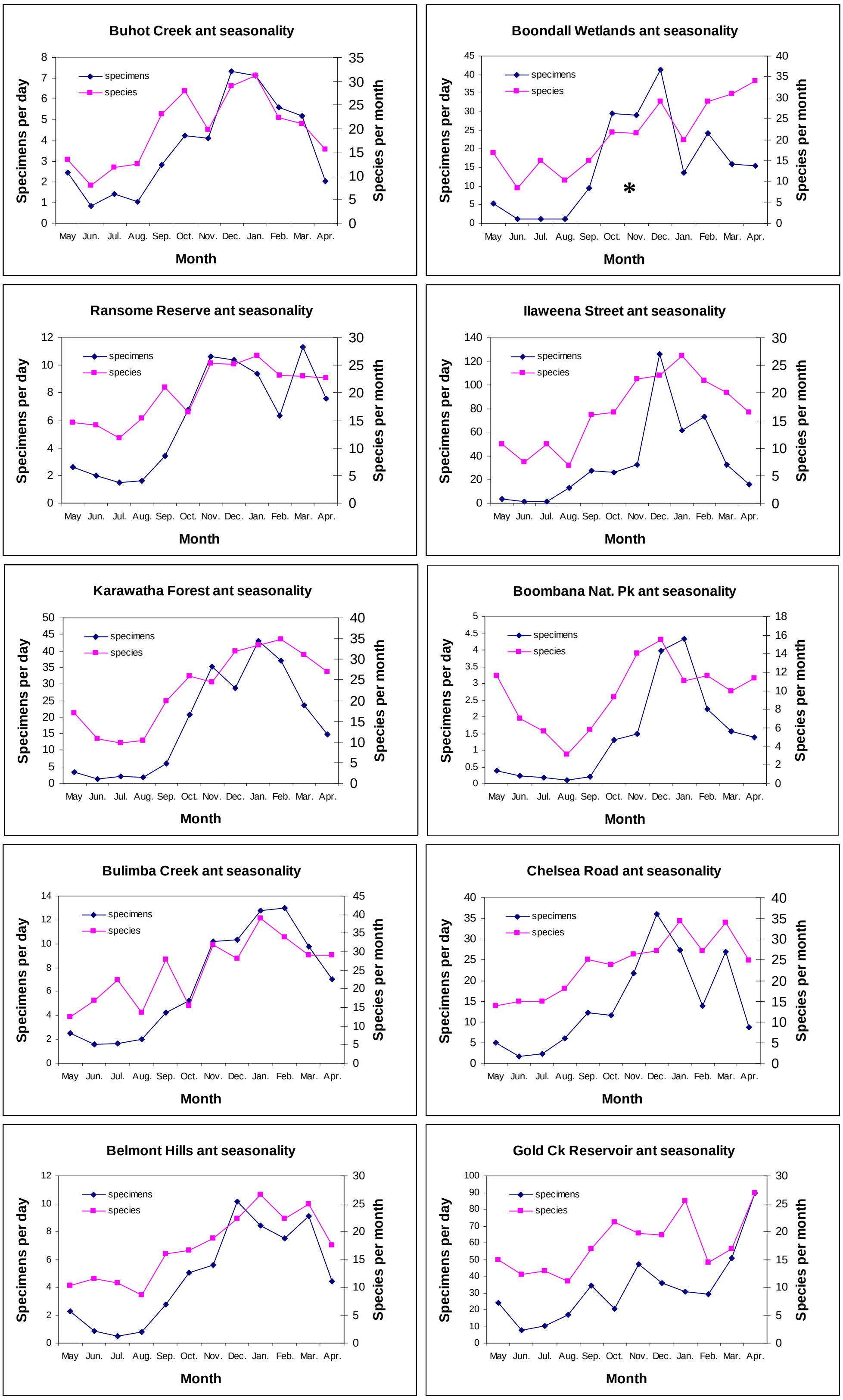


Figure 18. Influence of season on the numbers of individuals (blue, left axis) and species of ants (pink, right axis) collected in pitfall traps across the ten sites. Due to irregular trap emptying times, abundance data were converted to the numbers of individuals falling into the traps per day and species richness data were converted into the number of species collected for a standard month of 30 days.

Secondly, overall ant abundance at Gold Creek Reservoir did not show the clear seasonal pattern observed at the other sites. This is largely due to the dominance of a single species at this site, *Pheidole megacephala*, that made up more than 85% of the total pitfall trap catch. When the numbers of *P. megacephala* are separated, the combined abundance of all the other species shows a clearer seasonal influence (Fig. 19). *Pheidole megacephala* does not tolerate high temperatures and prefers to forage during cooler periods of the day and night. This preference for cooler temperatures may explain why relatively large numbers of *P. megacephala* were still captured in the pitfall traps during winter. In addition, the activity of *P. megacephala* is limited by water stress. It is interesting to note that following heavy rains in January, overall ant abundance climbed dramatically in March and particularly in April. The delayed increase in its abundance following the rain was probably due to the time taken to produce new workers. Fluker and Beardsley (1970) found the average life cycle of *P. megacephala* took 78 days to complete at approximately 21°C.

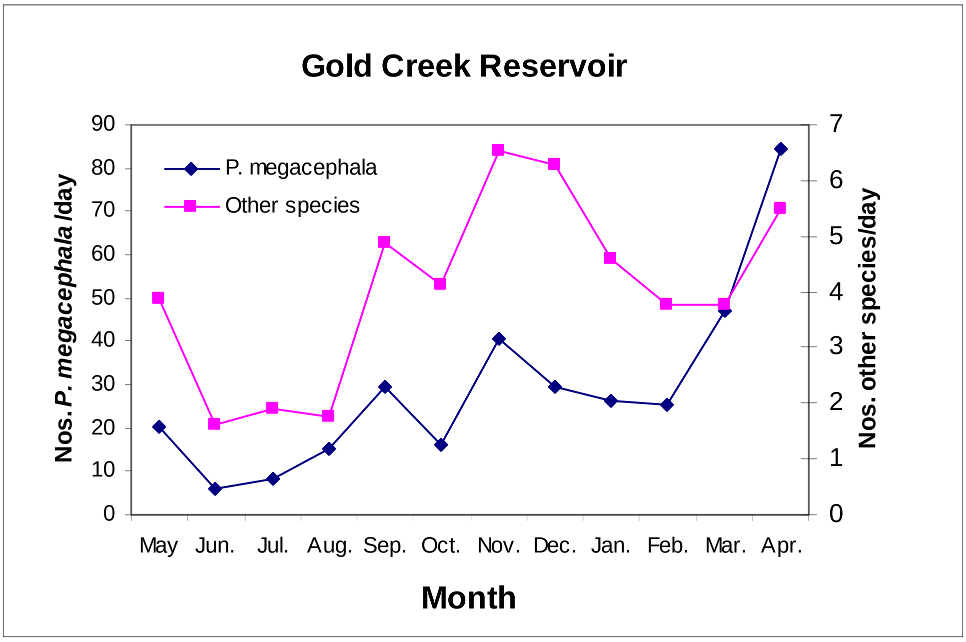


Figure 19. Influence of season on the numbers of individuals of *P. megacephala* (blue, left axis) and all other species of ants (pink, right axis) collected in pitfall traps at Gold Creek Reservoir. Due to irregular trap emptying times, raw abundance data were converted to the numbers of individuals falling into the traps per day.

Standardising Sampling Methodologies

This study was intended as a pilot project to obtain some baseline invertebrate data for native vegetation communities within metropolitan Brisbane. For ants to be used effectively by BCC staff for biodiversity assessment and as bioindicators of environmental change, standardised sampling protocols need to be developed. Our results indicate that a variety of sampling techniques must be utilised to effectively sample all elements of the ant fauna. A standardised method to sample the ground-dwelling ant fauna has been developed, the Ants of the Leaf Litter (ALL) Protocol (Agosti & Alonso 2000), that primarily utilises pitfall traps and leaf litter extracts.

Pitfall trapping and leaf litter extracts are relative simple techniques that can be standardised to provide both species richness and abundance data for the ground-active and leaf litter inhabiting ant fauna. The challenge is to develop protocols that effectively sample the species richness of the arboreal ant fauna as well as providing quantitative data on relative abundances of species. Hand collecting is probably the most effective method to obtain species richness data, while pyrethrum knockdowns or vegetation sweeping and perhaps photo-eclector traps (see Majer *et al.* 2003) could be developed to provide abundance data. No attempt was made in this study to survey the exclusively subterranean ants, but techniques are available (Lopez *et al*.1994).

Duration of pitfall trapping

Many ecological studies incorporating ants utilise short term pitfall trapping as their primary sampling technique. When investigating the effects of particular environmental variables this may be a valid approach, particularly in open arid or semiarid habitats where the majority of ant species are ground-active and large numbers of specimens can be captured in a short period of time. However, in more complex environments, pitfall trapping alone is not sufficient to sample the ant fauna, although prolonging the duration of pitfall trapping can increase its effectiveness (Majer 1997, Hinkley & New 1997). However, there are trade offs in such an approach and as the species accumulation curve for a particular site begins to plateau, increased sampling time, and processing time is required to add a few extra species. In addition, these extra species are often represented by single specimens of arboreal or cyptic species that eventually fall into a pitfall trap; species that could easily have been sampled using other techniques.

Raw species accumulation curves can give misleading results if sampling efficiency is influenced by seasonality as was strongly the case with the ants. Randomising the order of samples takes this into account and smoothes out curves, producing accurate projections of how many species are captured in relation to the sampling effort. Randomised cumulative species richness curves were generated with EstimateS, Version 6.0, (Colwell 2000) using the default settings (50 randomisations). Curves were generated from the pitfall trap data at each individual site (Fig. 21), and for the overall survey by combining the data from all sites (Fig. 20).

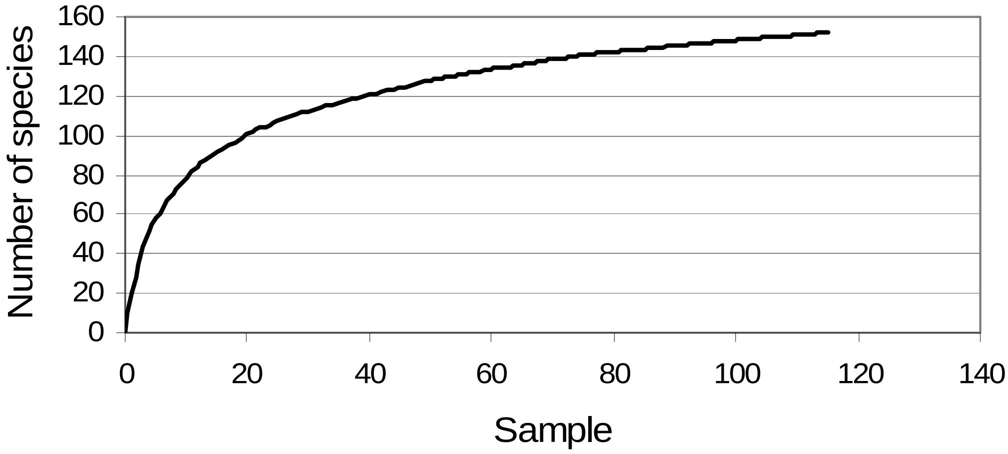


Figure 20. Randomised species accumulation curve generated from relative abundance data of ant species collected in pitfall traps (data from all 10 sites pooled).

Running the pitfall traps for a full year sampled the majority of ground active ant species across all of the 10 sites as indicated by the pronounced flattening of the species accumulation curve generated from the pooled data (Fig. 20). Similarly most ground active species were sampled at each of the individual sites over a full year of pitfall trapping (Fig. 21). However, at many sites the terminal slopes of the accumulation curves are steeper compared to the overall curve. This is because new species appearing in the pitfall traps at individual sites were not necessarily new for the survey.

In this survey, the pitfall traps were run continuously for a full year, primarily to capture spiders that mature during the winter months. With respect to ants, activity is much more pronounced in the warmer months of late spring, summer and early autumn. Pitfall trapping outside this period was particularly unproductive at most sites and is not recommended.

Although long term pitfall trapping yields a larger proportion of the species present at a site, it is labour intensive with regards to processing trap catches. The ideal duration for pitfall trapping should be a balance between processing time and effort for the number of species returned. Figure 22 presents data on the relative proportions of species collected in the pitfall traps from each site when the year long sampling period is broken into all possible continuous blocks of one, two and three months duration. When the data was broken into one month blocks, the maximum proportion of the total number of species from each site ranged from 52% at Ransome Reserve to 72% at Karawatha Forest Park (average of 61% across all 10 sites). For two monthly blocks the maximum proportions ranged from 61% at Ransome Reserve to 82% at Chelsea Road Bushlands (average 74%). For three monthly blocks the maximum proportions ranged from 71% at Ransome Reserve and 88% at Chelsea Road Bushlands (average 81%). An average return of 81% of the total species recorded over a full year for just 3 months pitfall trapping seems a reasonable trade off. However, the most productive 3 month block of pitfall trapping varied between sites from October 2003- December 2003 at Buhot Creek to January 2004– March 2004 at Ransome Reserve and Chelsea Road. At Boondall Wetlands, March to May 2004 proved the most productive 3 month block, but this result should be discounted as most of the pitfall traps were relocated to a more diverse locality in February 2004 due to local flooding. Across the ten sites, December 2003 to February 2004 proved on average the most productive block with a mean 78% of the total species recorded throughout a full year.

Pitfall trapping in summer alone could conceivably undersample species that have maximum peaks of activity in spring. Vanderwoude *et al*. (1997) examined the seasonality of ants in dry open forest in south-eastern Queensland. They found that the relative abundance of some ant species with Bassian biogeographical affinities was greatest during spring and early summer. Using our data set, the December 2003, January and February 2004 pitfall catches combined across all sites captured 126 ant species, 80% of the total captured over the full year. In almost all instances the 32 species that were not sampled in summer were represented by very few specimens (20 by single specimens) and only *Iridomyrmex* QM.9 was noticeably active during the colder months.

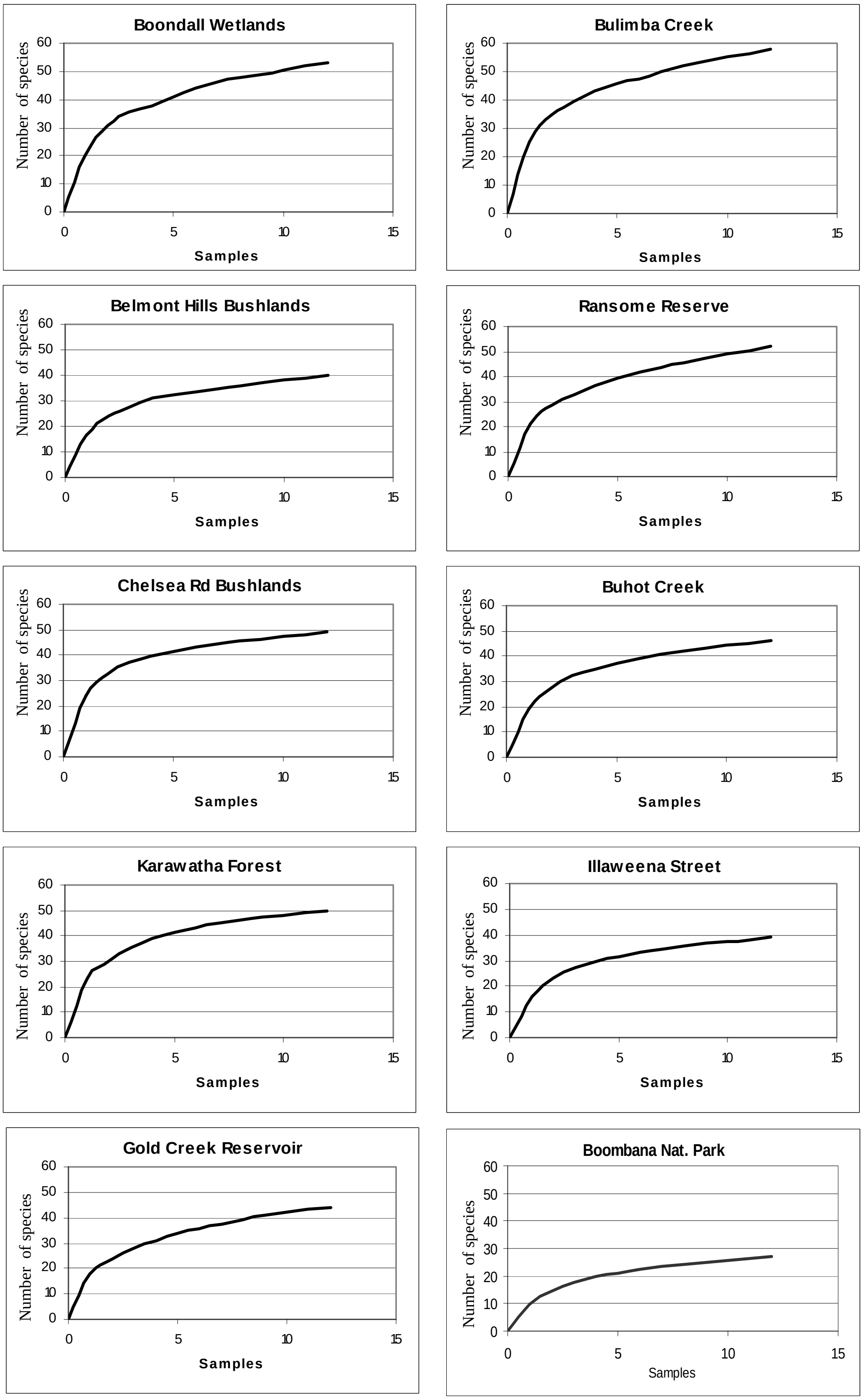


Figure 21. Randomised species accumulation curves generated from relative abundance data of ant species collected in pitfall traps from each individual site.

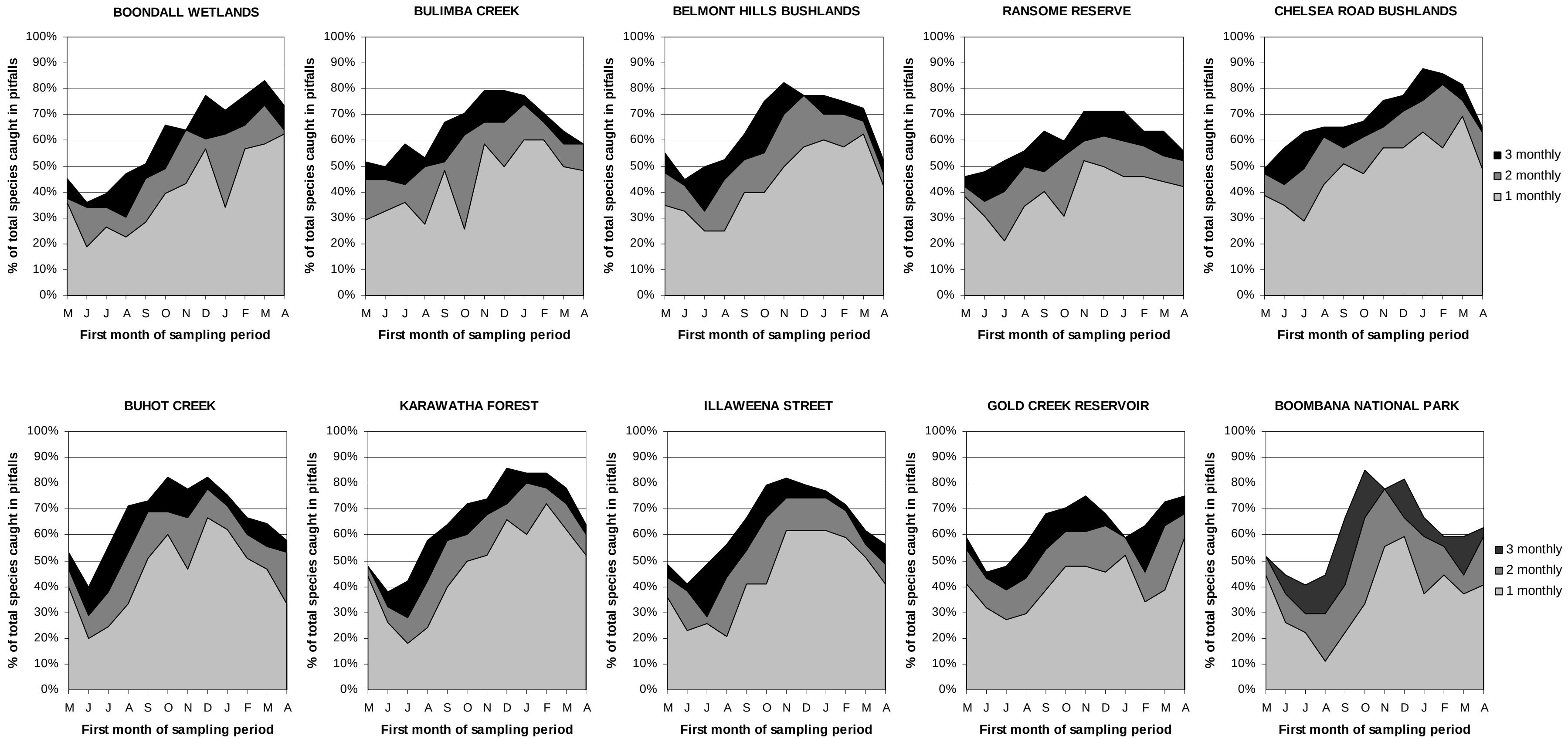


Figure 22. Ant species captured by pitfall traps each month (light grey portion of graph) by pitfall trapping expressed as a percentage of the total number of species collected over a full year at each of ten sites (May 2003-April 2004). The dark-grey portion represents the percentage of the total species collected in that month *plus* the subsequent month. The black portion represents the same, but for that month *plus* the subsequent two months. For example in the values for December: the light-grey is the percentage of species captured in December only; the dark grey the percentage collected in December and January; and the black the percentage collected in December, January and February.

Conclusions

1. This study represents one of the most comprehensive surveys of the ant fauna of natural reserves in a large metropolitan centre, especially with regard to variety of collecting techniques employed and the long duration of the sampling program. Basic site inventories for ants are uncommon both in Australia and elsewhere and rarely if ever concentrate on fragmented urban environments. The paucity of such surveys is reflected in some of the key findings of this study, namely significant range extensions of genera and species, and records of very rare species. It is clear that metropolitan Brisbane’s network of bushland reserves harbour a very diverse ant fauna and that numerous ant species are present at any given site.

2. The composition of ant species varies dramatically between rainforest and open forest habitats. In addition, within open forests, different vegetation communities have different ant assemblages, both in terms of the species present and their relative abundances. Further survey work, incorporating replicate sites is required to determine if ant community structure is linked to particular vegetation communities. Investigation of other rainforest communities is also likely to substantially increase the number of ant species known from metropolitan Brisbane.

3. At the vast majority of sites introduced ant species were present in only low abundances. The dominance of the introduced Coastal Brown Ant, *Pheidole megacephala* at the Gold Creek Reservoir site is cause for concern as there is increasing evidence that this species can invade natural habitats with detrimental effects on native ant communities and possibly those of other invertebrates. Ascertaining the extent of the infestation at Gold Creek Reservoir and its effects on native ants could be the focus of a future study. Perhaps management practices could be modified to reduce the spread of this pest ant.

4. The baseline data collected from this survey is invaluable as they can be used to monitor faunal changes over time such as responses to habitat degradation, invasions by exotic species, and responses to climate change. Ants have been widely used in Australia as bioindicators of environmental change and there is great potential to use this group to investigate the impact of various management practices.

5. The study clearly demonstrates that a variety of different sampling techniques are required to adequately document the ant fauna of a particular site. In particular hand collecting and pitfall trapping are very productive techniques to sample the ground active fauna. However, any sampling program should also include leaf litter extracts and some other method to sample the arboreal ant fauna.

6. The marked seasonality in ant abundance found in this study demonstrates that summer is the optimal period in which to use pitfall traps to sample ants, particularly if time and resources are limited.

SUCKING BUGS (HETEROPTERA) OF BRISBANE CITY

The sucking bugs comprise one of the major orders (Heteroptera) of the insects and are characterised by having their feeding apparatus in the form of a cylindrical, piercing rostrum beneath the head through which they suck liquids as food. This feature makes them fairly easy to recognise. The vast majority feed on the sap of plants and so the group as a whole is linked to the plants in the environment. Some groups, especially the well known assassin bugs (Family Reduviidae) are predatory, feeding on the juices of other insects.

About seventeen families of sucking bugs were collected during the BCC survey and, of these, the following three families were selected for critical sorting to species. The distribution of species of these families across the 10 sites is summarised in Appendix 14.

Lygaeidae (seed bugs)

This is a very large group of small, active bugs which specialise on seed feeding, using their sharp proboscis to pierce the hard seed coat and suck the nutritious sap from the inner tissues. The family has been divided into a number of smaller, separate families recently but the old usage is followed for simplicity here. The Australian species have been catalogued by Cassis & Gross (2002) who recognised 338 species. During the BCC survey a rich fauna of 62 species was collected representing about a fifth of the total Australian species (Appendix 14). A range of 18 species are shown in Figs 26 and Fig. 27a-f. Most species live among the leaf litter where they hunt for fallen seeds (e.g. *Ethaltomarus terraereginae*, Fig. 26f) and some of these have reduced wings (e.g. *Neolethaeus armstrongi*, Fig 26l) or mimic ants (e.g. *Daerlac nigricans*, Fig. 26d). Others live up on the plant where they suck seeds within the inflorescence (e.g. *Oxycarenus luctuosus*, Fig. 27b and *Nysius clevelandensis*, Fig. 27a) or have come to mimic grass seeds (e.g. *Heinsius explicatus*, Fig. 26i). Others feed on the toxic sap of plants such *Parsonsia* and have bright colours to advertise their own toxicity (e.g. *Scopiastes bicolor*, Fig. 27e and *Spilostethus decoratus*, Fig. 27f).

During the survey the ground species were sampled mostly by Berlese extraction of leaf litter and the others came from sweep samples of vegetation. The numbers of species at each site are shown in Fig. 23. Gold Creek and Chelsea Road were richest with 20 and 17 species, respectively, most of these being ground species. This element was almost absent from Karawatha which had the smallest fauna of only 6 seed bug species. The uniqueness of the Boombana rainforest fauna is illustrated by the fact that though it had only 10 species, 9 of them occurred at none of the other sites.

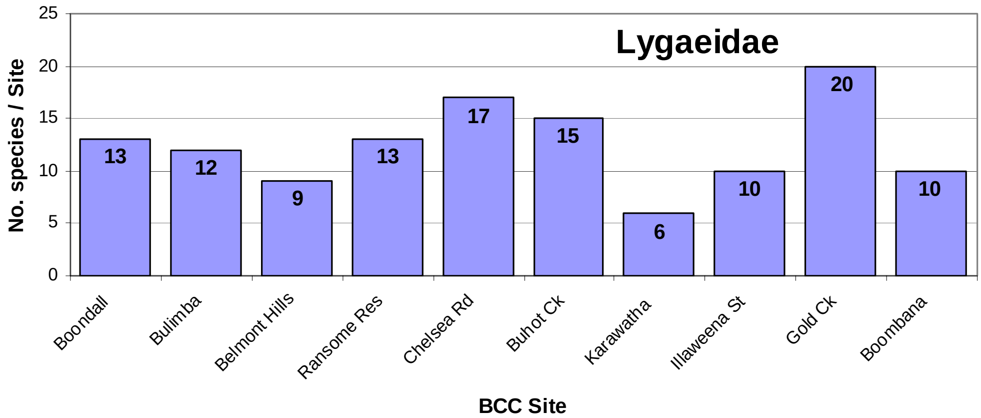


Figure 23. Overall species richness of Lygaeidae (seed bugs) across the 10 survey sites.

Tingidae (lace bugs)
This family is characterised by delicate and complex surface structures, giving them a striking appearance. They all feed directly on plant juices. The Australian fauna has been catalogued by Cassis & Gross (1995) who recognised 147 species. The BCC survey obtained only 10 species Appendix 14) which is clearly only a partial sample. Low numbers of species, at most four, were recorded from any one site (Fig. 24). Commonest were species of *Epimixia* (Fig. 27i) which were swept from their host plant, *Casuarina*, at all sites where the trees occurred. The three species of lace-bugs taken at Boombana were all unique to that site. Most striking was the large, broad *Allocader cordatus* (Fig. 27g) which belongs to the rare subfamily Cantacaderinae.

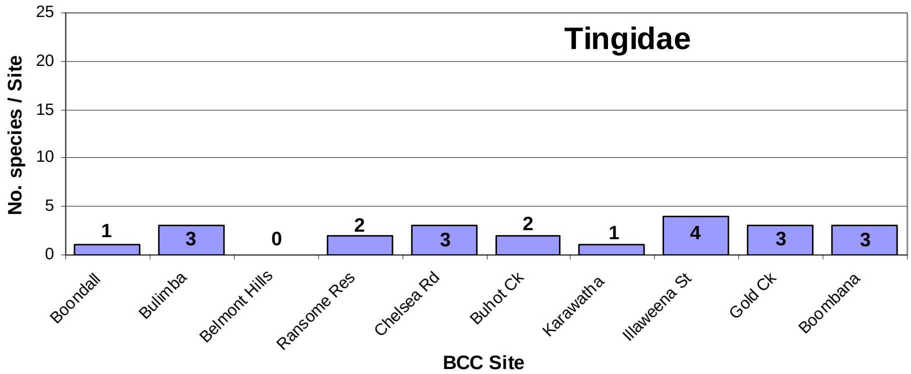


Figure 24. Overall species richness of Tingidae (lace bugs) across the 10 survey sites.

Aradidae (flat bugs)
Flat bugs are unusual among the sucking bugs in feeding on juices of wood decaying fungi which they tap by very long stylets inserted into the wood. Feeding is a slow process and the species have evolved a cryptic appearance to protect themselves during this process. Many rainforest species have lost their wings and live in the litter layer. The catalogue of Cassis & Gross (2002) listed 147 species from Australia. Twelve species were taken during the BCC survey (Appendix 14), including Australia's largest, *Drakiessa hackeri* (Fig. 27l), from Belmont Hills. Commonest was the unusual wing dimorphic species, *Carventus brachypterus*, which was taken in ground litter or in pitfall traps at seven of the open forest sites. A surprising diversity of 4 species of *Calisius* (Fig. 27k) was encountered, minute flat bugs that were all taken by pyrethrum spraying on eucalypt trunks. Both species from the rainforest at Boombana were flightless, typical of that habitat, and occurred at none of the other sites.

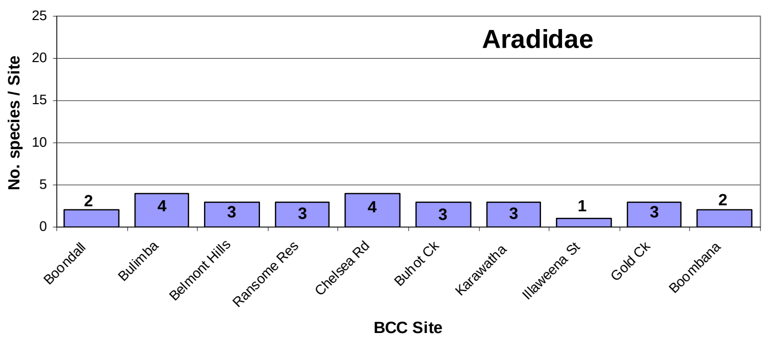


Figure 25. Overall species richness of Aradidae (flat bugs) across the 10 survey sites.

Figure 26. FAMILY LYGAEIDAE (seed bugs). **a.** *Brentiscerus obscurus*, **b.** *Crompus oculatus*, **c.** *Cymoninus sechellensis*, **d**. *Daerlac nigricans*, **e**. *Dieuches maculicollis*, **f.** *Ethaltomarus terraereginae*, **g.** *Euander torquatus*, **h.** *Geocoris woodwardi*, **i.** *Heinsius explicatus*, **j.** *Horridipamera robusta*, **k.** *Myocara* sp.3, **l.** *Neolethaeus armstrongi.*

Figure 27. FAMILY LYGAEIDAE (seed bugs): **a.** *Nysius clevelandensis*, **b.** *Oxycarenus luctuosus*, **c.** *Paramyocara irridescens*, **d**. *Scolopostethus* sp.1, **e**. *Scopiastes bicolor*, **f.** *Spilostethus decoratus*. FAMILY TINGIDAE (lace bugs): **g.** *Allocader cordatus*, **h.** *Australotingis* sp.1, **i.** *Epimixia* sp.1. FAMILY ARADIDAE (flat bugs): **j**. *Brachyrhynchus australis*, **k.** *Calisius* sp.1, **l.** *Drakiessa hackeri.*

BEETLES (COLEOPTERA) OF BRISBANE CITY

The beetles belong to the largest Order of insects with tens of thousands of species worldwide. They are easy to recognise because of their forewings which form heavy covers for their delicate hindwings. During the BCC survey, more than 40 families were taken. Three family groups of contrasting feeding habits have been processed for this report. The distribution of species of these families across the 10 sites is summarised in Appendices 15-17

Carabidae (Ground beetles)

The Carabidae is a very large group of beetles which are almost all predators, equipped with prominent jaws with which they attack and dismember other insects as food. They are most abundant on the ground, hence their common name of "ground beetles", but a large component live on tree trunks and this group is exceptionally well developed in Australia where the flaky bark of eucalypts forms ideal habitat. For discussion, it is useful to separate local faunas into these two components, the ground loving "geophiles" and the tree trunk "arboreals". The geophiles are readily sampled by pitfall traps and litter extracts, while the arboreal fauna is obtained by pyrethrum spraying of tree trunks.

The Australian fauna has been catalogued by Moore, Weir & Pyke (1987) who listed about 1800 species, with more than 100 extra species having been described since then. During the BCC survey, no less than 72 species were recorded, with arboreals (39 species) slightly outnumbering the geophiles (33 species). A selection of 24 of these diverse Brisbane species are illustrated in Figures 31 and 32. Among the arboreals the collection included 8 species of the distinctive ant-predator subfamily Pseudomorphinae (*Adelotopus*, Fig. 31a, and *Sphallomorpha*, Fig. 32j) and more than 20 species of the Lebiini (*Demetrida*, Fig. 31f,g,h; *Agonocheila*, Fig. 31b; *Philophloeus*, Fig. 32g). Both these groups have radiated on eucalypt trunks in Australia. Among the geophiles were the primitive snail-eating genus, *Pamborus* (Fig. 32f) from Illaweena Street, the swamp-loving *Platycoelus prolixus* (Fig. 32h) from Boondall Wetlands, and the large, wingless, rainforest burrower *Castelnaudia wilsoni* (Fig. 31d) from Mt Glorious.

Overall numbers of species of carabids at each site are given in Fig. 28. The richest sites were those in which the number of arboreals was very high. For example the 21 species at Buhot Creek include 16 species of arboreals. At Karawatha Forest Park only one geophile species was taken compared to 13 arboreals. In contrast, at nearby Illaweena Street 10 species of geophiles exceeded the 8 arboreals collected.

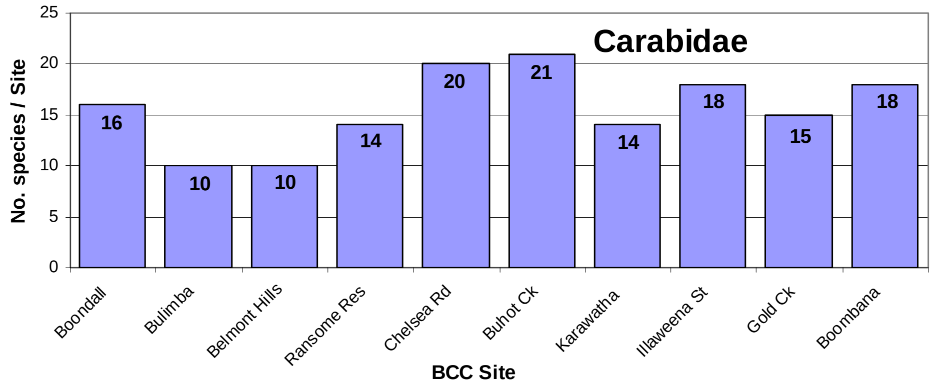


Figure 28. Overall species richness of Carabidae (ground beetles) across the 10 survey sites.

Scarabaeinae (Dung beetles)

The subfamily Scarabaeinae of the large beetle family Scarabaeidae contains beetles which specialize on mammalian dung as food, This group has been widely promoted as an ideal indicator group for biodiversity surveys (Halffter & Favila 1993; Favila & Halffter 1997). They were paid special attention during the BCC survey. A number of introduced African dung beetle species have been liberated in Australia to bury cattle dung. Several of these occur in the Brisbane area but they were not dealt with in this survey.

An attempt was made to estimate the total Brisbane fauna of dung beetles by drawing on 3 sources, viz. the published literature, the extensive prior holdings of Brisbane dung beetles in the Queensland Museum, and the current survey trapping at the BCC sample sites. For the purposes of the literature survey and the database search of the Museum collection, the "Brisbane area" was defined as extending north to Redcliffe, west to Mt Glorious and Ipswich, south to Beenleigh and east to the coast. The earliest reliable literature sources are the systematic monographs of Matthews (1972, 1974, 1976) which review the whole Australian fauna. Since that time additional Brisbane records have been published by Matthews & Stebnicka, (1986) and Storey (1974a, b). These publications provided records of 44 species from the region. The collection of the QM has specimens of 35 species from the region of which 11 are additional to the literature records.

Table 8. Compilation of records for 63 species of native dung beetles (Scarabaeinae) in the Brisbane area.

Dung Beetle species	Published Records	Specimen record in Qld Museum	Recorded during BCC Survey
Amphistomus calcaratus		X	
Amphistomus montanus	Matthews (1974)	X	
Amphistomus storeyi		X	X
Aulacopris maximus	Matthews (1974)	X	
Boletoscapter furcatus	Matthews (1974)		X
Canthonosoma castelnaui	Matthews (1974)	X	
Cephalodesmius armiger	Matthews (1974)	X	
Cephalodesmius quadridens	Matthews (1974)	X	X
Demarziella geminata	Matthews (1976)		
Demarziella interrupta	Matthews (1976)		X
Demarziella metallica	Matthews & Stebnicka (1986)		X
Demarziella pratensis	Matthews & Stebnicka (1986)		
Demarziella sp 1			X
Demarziella sp 2			X
Diorygopyx tibialis	Matthews (1974)	X	X
Lepanus CQ1			X
Lepanus politus	Matthews (1974)		X
Lepanus ustulatus	Matthews (1974)	X	X
Monoplistes leai	Matthews (1974)	X	X
Onthophagus anchommatus	Matthews (1972)		
Onthophagus arrilla		X	X
Onthophagus atrox	Matthews (1972)		
Onthophagus auritus	Matthews (1972)	X	X
Onthophagus australis	Matthews (1972)		
Onthophagus bicarinaticeps		X	
Onthophagus bornemisszai		X	X
Onthophagus capella	Matthews (1972)	X	X

Table 8 continued. Compilation of records for 63 species of native dung beetles (Scarabaeinae) in the Brisbane area.

Dung Beetle species	Published Records	Specimen record in Qld Museum	Recorded during BCC Survey
Onthophagus consentaneus	Matthews (1972)	X	
Onthophagus CQ2			X
Onthophagus CQ8		X	
Onthophagus dandalu	Matthews (1972)	X	X
Onthophagus desectus	Matthews (1972)		
Onthophagus dunningi	Matthews(1972);Storey (1974b)	X	X
Onthophagus granulatus	Matthews (1972)	X	
Onthophagus incornutus		X	X
Onthophagus koebelei	Matthews (1972)		
Onthophagus kokereka		X	X
Onthophagus leanus		X	X
Onthophagus macleayi	Matthews (1972)		
Onthophagus mamillatus	Matthews (1972)	X	
Onthophagus manya		X	X
Onthophagus millamilla	Matthews (1972)		X
Onthophagus muticus	Matthews (1972)		
Onthophagus neostenocerus	Matthews (1972)	X	X
Onthophagus nodulifer	Matthews (1972)		
Onthophagus parvus	Matthews (1972)		
Onthophagus peramelinus	Matthews (1972)		
Onthophagus perpilosus	Matthews (1972)		
Onthophagus phoenicocerus	Matthews (1972)		
Onthophagus pugnax	Matthews (1972)		X
Onthophagus quadripustulatus	Matthews (1972)	X	X
Onthophagus rubicundulus		X	X
Onthophagus rubrimaculatus	Matthews (1972)		
Onthophagus rufosignatus		X	
Onthophagus semimetallicus		X	
Onthophagus squalidus		X	X
Onthophagus subocelliger	Matthews (1972)		
Onthophagus sydneyensis	Matthews (1972)	X	X
Onthophagus tenebrosus			X
Onthophagus thoreyi	Matthews (1972)		
Onthophagus tuckonie	Storey (1974a)	X	X
Onthophagus tweedensis	Matthews (1972)	X	X
Onthophagus walteri	Matthews (1972)	X	

The BCC survey trapped 33 species, of which 3 were new records for the region. Most notable is the large, rugose *Onthophagus tenebrosus* (Fig. 34e) which was detected at Karawatha Forest Park and Illaweena Street but had not been previously taken closer to Brisbane that Stanthorpe and the Darling Downs. The other two new records were of undescribed species known previously from slightly north of Brisbane, viz. *Lepanus CQ1* (Bulimba, Gold Creek, Boombana) and *Onthophagus CQ2* (Boombana).

The cumulative total for Brisbane from all sources is shown in Table 8 which lists 63 species. Currently the Australian dung beetle fauna is known to comprise about 389 species so the Brisbane fauna represents about one sixth of the entire Australian fauna. A selection of the species taken during the BCC survey are shown in Figures 33 and 34a-f. Highest numbers were taken at Boombana (22 species) with substantial numbers also being taken at Belmont

Hills and Buhot Creek (both 13 species) (Fig. 29). These were all sites at which evidence of macropods was regularly seen. Very low dung beetle numbers were found at Ransome Reserve (1 sp.), Boondall (2 spp.) and Chelsea Road (3 spp.) (Fig. 29) and this may be related to low mammal numbers at these sites. The high species numbers at Boombana included 9 which were not taken at any of the Brisbane lowland sites, evidence of the distinctive nature of the upland rainforest fauna at Boombana NP.

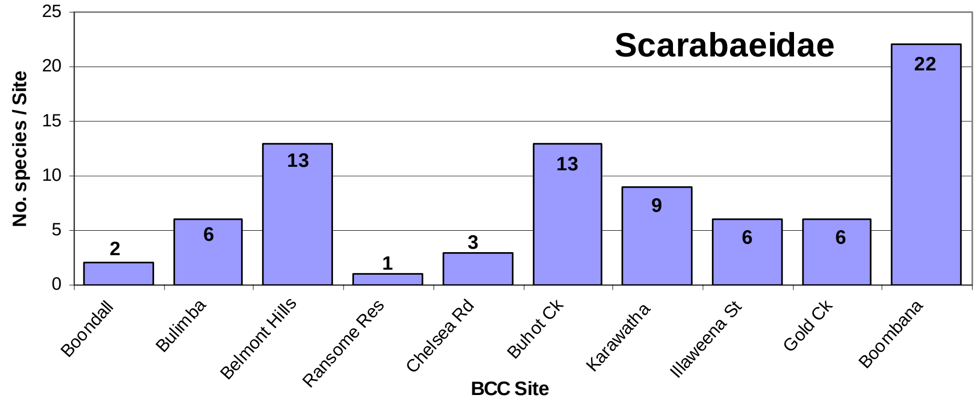


Figure 29. Overall species richness of Scarabaeinae (dung beetles) across the 10 survey sites.

Tenebrionidae (Darkling Beetles)

This large family of beetles is very diverse in form and habits but most feed on dead and decaying vegetable matter which places the group as a major decomposer element in local ecosystems. The Australian fauna is not well documented but is estimated to number about 1500 species (Lawrence & Britton 1991). The BCC survey obtained 49 species and 18 of these are illustrated in Figs 34g-l and 35. The subfamily Adeliinae is a primitive group of mostly wingless species which has Gondwanaland affinities. There were 16 species taken in the genera *Adelium*, *Cardiothorax*, *Coripera*, *Leptogastrus*, *Licinoma*, *Nolicima* and *Seirotrana* and many of these have rather localised distributions within the survey sites. Numbers of overall species at the sites are shown in Fig. 30. Boombana (18 spp., including 9 not taken elsewhere) and Belmont Hills (17 spp, including 6 not taken elsewhere) were the most diverse.

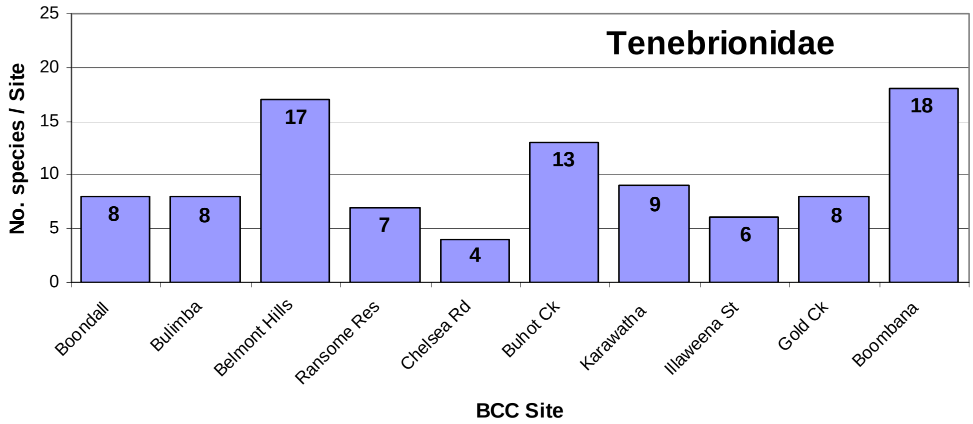


Figure 30. Overall species richness of Tenebrionidaae (darkling beetles) across the 10 survey sites.

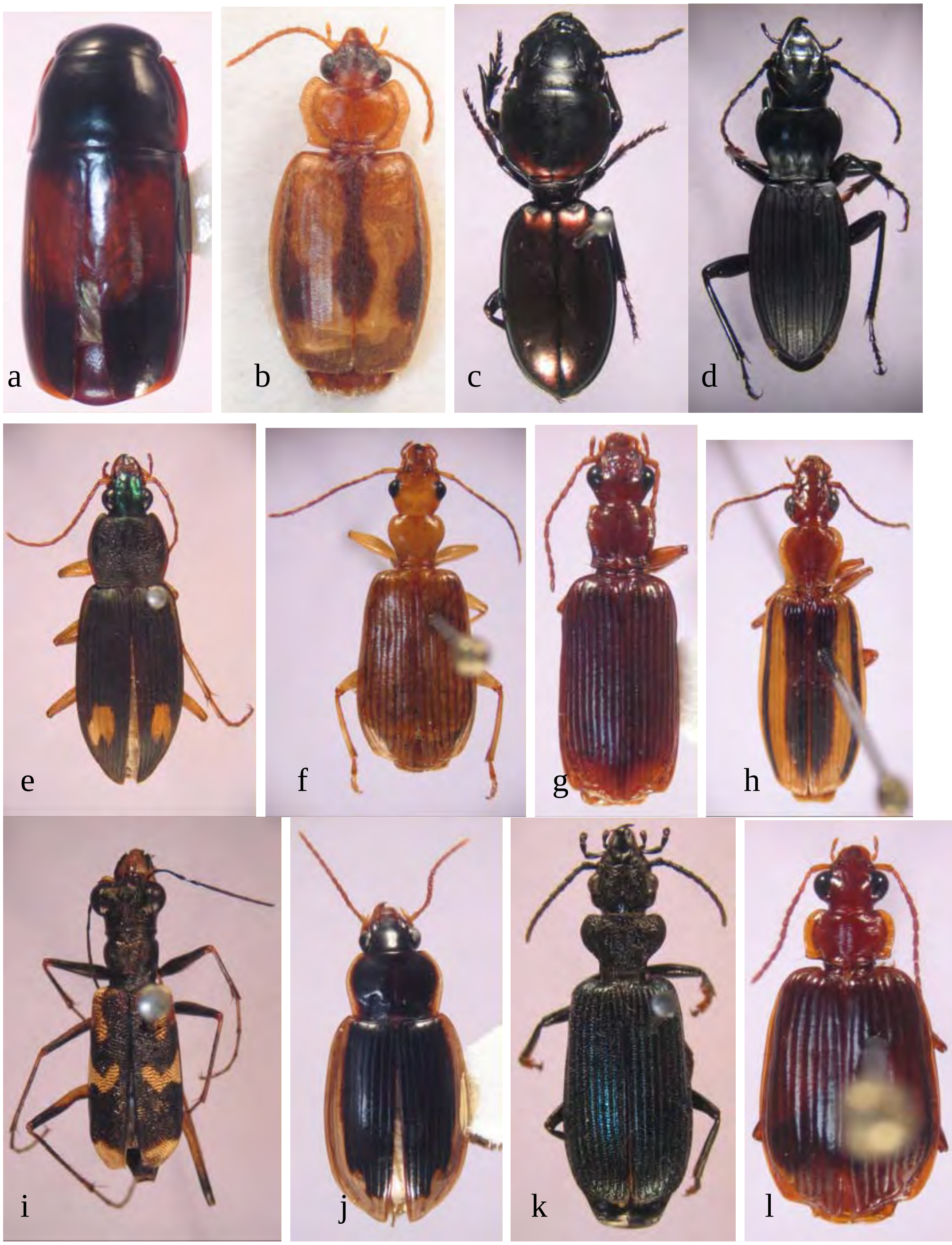


Figure 31. FAMILY CARABIDAE (ground beetles) **a.** *Adelotopus bimaculatus*, **b.** *Agonocheila punctata*, **c.** *Carenum brisbanense*, **d**. *Castelnaudi*a *wilsoni*, **e.** *Chlaenius flaviguttatus*, **f.** *Demetrida brachinodera*, **g.** *Demetrida longicornis*, **h.** *Demetrida vittata*, **i.** *Distipsidera flavicans*, **j.** *Harpaline* sp.1, **k.** *Helluonidius cyaneus*, **l.** *Lebia papuensis.*

Figure 32. FAMILY CARABIDAE (ground beetles) **a.** *Mecyclothorax punctipennis*, **b.** *Minuthodes minima*, **c.** *Notagonum submetallicum*, **d**. *Notiobia* sp.1, **e**. *Notonomus* sp.1, **f.** *Pamborus alternans*, **g.** *Philophloeus* sp., **h.** *Platycoelus prolixus*, **i.** *Setalis niger*, **j.** *Sphallomorpha maculigera*, **k.** *Trigonothops* sp.1, **l.** *Trigonothops* sp.2.

Figure 33. FAMILY SCARABAEIDAE (dung beetles) **a.** *Amphistomus storeyi*, **b.** *Boletoscapter furcatus*, **c.** *Cephalodesmius quadridens*, **d**. *Demarziella interrupta*, **e**. *Diorygopyx tibialis* **f.** *Lepanus ustulatus*, **g.** *Monoplistes leai*, **h.** *Onthophagus bornemisszai*, **i.** *Onthophagus capella*, **j.** *Onthophagus dandalu*, **k.** *Onthophagus dunningi*, **l.** *Onthophagus incornutus.*

Figure 34. FAMILY SCARABAEIDAE (dung beetles) **a.** *Onthophagus kokereka*, **b.** *Onthophagus manya*, **c.** *Onthophagus neostenocerus*, **d**. *Onthophagus rubicundulus*, **e**. *Onthophagus tenebrosus*, **f.** *Onthophagus tweedensis*, FAMILY TENEBRIONIDAE (darkling beetles) **g.** *Achthosus westwoodi*, **h.** *Adelium pilosum*, **i.** *Adelium reductum*, **j.** *Adelium striatum*, **k.** *Aethyssius viridis*, **l.** *Apterotheca* sp.1.

Figure 35. FAMILY TENEBRIONIDAE (darkling beetles) **a.** *Cardiothorax errans*, **b.** *Cardiothorax macleayi*, **c.** *Coripera mastersi*, **d**. *Dimorphochilus pascoei*, **e**. *Ecnolagria aurofasciata* **f.** *Emcephalus floccosus*, **g.** *Euomma lateralis*, **h.** *Licinoma* sp.1, **i.** *Meneristes* sp.1, **j.** *Pterohelaeus walkeri*, **k.** *Seirotrana catenulata*, **l.** *Seirotrana* sp.1.

BUTTERFLIES OF BRISBANE CITY

Overall species richness and diversity

A total of 82 species of butterflies were recorded during the survey and their distribution across the 10 sites is presented in Appendix 18. Common names follow Braby (2000). All of the species recorded during the survey are known from the Brisbane area. None of the species collected during the survey are protected by either State or Federal legislation.

Table 9 lists 165 species of butterflies that have been recorded from the "Brisbane area", either from the current survey, from published records or from personal communications (D. Sands). This is not a definitive list of butterflies from metropolitan Brisbane. Hill & Kitching (1983), upon which Table 10 is substantially based, listed species from the Brisbane area and their occurrence within Brisbane city is not guaranteed. Conversely, there are several substantial insect collections (including those of private collectors) that probably contain data on additional species from Brisbane city. It would be a useful exercise to compile a definitive list of the butterflies species recorded from Brisbane city.

About half of the species listed from the Brisbane area were recorded during the survey, an appreciable number given that the collection effort devoted to butterflies was not particularly intensive. In total, nine person hours of hand netting was conducted at each site. Butterfly species observed while conducting other sampling methods were also noted. At some sites, extra hand netting was carried out in addition to the standard sampling protocol. This was particularly the case at Illaweena Street where many butterfly species were collected from flowering *Leptospermum* in September 2003. As a result, sampling effort was not even across sites and species richness values cannot reliably be used to compare sites. A selection of butterfly species recorded during the survey are presented in Figures 37-41.

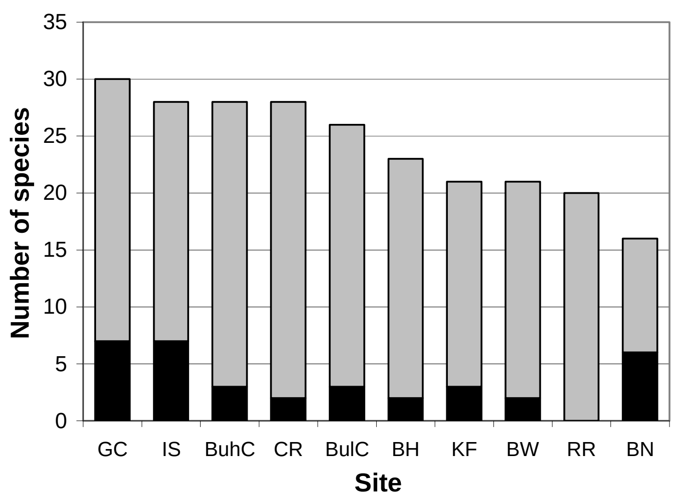


Figure 36. Overall butterfly species richness across the 10 survey sites. The black area at the base of each bar is the number of species collected only at that site. [GC - Gold Creek Reservoir; IS – Illaweena St, Drewvale; CR – Chelsea Road Bushlands; BuhC – Buhot Creek, Burbank; BulC – Bulimba Creek, Carindale; BH – Belmont Hills Bushland Reserve; KF – Karawatha Forest Park; BW – Boondall Wetlands; RR – Ransome Reserve; BN – Boombana NP].

Between 20 and 30 butterfly species were recorded from most sites (Fig. 36). Only 16 species were recorded from Boombana NP but the vegetation structure of this site, rainforest is not conducive to hand netting butterfly species at ground level. Species inventories from all sites will be far from complete and far more intensive sampling is required. Even within suburban situations, the butterflies at a given site can be quite diverse. Hill and Kitching (1983) recorded 48 butterfly species from Sunnybank. Schmidt and Rice (2002) provided distribution records for many species of lycaenid butterflies (blues and coppers) in suburban Brisbane. They found that many species are able to tolerate human disturbance and are able to breed on suitable garden or street trees, sometimes even within the central business district. Selection of street trees that are food plants, particularly those that can support parasitic mistletoes, themselves food plants of several species, may increase the diversity of butterflies in suburban settings. However preservation of natural bushland remnants is important to maintain local populations of species with food plants that are not well represented in urban landscapes (Schmidt & Rice 2002).

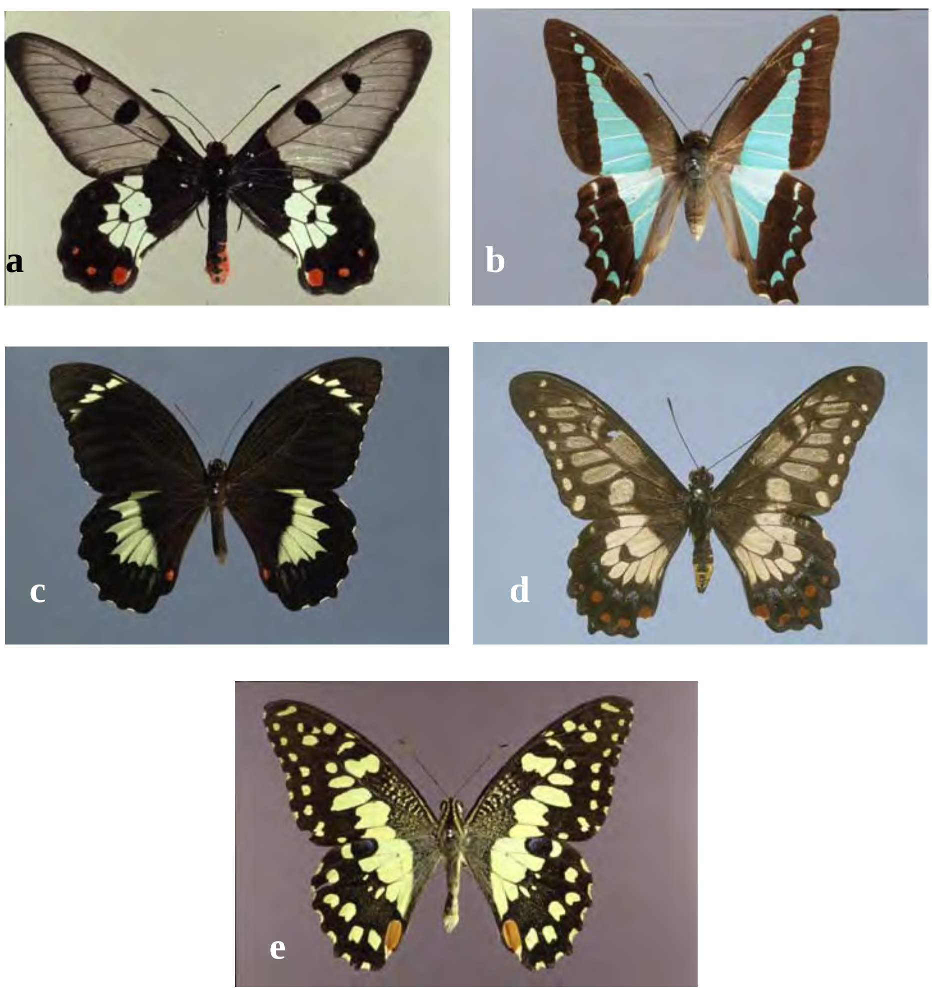


Figure 37. FAMILY PAPILIONIDAE. **a.** Clearwing Swallowtail, *Cressida cressida cressida*. **b.** Blue Triangle, *Graphium sarepdon*. **c.** Orchard Swallowtail, *Papilio aegeus*. **d.** Dingy Swallowtail, *Papilio anactus*. **e.** Chequered Swallowtail, *Papilio demoleus sthenelus*.[not to scale].

Figure 38. FAMILY PIERIDAE: **a.** Caper White, *Belenois java*. **b.** Lemon Migrant, *Catopsilia pomona*. **c.** Black Jezebel, *Delias nigrina* underside. **d.** Black Jezebel, *Delias nigrina* upperside. **e.** Southern Pearl-white, *Elodina angulipennis*. **f.** Yellow Albatross *Appias paulina*. **g.** No-brand Grass-yellow, *Eurema brigitta*. **h.** Large Grass-yellow, *Eurema hecabe*. [not to scale].

Figure 39. FAMILY NYMPHALIDAE: **a.** Swamp Tiger *Danaus affinus*. **b.** Lesser Wanderer, *Danaus chrysippus petilia*. **c.** Wanderer, *Danaus plexippus*. **d.** Common Crow, *Euploea core corinna*. **e.** Blue Tiger, *Tirumala hamata hamata*. **f.** Glasswing, *Acraea andromacha andromacha*.[not to scale].

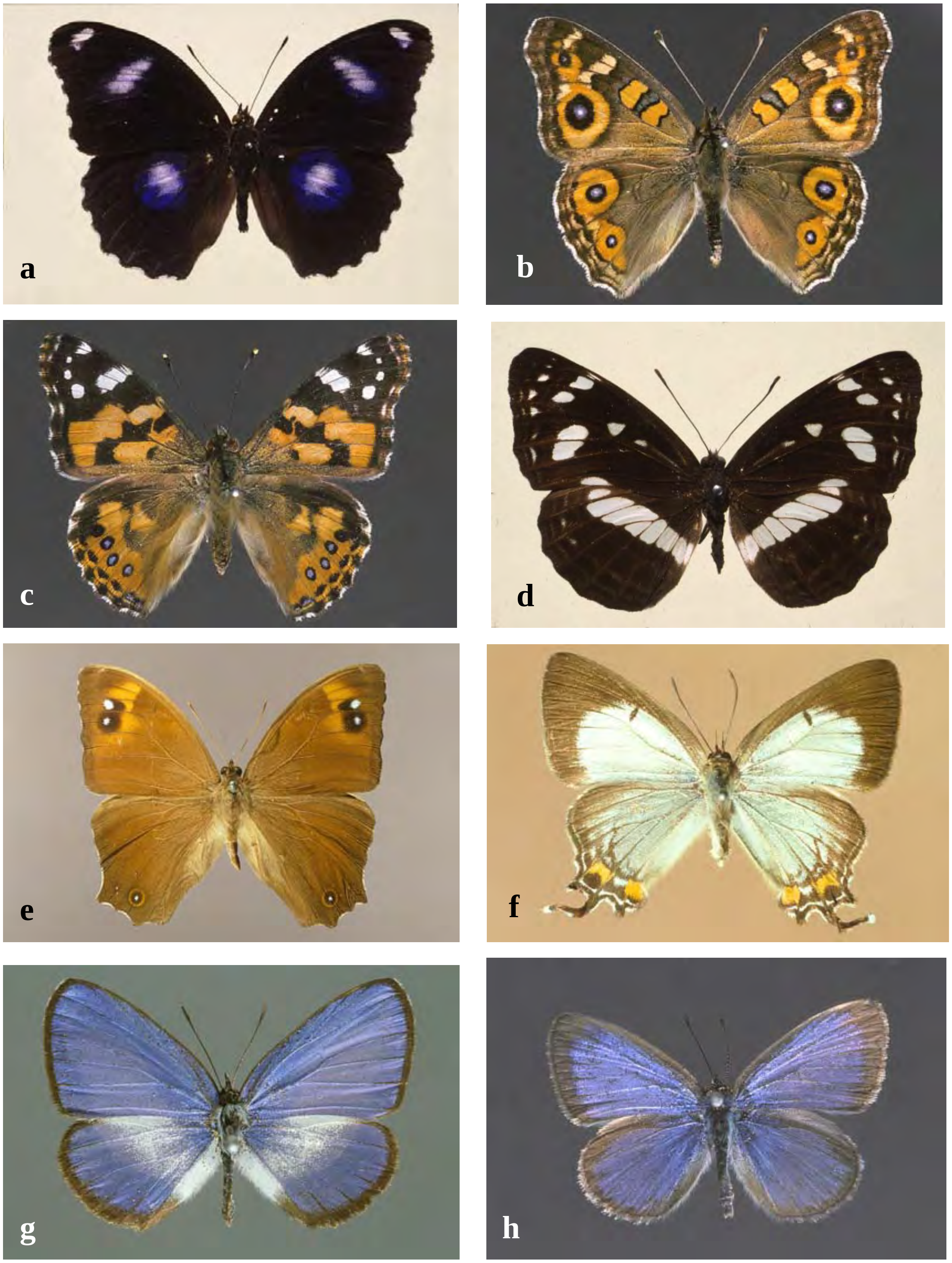


Figure 40. FAMILY NYMPHALIDAE: **a.** Varied Eggfly, *Hypolimnas bolina nerina*. **b.** Meadow Argus, *Junonia villida calybe*. **c.** Australian Painted Lady, *Vanessa kershawi* **d.** Common Aeroplane, *Phaedyma shepherdi shepherdi*. **e.** Evening Brown, *Melanitis leda bankia*. FAMILY LYCAENIDAE: **f.** Imperial Hairstreak, *Jalmenus evagorus*. **g.** Small Green Line-blue, *Psychonotis caelius*. **h.** Common Grass-blue, *Zizina labradus*. [not to scale].

Figure 41. FAMILY HESPERIIDAE: **a.** Narrow-winged Awl, *Badamia exclamationis*. **b.** Orange Palm-dart, *Cephrenes augiades sperthias*. **c.** Regent Skipper, *Euschemon rafflesia rafflesia.* **d.** White-margined Grass-dart, *Ocybadistes hypomeloma*, upperside, **e.** Splendid Ochre, *Trapezites symmomus*. **f.** Wide-brand Grass-dart, *Suniana sunias*. **g.** Orange Ochre, *Trapezites eliena*. **h.** Orange Ochre, underside (not to scale).

Table 9. Butterfly species occurring in the "Brisbane area" compiled from published records (Hill & Kitching 1983; Schmidt & Rice 2002; Sands 2004), D. Sands pers comm.) and the current survey. * species recorded during this survey.

Hesperiidae	
Arrhenes marnas affinis	Swamp Darter
Badamia exclamationis	Narrow-winged Awl*
Cephrenes augiades sperthias	Orange Palm-dart*
Cephrenes trichopepla	Yellow Palm-dart
Chaetocneme beata	Eastern Dusk-flat
Chaetocneme denitza	Ornate Dusk-flat
Dispar compacta	Barred Skipper
Euschemon rafflesia rafflesia	Regent Skipper*
Hasora chromus chromus	Chrome Awl
Hasora discolor mastusia	Green Awl
Hasora khoda haslia	Narrow-banded Awl*
Hesperilla crypsigramma	Wide-brand Sedge-skipper
Hesperilla donnysa donnysa	Varied Sedge-skipper
Hesperilla malindeva malindeva	Two-spotted Sedge-skipper*
Hesperilla ornata ornata	Spotted Sedge-skipper*
Hesperilla picta	Painted Sedge-skipper
Mesodina halyzia	Eastern Iris-skipper*
Neohesperilla xanthomera	Yellow Grass-skipper
Netrocoryne repanda repanda	Bronze Flat
Ocybadistes ardea heterobathra	Orange Grass-dart
Ocybadistes flavovittatus flavovittatus	Narrow-brand Grass-dart*
Ocybadistes hypomeloma hypomeloma	White-margined Grass-dart*
Ocybadistes walkeri sothis	Green Grass-dart*
Parnara amalia	Orange Swift*
Parnara bada sida	Grey Swift*
Pelopidas agna dingo	Dingy Swift*
Pelopidas lyelli lyelli	Lyell's Swift
Suniana lascivia lascivia	Dingy Grass-dart
Suniana sunias nola	Wide-brand Grass-dart*
Taractrocera anisomorpha	Large Yellow Grass-dart
Taractrocera dolon dolon	Small Yellow Grass-dart
Taractrocera ina	No-brand Grass-dart*
Taractrocera papyria papyria	White Grass Dart
Telicota ancilla ancilla	Green Darter*
Telicota anisodesma	Southern Large Darter
Telicota colon argeus	Pale-orange Darter*
Toxidia doubledayi	Lilac Grass-skipper*
Toxidia parvula	Banded Grass-skipper
Toxidia peron	Dingy Grass-skipper*
Toxidia rietmanni rietmanni	White-brand Grass-skipper*
Trapezites eliena	Orange Ochre*

Table 9 continued. Butterfly species occurring in the "Brisbane area" compiled from published records (Hill & Kitching 1983; Schmidt & Rice 2002; Sands 2004 and Sands pers comm.) and the current survey.
* species recorded during this survey.

Trapezites iacchus	Brown Ochre*
Trapezites lutea	Yellow Ochre
Trapezites maheta	Northern Silver Ochre*
Trapezites petalia	Black-ringed Ochre*
Trapezites praxedes	Southern Silver Ochre
Trapezites symmomus symmomus	Splendid Ochre*
Papilionidae	
Cressida cressida cressida	Clearwing Swallowtail*
Graphium eurypylus lycaon	Pale Triangle*
Graphium macleayanum macleayanum	Macleay's Swallowtail*
Graphium sarpedon choredon	Blue Triangle*
Ornithoptera richmondia	Richmond Birdwing
Papilio anactus	Dainty Swallowtail*
Papilio aegeus aegeus	Orchard Swallowtail*
Papilio demoleus sthenelus	Chequered Swallowtail*
Papilio fuscus capeneus	Fuscous Swallowtail
Protographium leosthenes leosthenes	Four-barred Swordtail
Pieridae	
Appias paulina ega	Yellow Albatross*
Belenois java teutonia	Caper White*
Catopsilia gorgophone gorgophone	Yellow Migrant
Catopsilia pomona pomona	Lemon Migrant*
Catopsilia pyranthe crokera	White Migrant*
Cepora perimale scyllara	Caper Gull*
Delias aganippe	Spotted Jezebel
Delias argenthona argenthona	Scarlet Jezebel
Delias harpalyce	Imperial White
Delias nigrina	Black Jezebel*
Delias nysa nysa	Yellow-spotted Jezebel
Elodina angulipennis	Southern Pearl-white*
Elodina padusa	Narrow-Winged Pearl-white
Elodina parthia	Striated Pearl-white*
Eurema brigitta australis	No-Brand Grass-yellow*
Eurema hecabe phoebus	Large Grass-yellow*
Eurema herla	Pink Grass-yellow*
Eurema smilax smilax	Small Grass-yellow*
Pieris rapae	Cabbage White*

Table 9 continued. Butterfly species occurring in the "Brisbane area" compiled from published records (Hill & Kitching 1983; Schmidt & Rice 2002; Sands 2004 and Sands pers comm.) and the current survey.
* species recorded during this survey.

Nymphalidae	
Acraea andromacha andromacha	Glasswing*
Cupha prosope prosope	Bordered Rustic
Danaus affinis affinis	Swamp Tiger*
Danaus chrysippus petilia	Lesser Wanderer*
Danaus plexippus plexippus	Monarch*
Doleschallia bisaltide australis	Leafwing*
Euploea core corinna	Common Crow*
Euploea darchia niveata	Small Brown Crow
Euploea tulliolus tulliolus	Purple Crow
Geitoneura acantha acantha	Ringed Xenica
Heteronympha merope merope	Common Brown
Heteronympha mirifica	Wonder Brown*
Hypocysta adiante adiante	Orange Ringlet*
Hypocysta euphemia	Rock Ringlet
Hypocysta irius	Orange-streaked Ringlet
Hypocysta metirius	Brown Ringlet*
Hypocysta pseudirius	Grey Ringlet
Hypolimnas alimena lamina	Blue-banded Eggfly
Hypolimnas bolina nerina	Varied Eggfly*
Hypolimnas misippus	Danaid Eggfly
Junonia hedonia zelima	Chocolate Argus
Junonia orithya albicincta	Blue Argus
Junonia villida calybe	Meadow Argus*
Melanitis leda bankia	Evening Brown*
Mynes geoffroyi guerini	Jezebel Nymph
Phaedyma shepherdi shepherdi	White-banded Plane*
Polyura sempronius sempronius	Tailed Emperor*
Tirumala hamata hamata	Blue Tiger*
Vanessa itea	Yellow Admiral
Vanessa kershawi	Australian Painted Lady*
Ypthima arctoa arctoa	Dusky Knight
Lycaenidae	
Acrodipsas brisbanensis	Bronze Ant-blue
Acrodipsas illidgei	Illidge's Ant-blue
Acrodipsas myrmecophila	Small Ant-blue
Candalides absimilis	Common Pencilled-blue*
Candalides acastus	Blotched Dusky-blue
Candalides consimilis consimilis	Dark Pencilled-blue
Candalides cyprotus cyprotus	Copper Pencilled-blue
Candalides erinus erinus	Small Dusky-blue*

Table 9 continued. Butterfly species occurring in the "Brisbane area" compiled from published records (Hill & Kitching 1983; Schmidt & Rice 2002; Sands 2004 and Sands pers comm.) and the current survey.
* species recorded during this survey.

Candalides heathi heathi	Rayed Blue
Candalides hyacinthinus hyacinthinus	Varied Dusky-blue*
Candalides margarita margarita	Trident Pencilled-blue
Candalides xanthospilos	Yellow Spotted-blue*
Catochrysops panormus platissa	Pale Pea-blue
Catopyrops florinda halys	Speckled Line-blue*
Deudorix diovis	Bright Cornelian
Erysichton lineata lineata	Hairy Line-blue*
Erysichton palmyra tasmanicus	Marbled Line-blue
Euchrysops cnejus cnidus	Spotted Pea-blue*
Everes lacturnus australis	Orange-tipped Pea-blue*
Famegana alsulus alsulus	Black-Spotted Grass-Blue*
Freyeria putli	Jewelled Grass-blue
Hypochrysops apelles	Copper Jewel
Hypochrysops cyane	Cyane Jewel
Hypochrysops delicia delicia	Moonlight Jewel
Hypochrysops digglesii	Silky Jewel
Hypochrysops epicurus	Mangrove Jewel
Hypochrysops ignitus ignitus	Fiery Jewel
Jalmenus daemeli	Emerald Hairstreak
Jalmenus evagoras evagoras	Imperial Hairstreak*
Jalmenus ictinus	Stencilled Hairstreak
Jamides phaseli	Purple Cerulean
Lampides boeticus	Long-tailed Pea-Blue*
Leptotes plinius pseudocassius	Plumbago Blue
Lucia limbaria	Grassland Copper
Nacaduba berenice berenice	Large Purple Line-blue*
Nacaduba biocellata biocellata	Two-spotted Line-blue*
Nacaduba kurava parma	White-banded Line-blue*
Neolucia agricola agricola	Fringed Heath-blue
Nesolycaena albosericea	Satin Opal
Ogyris amaryllis amaryllis	Satin Azure
Ogyris olane ocela	Broad-margined Azure
Ogyris oroetes oroetes	Silky Azure
Ogyris zosine zosine	Northern Purple Azure
Paralucia aurifera	Bright Copper
Paralucia pyrodiscus pyrodiscus	Fiery Copper
Philiris innotata innotata	Purple Moonbeam
Prosotas dubiosa dubiosa	Small Purple Line-blue*
Prosotas felderi	Felder's Line-blue*
Pseudodipsas cephenes	Bright Forest-blue
Psychonotis caelius taygetus	Small Green-banded Blue*

Table 9 continued. Butterfly species occurring in the "Brisbane area" compiled from published records (Hill & Kitching 1983; Schmidt & Rice 2002; Sands 2004 and Sands pers comm.) and the current survey.
* species recorded during this survey.

Rapala varuna simsoni	Indigo Flash
Sahulana scintillata	Glistening Blue*
Theclinesthes miskini miskini	Wattle Blue
Theclinesthes onycha onycha	Cycad Blue
Theclinesthes sulpitius	Samphire Blue
Zizeeria karsandra	Spotted Grass-blue*
Zizina labradus labradus	Common Grass-blue*
Zizula hylax attenuata	Dainty Grass-blue*

DRAGONFLIES AND DAMSELFLIES OF BRISBANE CITY

Adult dragonflies and damselflies were specifically targeted during bouts of hand netting. Additional species observed at other times were also noted. Species were identified using Watson *et al.* (1991), supplemented by the more recent taxonomic literature. Common names follow Hawking & Theischinger (2002). The immature stages of dragonflies and damselflies are aquatic predators and have proven to be useful indicators of the health of freshwater habitats (Watson *et al.* 1982). Keys are available to identify the larvae of most dragonfly species occurring in Brisbane (Hawking & Theischinger 1999, Theischinger 2000a, Theischinger 2001, Theischinger 2002) but no attempt was made to sample larvae during this survey. Obtaining a complete list of the adult dragonflies and damselflies of a site is difficult given that many species are rapid, agile fliers and difficult to capture. More intensive sampling than utilised during our survey would be required to obtain complete inventories.

Overall species richness and diversity.

Across all 10 sites, 34 species of Odonata were collected, 23 species of dragonflies (Anisoptera) and 11 species of damselflies (Zygoptera) (Appendix 19). None of the species recorded represented significant records, either in terms of rarity or range extensions. Some examples of species recorded during the survey are presented in Figures 42 and 43.

Published data on the distribution of dragonflies in Brisbane is scarce and generally scattered throughout the taxonomic literature. However, two studies document the odonate fauna of water bodies within the Brisbane metropolitan area, Bulimba Creek (Watson *et al.* 1982) and Enoggera Reservoir (Reeves 2002). Watson *et al.* (1982) recorded 36 species from about a 10 km stretch of the upper reaches of Bulimba Creek. Reeves (2002) recorded 26 species from Enoggera reservoir, with an additional species, *Urothemis aliena*, recorded by Burwell & Theischinger (2003).

All but five of the species from Enoggera Reservoir were recorded during the survey. Additional species from Enoggera Reservoir were, *Nannodiplax rubra*, *Aetheriamanta circumsignata*, *Macrodiplaxa cora*, *Urothemis aliena* and *Pseudagrion microcephalum*. Additional species recorded by Watson *et al.* (1982) but not collected during our survey include *Nososticta solida*, *Agriocnemis rubricunda*, *Pseudagrion aureofrons*, *P. ignifer*, *Griseargiolestes griseus*, *Austroaeschna unicornis* (larva only), *Choristhemis flavoterminata*, and *Hemicordulia tau*.

Four species collected during the survey were not recorded by Watson *et al.* (1982) nor Reeves (2002); *Aeshna brevistyla*, *Austrogynacantha heterogena*, *Hemicordulia superba* and *Ischnura aurora*.

Table 10 lists species of dragonflies and damselflies that have been recorded from Brisbane in the literature and during the survey, supplemented by additional specimen records in the Queensland Museum.

Figure 42. Representatives of dragonflies recorded during the survey. FAMILY LIBELLULIDAE: **a.** Wandering Percher, *Diplacodes bipunctata.* **b.** Scarlet Percher, *Diplacodes haematodes*. **c.** Blue Skimmer, *Orthetrum caledonicum.* **d.** Slender Skimmer, *Orthetrum sabina sabina*. **e.** Fiery Skimmer, *Orthetrum villosovittatum villosovittatum*. **f.** Red Arrow, *Rhodothemis lieftincki*. **g.** Common Glider, *Trapezostigma loewii*. **h.** Short-tailed Dusk-darter, *Zyxomma elgneri*. [not to scale].

Figure 43. Live representatives of dragonflies and damselflies recorded during the survey. FAMILY AESHNIDAE: **a.** Australian Emperor, *Hemianax papuensis*. FAMILY CORDULIIDAE: **b.** Australian Emerald, *Hemicordulia australiae*. FAMILY GOMPHIDAE: **c.** Twin-spot Hunter, *Austrogomphus melaleucae*, **d.** Australian Tiger, *Ictinogomphus australis.* FAMILY COENAGIONIDAE: **e.** Pygmy Wisp, *Agriocnemis pygmaea*, **f.** Redtail, *Ceriagrion aeruginosum.* **g.** Aurora Bluetail, *Ischnura aurora*. [not to scale].

In entries marked by an asterisk, the locality for the species has been recorded only as Brisbane and it is possible that the species may not have been captured within the metropolitan region. Reeves (1995) lists some additional species from the Greater Brisbane region but whether they occur within metropolitan Brisbane is unclear. Table 10 is far from complete. Not all the published taxonomic literature has been searched, nor the specimen records of other insect collections accessed. There are certain to be a number of additional dragonfly species that occur in Brisbane City. Local dragonfly collectors, particularly Deniss Reeves, would be a valuable source of information on the occurrence and distribution of species in Brisbane.

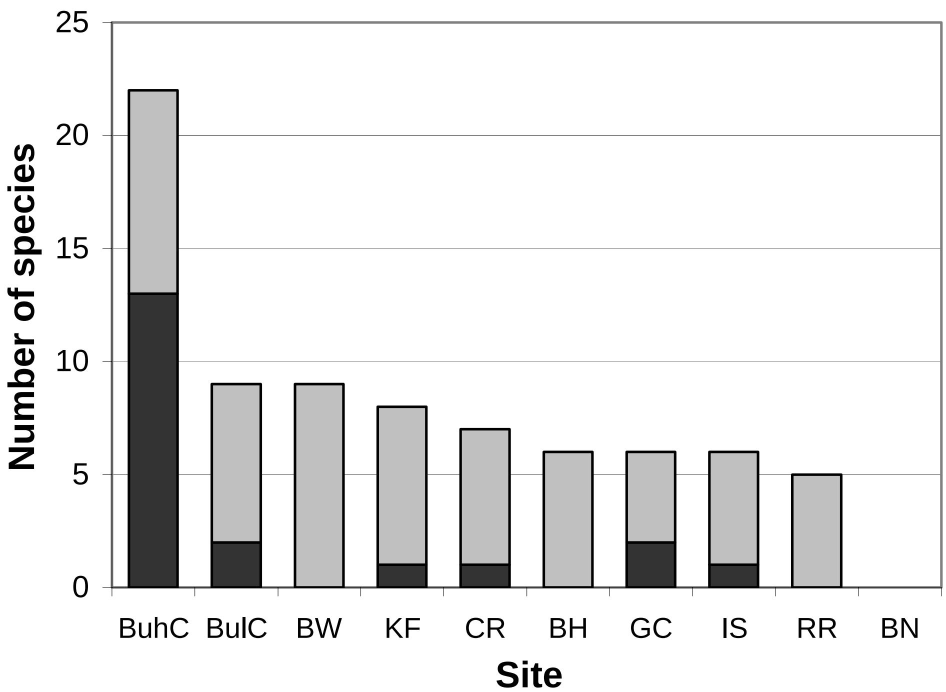


Figure 44. Overall dragonfly species richness across the 10 survey sites. The black area at the base of each bar is the number of species unique to that particular site. BuhC – Buhot Creek, Burbank; BulC – Bulimba Creek, Carindale; KF – Karawatha Forest; BW – Boondall Wetlands; CR – Chelsea Road Bushlands; BH – Belmont Hills Bushland Reserve; GC - Gold Creek Reservoir; IS – Illaweena St, Drewvale; RR – Ransome Reserve; BN – Boombana NP.

Comparison of Different Sites

Buhot Creek clearly had the most diverse and distinctive dragonfly fauna of the 10 sites surveyed (Fig. 44). More than half of its 22 species were not recorded from any other site. This is hardly surprising given that this was the only site that encompassed a permanent water body, a substantial impoundment. Many species of damselflies stay in close proximity to their breeding sites and it is not surprising that seven species were unique to the Buhot Creek site. *Austroargiolestes icteromelas* was also collected at the site and is the only species recorded during the survey that does not breed in still waters. Presumably this species breeds in the nearby Buhot Creek.

All other sites had depauperate dragonfly faunas (Fig. 44), reflecting their lack of permanent water bodies. Most species recorded at these sites are capable of flying long distances from water and some are able to utilise temporary water bodies for larval development. For example, most of the species from Boondall Wetlands are able to breed in the seasonally inundated pools at this site. No dragonflies were collected from Boombana NP. However, some specimens were observed but could not be captured amongst the dense vegetation.

Table 10. Species of dragonflies and damselflies (Odonata) occurring in Brisbane, derived from this survey and published records, and supplemented by additional specimen records in the Queensland Museum collection. An * denotes that collection data is given as 'Brisbane' only. Species recorded by: [1] this survey; [2] Reeves 2002; [3] Watson *et al.* 1982; [4] Burwell & Theischinger 2003; [5] Watson 1991; [6] Theischinger 2000b; [7] Theischinger 1985; [8] Theischinger 1996; [9] Woodall 1985; [10] D. Reeves pers comm.; [11] additional specimen records for Brisbane in QM.

DRAGONFIES (ANISOPTERA)

Aeschnidae	
Aeshna brevistyla	Blue-spotted Hawker [1]
Austrogynacantha heterogena	Australian Duskhawker [1]
Hemianax papuensis	Australian Emperor [1,2,3]
Telephebiidae	
Acanthaeschna victoria	Thylacine Darner [6]
Austroaeschna unicornis	Unicorn Darner [3]
Austrophlebia costalis	Southern Giant Darner [8,9]
Telephlebia cyclops	Northern Evening Darner [7*]
Telephlebia tryoni	Coastal Evening Darner [7*]
Petaluridae	
Petalura litorea	Coastal Petaltail [10]
Gomphidae	
Antipodogomphus acolythus	Southern Dragon [5*]
Austrogomphus amphiclitus	Pale Hunter [5]
Austrogomphus cornutus	Unicorn Hunter [5*]
Austrogomphus melaleucae	Twin-spot Hunter [1,3,5]
Austrogomphus ochraceus	Jade Hunter [5]
Hemigomphus heteroclytus	Stout Vicetail [5]
Ictinogomphus australis	Australian Tiger [2]
Synthemistidae	
Choristhemis flavoterminata	Yellow-tipped Tigertail [3]
Parasynthemis regina	Royal Tigertail [11*]
Corduliidae	
Cordulephya pygmaea	Common Shutwing [11*]
Hemicordulia australiae	Australian Emerald [1,2,3]
Hemicordulia continentalis	Fat-bellied Emerald [1,3]
Hemicordulia superba	Superb Emerald [1]
Hemicordulia tau	Tau Emerald [3]
Libellulidae	
Aethriamanta circumsignata	Squarespot Basker [2]
Agrionoptera insignis allogenes	Red Swampdragon [11*]

Table 10 (continued). Species of dragonflies and damselflies (Odonata) occurring in Brisbane, derived from this survey and published records, and supplemented by additional specimen records in the Queensland Museum collection. An * denotes that collection data is given as 'Brisbane' only. Species recorded by: [1] this survey; [2] Reeves 2002; [3] Watson *et al.* 1982; [4] Burwell 2003; [5] Watson 1991; [6] Theischinger 2000; [7] Theischinger 1985; [8] Theischinger 1996; [9] Woodall 1985; [10] D. Reeves pers comm.; [11] additional specimen records for Brisbane in QM.

Libellulidae continued	
Brachydiplax denticauda	Palemouth [1,2,7]
Crocothemis nigrifrons	Black-headed Skimmer [1,2,]
Diplacodes bipunctata	Wandering Percher [1,2,3]
Diplacodes haematodes	Scarlet Percher [1,2,3]
Diplacodes melanopsis	Black-faced Percher [1,2]
Hydrobasileus brevistylus	Water Prince [1,2]
Macrodiplax cora	Wandering Pennant [2]
Nannodiplax rubra	Pygmy Percher [2]
Nannophlebia risi	Common Archtail [7]
Nannophya australis	Australian Pygmyfly [11]
Orthetrum caledonicum	Blue Skimmer [1,2,3]
Orthetrum sabina	Slender Skimmer [1,3]
Orthetrum villosovittatum villosovittatum	Fiery Skimmer [1,2,3]
Pantala flavescens	Wandering Glider [1,2]
Rhodothemis lieftincki	Red Arrow [1,2,3]
Rhyothemis graphiptera	Graphic Flutterer [1,2]
Rhyothemis phyllis chloe	Yellow-striped Flutterer [1,2,3]
Trapezostigma loewii	Common Glider [1,2,3]
Urothemis aliena	Red Baron [4]
Zyxomma elgneri	Short-tailed Duskdarter [1,3]
DAMSELFLIES (ZYGOPTERA)	
Coenagrionidae	
Agriocnemis pygmaea	Pygmy Wisp [1,2,3]
Agriocnemis rubricauda	Red-rumped Wisp [3]
Argiocnemis rubescens	Red-tipped Shadefly [1,3]
Austroagrion watsoni	Eastern Billabongfly [1,3]
Austrocnemis splendida	Splendid Longlegs [1,2]
Ceriagrion aeruginosum	Redtail [1,2,7]
Ischnura aurora	Aurora Bluetail [1]
Ischnura heterosticta	Common Bluetail [1,2,3]
Pseudagrion aureofrons	Gold-fronted Riverdamsel [3]
Pseudagrion ignifer	Flame-headed Riverdamsel [3]
Pseudagrion microcephalum	Blue Riverdamsel [2,7]
Xanthagrion erythroneurum	Red and Blue Damsel [1,2,3]

Table 10 (continued). Species of dragonflies and damselflies (Odonata) occurring in Brisbane, derived from this survey and published records, and supplemented by additional specimen records in the Queensland Museum collection. An * denotes that collection data is given as 'Brisbane' only. Species recorded by: [1] this survey; [2] Reeves 2002; [3] Watson *et al.* 1982; [4] Burwell 2003; [5] Watson 1991; [6] Theischinger 2000; [7] Theischinger 1985; [8] Theischinger 1996; [9] Woodall 1985; [10] D. Reeves pers comm.; [11] additional specimen records for Brisbane in QM.

Protoneuridae	
Nososticta solida	Orange threadtail [3]
Isostictidae	
Rhadinosticta simplex	Powdered Wiretail [1,3]
Lestidae	
Austrolestes leda	Wandering Ringtail [1,3]
Megapodagrionidae	
Austroargiolestes icteromelas nigrolabiatus	Common Flatwing [1,2,3]
Griseargiolestes albescens	Coastal Flatwing [11*]
Griseargiolestes griseus	Grey Flatwing [3]

SPIDERS OF BRISBANE CITY

A total of 568 species of spiders belonging to 56 families were taken across all sites. Of these 405 have yet to be described. In addition at least 90 described species known from the region were not taken. Hence, the total spider diversity for Brisbane is estimated to be at least 658 species. Species diversity at each site varied between 123 and 187 species, with an average of 141 per site, while the number of families at each site varied from 24 to 38. Relative contributuion of the larger spider families to site diversity is shown in Table 12. Species collected during the survey are listed in Appendix 20. Where species have yet to be formally described they have been assigned a code number.

Relative diversities of the most commonly encountered families are shown in Figure 45.

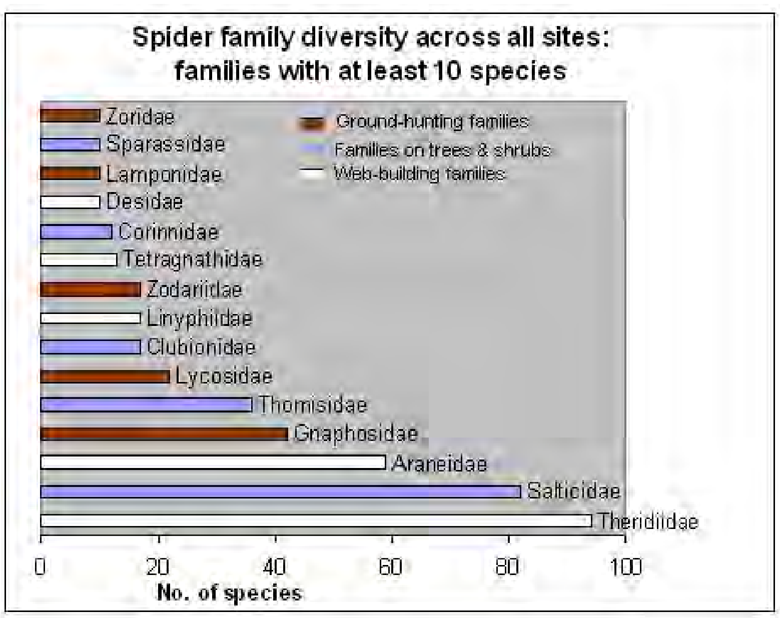


Figure 45. Relative diversities of the most common spider families across TISR sites.

In order to place the TISR spider survey into context the following list presents the results of other surveys undertaken by the QM spider section in the past:

Kakadu (rainforest): 194 species at 19 seasonal-sites.
Boggomosses, near Taroom: 164 species, predictive 300 species.
Tasmanian Button Grass: 295 species.
Iron Range (rainforest): 147 species.
North Queensland (6 rainforest sites, with 76-147 species per site, excluding Mt Bellenden Ker): 331 species.
Mt Bellenden Ker (rainforest, altitudinal transect, 88-144 species per site): 314 species (Monteith & Davies, 1984).
Mid-eastern Queensland (6 rainforest sites, 65-104 species per site): 291 species.
South-east Queensland (5 rainforest sites, 61-119 species per site): 307 species.
North Stradbroke Island: actual 258 species, predictive 443.

In all previous surveys, the most diverse family was the Comb-footed Spiders (Theridiidae, comprising 14-19% of the total fauna, that was followed by the Jumping Spiders (Salticidae, 10-14%) and Amaurobiidae *s. lat*. (5-10%). Site endemicity varied from 11-32%. In the Greater Brisbane area, Orb-weaving Spiders (Araneidae and Tetragnathidae) dominate with 15%, Jumping Spiders follow with 14%, Comb-footed Spiders follow with 10%.

Family diversity across sites

Spiders belong to one of three infraorders, of which Australia has only two: the primitive Mygalomorphae (Trapdoor, Funnelweb and Mouse Spiders) represented by six families in the survey and the more evolved Araneomorphae (represented by 50 families). The latter group includes several exciting evolutionary species that are known to be highly habitat specific.

MYGALOMORPHAE

The Trapdoor, Funnelweb and Mouse Spiders (Figs. 46, 47, 48) are the most ancient, long lived spiders and most sensitive to soil disturbance. The six mygalomorph families (Actinopodidae, Barychelidae, Dipluridae, Hexathelidae, Idiopidae, Nemesiidae) found in the survey are represented by 14 species and the group occurs at all sites except Bulimba Creek, Boondall Wetlands and Illaweena Street. Of those, the Hexathelidae and Nemesiidae (four species) were taken at only one site, Boombana NP, but are known to occur outside these areas. The internested distributions show a clear pattern. Boombana is a unique site. Four families (Actinopodidae, Barychelidae, Dipluridae, Idiopidae) are present at Boombana + Buhot. Three families (Actinopodidae, Barychelidae, Idiopidae) are also present at Boombana + Buhot + Belmont. Two families (Dipluridae, Idiopidae) are present at Boombana + Buhot + Karawatha. Hence, the most informative sites based on the mygalomorphs are those not subject to inundation by tide or flooding. The absence of mygalomorphs at Bulimba Creek was not surprising as the area surveyed was small and highly disturbed.

Mygalomorphs are long-lived (5-30 years), sedentary spiders. They are readily affected by soil disturbance like ploughing and some are highly habitat specific, not being found out of rainforests. Unlike many more evolved spiders, most cannot colonise new areas easily because they are restricted to ground dispersion of the young. Tight clusters of young can often be found around the maternal burrow. Their longevity coupled with the subterranean existence provides an indication of site history and stability. Large maternal females indicate site stability and food availability for at least 20 years.
Mygalomorphs are also notoriously clustered in distribution and hence can be easily “missed” simply because of the small size of the site, as is clearly the case herein. Of the 10 families of the mygalomorphs known from Australia, seven (Actinopodidae, Barychelidae, Dipluridae, Hexathelidae, Idiopidae, Migidae, Nemesiidae) are known from the areas surveyed herein and only one (Migidae) was not found in the survey.

FIGURE 46. Funnelweb, trapdoor and other mygalomorph spiders of Brisbane City (spiralling clockwise from top left). Male Funnelweb in "defensive" pose, *Hadronyche infensa*, Hexathelidae; webs of Toowoomba Funnelweb (*Hadronyche infensa*, top) and Tree Funnelweb (*Hadronyche formidabilis*, below); Mottled trapdoor, *Namea brisbanensis*, Nemesiidae; Curtain web spider, *Namirea planipes*, Dipluridae; burrows of Brisbane Trapdoor (*Arbanitis longipes*, left) and Golden Trapdoor (*Euoplos variabilis*, right), Idiopidae; female, Brisbane Trapdoor, *Arbanitis longipes*, Idiopidae; female Mouse spider, *Missulena bradleyi*, Actinopodidae, "greeting" pose, and from above; Brushfooted Trapdoor, Barychelidae, at burrow entrance; Curtain web, Dipluridae; female Brisbane Brushfooted Trapdoor, *Seqocrypta jakara*, Barychelidae

The Migidae (a single species) are very tiny spiders that build short tube nests in trees and can only be found by intensive searching; in this survey, such focus would have been at the cost of generalised search time.

Because of their large size and stable burrows, mygalomorphs form an important food reserve for large lizards, insectivorous mammals and some birds. They are also prey for large wasps, centipedes, White-tailed spiders (*Lampona* species, family Lamponidae), flatworms, velvet worms (Onychophora), and even fungi which infect the spiders and force them to the burrow entrance so that the fungi fruits outside of the burrow.

Actinopodidae (Mouse Spiders)
Missulena bradleyi Rainbow, 1914. These small black spiders appear as stout Funnelwebs and can be equally as toxic. They make cryptic burrows (up to 30cm deep) with no discrete opening or door; a floppy soil-encrusted tube extends shortly above the ground and folds closed. Hence, they are rarely found by manual searching, but males searching for females may be encountered at night or taken in pitfall traps. They were only taken at Boombana, Belmont & Buhot. Their presence at Boombana & Buhot was consistent with the richness of the sites generally. However, their presence at Belmont, despite the superficial paucity of the site (see Ants), indicates the area has not been so badly disturbed as the landscape might suggest. Absence of Mouse Spiders (or indeed most mygalomorphs) at sites which are subject to inundation (e.g., Illaweena, Boondall) is understood; mygalomorphs generally are not found in areas prone to flooding.

Barychelidae (Brushfooted-Spiders)
Seqocrypta jakara Raven, 1994, Brisbane Brushfooted trapdoor (Figs 46, 47). These spiders are among the last mygalomorphs to disappear from suburbs in disturbance. They are frequently reported from near-city suburbs (e.g., West End) where they are disturbed by gardeners. They make a short (2-4cm) barrel-like burrow with a thin flap door at each end; the burrow is made in the top layer of the soil.

Because they have thick pads at the end of the legs, they are able to scale smooth or otherwise slippery surfaces. They are among the most docile of the mygalomorphs and no bites have been confirmed.

Figure 47. *Seqocrypta jakara*.

Like the Mouse spiders, Brushfooted trapdoors were taken at Boombana, Belmont &

Buhot and also at Gold Creek where previous QM surveys had reported them; the absence of *Seqocrypta* at a number of non-inundated sites remains enigmatic. The species is found in rainforest throughout south-eastern Queensland.

Dipluridae (Curtain-web Spiders)
Australothele jamiesoni Raven, 1984 and *Namirea planipes* Raven, 1984. These are small spiders (total length about 20mm) that build curtains of web amongst logs and rocks, and the other similar spaces. They are unusual amongst Australian mygalomorphs for their long spinnerets which are held high behind the spiders as it runs through its silken corridors & pay out silk. Their prey seems to be primarily small snails found in the litter (Raven, 1984). Both species occur widely through south-eastern Queensland, with *Australothele* being more commonly found in rainforest or at least closed forest. Hence, its presence in the Boombana NP and Buhot Creek sites was predictable but its presence in the near mangrove site at Ransome is remarkable. The dusky *Namirea*, with his low golden-haired head, tends to be found in drier areas adjacent to rainforest but here was only taken at Buhot. Both species have previously been recorded from Gold Creek, Brookfield, and the lower slopes of Mt Coot-tha. Neither species is harmful to humans; no bites have been recorded. Males are active in mid-Winter.

Hexathelidae (Funnelweb Spiders)
Hadronyche infensa (Hickman, 1968), Toowoomba Funnelweb. These were taken only at Boombana but again these are known from rainforest at Gold Creek, Brookfield, Kenmore, outer Rochedale and the lower slopes of Mt Coot-tha. These spiders grow to a large size (total length, 30-40mm) and the species is found throughout south-eastern Queensland in rainforest, especially montane areas. Unlike all of the other Mygalomorphae, males are active only in the summer months, especially October to March. The venom of the male Funnelweb is highly toxic to humans with death occurring in as little as 15 minutes. However, serious envenomations are not common as the co-incidence of high population densities of both humans and funnelwebs is rare in Queensland; greatest danger exists in the Gold Coast and Sunshine Coast Hinterlands, especially Maleny.

Idiopidae (Trapdoor Spiders)
Four genera, eight species (see Appendix 20). These are medium-size to large trapdoor spiders and represent one of the two most diverse mygalomorph families in Australia and the survey. Most of the species taken build open burrows and are more common in embankments than flat ground. Because they are so diverse and tend to show high degrees of endemicity (i.e., species are restricted to relatively small patches of forest), they are important indicators both of site stability and integrity. Idiopids were taken at Boombana NP, Buhot Creek, Belmont Hills, Ransome Reserve and Karawatha SF; and hence show a more inclusive group of sites than the other mygalomorphs. They are also present in rainforest areas around Gold Creek but were not taken in this survey as the site was a very dry ridge with thin soil layer. In this survey, two totally new species were taken. Also, one tube dwelling species *Homogona pulleinei*, known to be at Boombana NP, was not taken.

FIGURE 48. Some common spiders of Brisbane City. (clockwise from top left). Ant spider, *Storosa obscura*, Zodariidae; Dome tent spider, *Cyrtophora moluccensis*, Araneidae; Garden Orb Weaver, red variety, *Eriophora transmarina*; Brisbane Trapdoor, *Arbanitis longipes*, Idiopidae; Stradbroke Sac spider, Anyphaenidae; Lynx spider, *Oxyopes*, Oxyopidae.

The Idiopodae are the mygalomorphs about which we know most. The burrow is built in the ground and densely lined with silk. The entrance or lip of the burrow is often well silked also and includes leaves and twigs. Unlike the Western Australian trapdoor spiders, *Misgolas* does not greatly expand its sensory area using those leaves. The burrow may extend for over 40cms into the soil. Brown Trapdoors include many species and are found along coastal eastern and southern Australia.

In some species, the Tube spiders, the burrow extends up to 30cms from the ground and is attached to a sapling, tree, or rock. The adaptation was thought to be useful in preventing flooding but is now found in areas where flooding is not a problem for other burrowing spiders. Like other species, they hunt near the top of the burrow at night. At night, these spiders slip back down the burrow below ground at the first sign of a large vibration on the ground or bump to the burrow.

Misgolas and some other trapdoor spiders seem to find artifical embankments more livable than the rest of the forest floor; this does not apply, however, to the steep and unstable slopes of creek banks. During the day, *Misgolas* hide a few centimetres down from the entrance. They are typically spiders of rainforest but they occur also in open forest.

Like most trapdoor spiders, they live for many years. Mating and maternal care are probably like that in other trapdoor spiders. The females receive males at the burrow entrance and presumably mate below the earth in the large chamber up to 40cms down. Here the egg sac is made and suspended in the burrow. The young hatch and remain with the female in the main chamber where they cling to the walls with remarkable ease. After a short period and probably after rain, the young leave the maternal burrow and move a short distance away to make their burrow. The clustering effect so produced is remarkable. The young are no doubt eaten by centipedes which burrow through the soil and stung by wasps which use their bodies as live food bags for their developing larvae. The young that survive enlarge the burrow and line it with silk. Each moult occurs within the burrow and the shed skin is bound into the walls.

The females have narrower, browner and hairier heads than the Golden Trapdoors (*Euoplos*) that occur nearby. Their legs often have a narrow black band along the sides that give the appearance of having been burnt. But these spiders can probably easily survive a fire simply by silking over an upper part of the burrow and allowing soil to fall onto it.

Nemesiidae

Two genera (*Ixamatus* & *Namea*) and 3 species were taken only at Boombana NP. They have been collected at Gold Creek previously. Also, one of Australia's largest members of the family, *Xamiatus rubrifrons,* has been taken previously from Boombana where the known diversity of the family is 6 species over 3 genera. These spiders build either silken tube webs under rotting logs (*Ixamatus*), open silk lined burrows with leafy entrances, like the idiopid *Misgolas* (see above), or large unadorned burrows in creek embankments

(*Xamiatus*). None have bitten but *Xamiatus rubrifrons* are reported each year by motorists who see the large males at night in the headlights of their cars. Like most other mygalomorphs, the males of these species are active outside of non-summer.

ARANEOMORPHAE

Most araneomorph families showed considerable species diversity across sites. However, significantly not all families reflect the high species diversity of Buhot Creek (187 species). Notably, the Comb-footed spiders (Theridiidae) show highest diversity at Bulimba, one of the least speciose sites overall, and Belmont Hills, the second most speciose site. The Theridiidae include many species which are specific ant-feeders and reflects the high diversity of ants at least at the Bulimba site. The relative contribution of the more diverse araneomorph families to site diversity is shown in Table 12. Some common Brisbane araneomorphs are shown in Figure 48. Sometimes these are more recognisable by their oft encountered webs (Fig. 49).

Apart from several evolutionary oddities (see below), three families of Araneomorphae (Nicodamidae, Pisauridae and Stiphidiidae, total 3 species) were taken from only one site, Boombana NP. Hence, seven of the 56 spider families were taken only from Boombana but are known from other rainforest areas throughout south-eastern Queensland. No other site showed such high endemicity at the family level. Of those three families, the absence of Pisauridae from other sites cannot be seen as significant because these are water spiders and are usually only found around creek edges, none of which were in any site.

Table 12. Percentage contribution of most diverse families to total site diversity.

TotalInSurvey		Boombana	GoldCk%	Belmont%	Boondall%	Bulimba%	Karawatha	Chelsea%	Ransome%	Illaweena%	Buhot%
10	Lamponida	0	30	30	20	10	10	30	10	0	60
10	Sparassida	30	30	40	50	20	20	30	40	20	40
22	Lycosidae	5	18	5	36	14	18	32	18	27	36
16	Zodariidae	0	19	13	19	13	19	19	69	19	50
13	Tetragnath	31	23	46	46	38	23	77	38	31	46
42	Gnaphosid	12	26	17	17	14	21	19	24	33	21
36	Thomisida	17	33	25	25	25	28	28	22	22	42
59	Araneidae	10	25	34	15	31	22	24	25	25	25
94	Theridiidae	30	21	39	29	38	30	29	29	19	29
82	Salticidae	18	29	27	18	20	23	29	20	28	30
17	Linyphiidae	35	41	18	6	12	6	0	0	12	35
17	Clubionida	29	29	12	6	29	6	29	24	41	41
12	Corinnidae	8	33	25	42	25	33	25	25	42	25
8	Hahniidae	13	50	38	25	25	38	25	0	25	0
7	Oonopidae	57	57	57	43	57	43	14	43	14	86
10	Zoridae	0	40	30	30	30	20	30	50	40	60
8	Amaurobii	38	38	25	13	0	25	13	25	38	13
10	Desidae	10	20	30	0	20	10	20	0	10	30
	Mean	19	31	28	24	23	22	26	26	25	37
	Species	124	152	161	138	123	128	130	138	140	188
			CONTRIBUTION OF SITE TO TOTAL DIVERSITY IN LARGER FAMILIES								

Figure 49. Spider webs of Brisbane City (clockwise from top left). St Andrew’s cross Spider, *Argiope keyslingeri*, Araneidae; Camel Spider, *Leucauge granulata*, Tetragnathidae; Micro-orb Spider, Anapidae (small left); Ladder-web Spider, *Paramatachia*, Desidae (small right); Sombrero-web Spider, *Stiphidion facetum*, Stiphidiidae; White-tailed Wolf Spider, *Venonia micarioides*, Lycosidae; Money Spider, LinyPhiidae; Retarius or Net casting Spider, *Deinopis*, Deinopidae.

Within the 50 araneomorph families, 13 (Araneidae, Clubionidae, Corinnidae, Cycloctenidae, Gnaphosidae, Linyphiidae, Lycosidae, Oonopidae, Salticidae, Sparassidae, Tetragnathidae, Theridiidae, Thomisidae) were found at all sites. A further 8 families (Amaurobiidae, Desidae, Hahniidae, Hersiliidae, Oxyopidae, Theridiosomatidae, Zodariidae, Zoridae) were taken at 9 (but not the same 9) of the 10 sites

Huntsman spiders (Sparassidae) are most diverse at Boondall Wetlands, the least speciose site, and may reflect the high incidence of loose eucalypt bark and paperbark under which these spiders rest and make their egg sacs.

Long-jawed spiders & Golden Orb Weavers (Tetragnathidae) show substantially higher diversity at Chelsea Road and that may reflect the proximity of nearby mangroves (not sampled) combined with the more open vegetation compared to that at nearby Ransome Reserve, also close to mangroves.

Families with High Site Diversity

Corinnidae (Ant-mimicking Spiders)

These spiders are both ant-mimics and ant hunters (Fig. 50) and their diversity may be expected to reflect that of the ants; however, they do not. Twelve species belonging to 8 genera were found; of those, 9 species are ant mimics. Two other species (*Supunna funerea*, *Supunna picta*) are widely distributed mimics of mutilid or other wasps; in fact, *Supunna funerea*, was found at all but one site and hence can be taken as “noise” rather than signal, providing little information on local ant diversity.

Figure. 50 Ant-mimicking spiders of Brisbane City (clockwise from top left) Four unnamed genera and new species of Corinnidae with an ant-mimicking jumping spider, Myrmarachnae, Salticidae at centre.

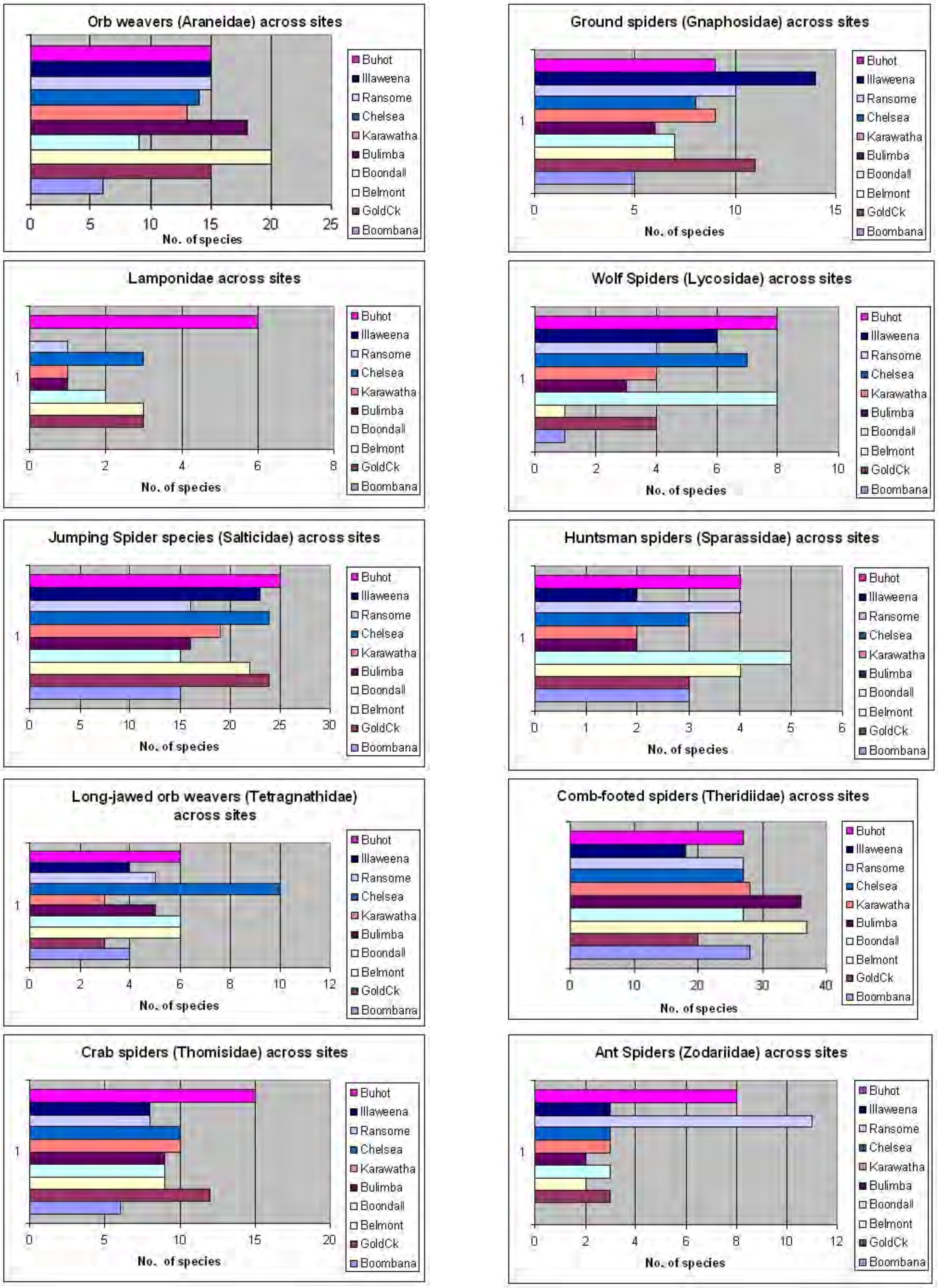


Figure 51. Site by site analysis of some of the most diverse families.

Setting aside the “noise”, the two richest sites (4 species) were Boondall & Illaweena which are both inundated; next richest were Karawatha & Gold Creek with 3 species. However, there is little overlap between the species at these sites. Ten of the 12 species (i.e., 83%) are new to science. Hence, in as much as the inundated sites lack burrowing mygalomorphs, they are rich in unusual araneomorph species.

Zodariidae (Ant Spiders)
These are medium-sized to small ground hunting spiders that resemble and feed on ants. Fourteen (14) species over 9 genera were taken; four of those species are new and one will be named for the BCC. These spiders are notably absent from the rainforest but attain their highest diversity (8 species) at Buhot and Ransome which together contain 12 of the 14 total species in the survey, but with only 50% of species shared by both.

Salticidae (Jumping Spiders)
Sites segregate into two groups: those with 22-25 species (in order of descending diversity (Buhot Creek, Gold Creek Reserve, Chelsea Road, Illaweena Street, Belmont Hills) and those with 15-18 species (Ransome Reserve, Karawatha SF, Bulimba Creek, Boondall Wetlands, Boombana NP). However, the absolute values are deceptive as the relative diversity of salticids across all sites only varies from 11-17%. In order of relative descending diversity the sites are: Illaweena, Gold Creek, Belmont/Karawatha, Chelsea, Buhot, Bulimba, Boondall/Boombana, Ransome. Hence, Jumping Spiders are relatively more diverse in Illaweena (17% of species) than in Buhot, the most diverse site overall. Thus while salticids are one of the most diverse families in the survey, Jumping Spiders do not accurately reflect site diversity and are not reliable surrogates for measuring site diversity.

Site by site analyses of the diversity of the most highly species families are shown in Figure 51.

Family Surrogacy
Given the very high number (568) of spider species across the area (and hence the logistics of identification), a search for a surrogate family with similarities across and between the sites was undertaken. Jaccard values for each of several families were tested and these compared pairwise to the Jaccard values across all sites. The object was to find a family that best reflected the overall relationships between the sites.

The five most diverse families encountered in the TISR survey (most to least diverse, Theridiidae, Salticidae, Araneidae, Gnaphosidae, Thomisidae) were tested. The Theridiidae showed poor correspondence to the overall similarities. However, the Araneidae combined with their phylogenetic relatives (Tetragnathidae, Uloboridae, Deinopidae, Linyphiidae) showed high agreements, as did the Gnaphosoidea (Gnaphosidae, Lamponidae, Gallieniellidae, Prodidomidae, Trochanteriidae).

The results of these analyses are shown in Figure 52.

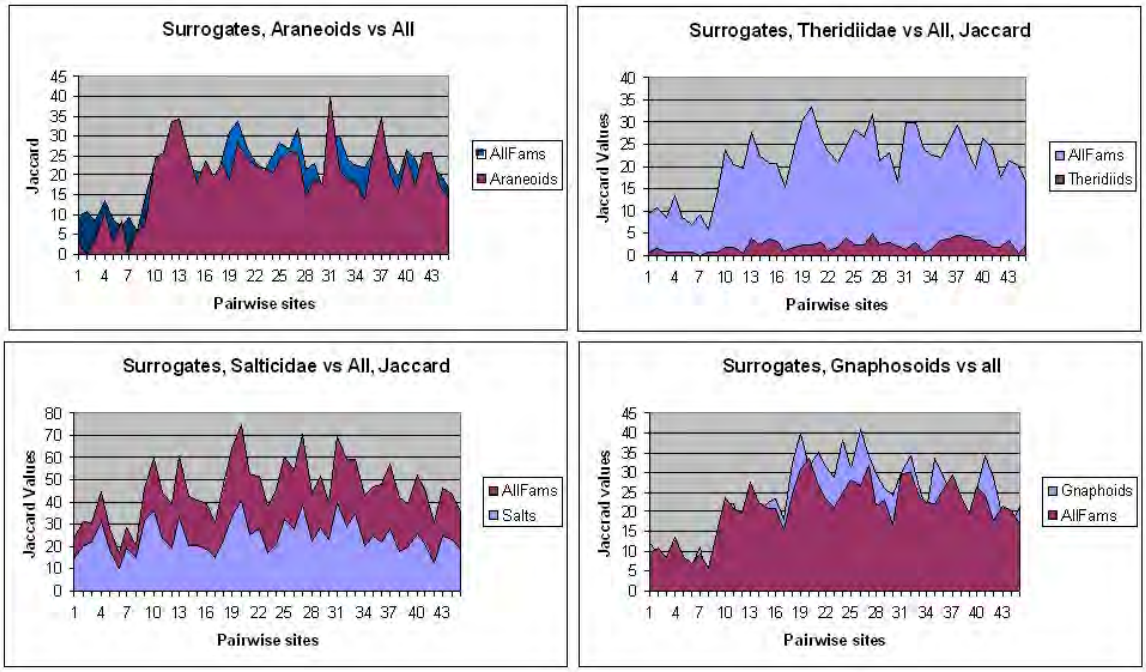


Figure 52. Surrogacy values of four of the most diverse families. The Araneidae and relatives (araneoids) have high surrogacy values as do the Gnaphosidae. In comparison the Theridiidae showed very poor levels of correspondence.

But remarkably, among the smaller families, the Zodariidae also reflected total site similarity well (Fig. 53).

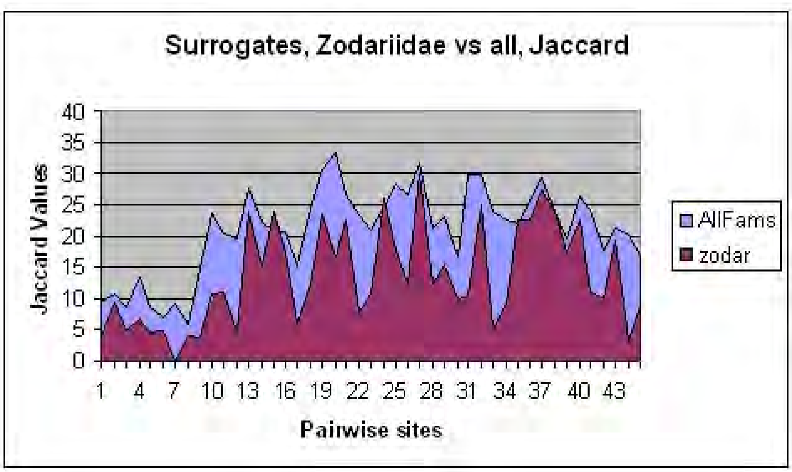


Figure 53. High surrogacy value of the moderately diverse Ground Spiders belonging to the familiy Zodariidae.

Significant Species

Evolutionary Oddities

Three species belonging to three araneomorph families deserve attention.
Kilyana hendersoni Raven & Stumkat, 2005 (family Zoropsidae) is a litter dwelling spider (Fig. 54) resembling a small huntsman. It was found only at Boombana and 24 were taken in $4m^2$ of litter; hence, the species is common and no doubt represents an important food source for ground-feeding insectivorous birds & mammals. These spiders are very small in October and adult through to March-April at least.

Figure 54. *Kilyana hendersoni*.

This species is found in rainforest or closed forest also at Gold Creek (but not in this survey), Brookfield, The Gap, and Enoggera Reserve. The genus includes a number of species from Kroombit Tops, south of Calliope, to northern New South Wales; all are found in rainforest or at least wet sclerophyll (Raven & Stumkat, 2005). The family had not been formally recorded by Australia before this year.

Austrarchaea nodosa (Forster, 1956) (Archaeidae) [Fig. 55] is a small, peculiar, high-headed spider that was taken only at Boombana NP in litter, but only as juveniles. It is a very rare spider and typically found on single lines of silk in shrubs and bushes. Mid-height vegetation was rare within the Boombana site and that was reflected also in the low diversity of orb-weaving spiders collected there (10 species).

Figure 55. *Austrarchaea nodosa*.

The species is found in rainforest throughout south-eastern Queensland. The genus *Austrarchaea* includes 6 species from Australia; only two are known from south-east Queensland. The rarity of these spiders coupled with their small size indicates they are not a significant food source in the forest. Like *Kilyana*, they are summer maturing. The Archaeidae were first found as fossilised animals in Baltic amber (around 50 million years old) and only later found alive in South Africa, Madagascar and Australia.

An undescribed species and genus of the Tengellidae was taken at Boombana NP and Buhot Creek (Fig. 56).These spiders are similar to the Zoropsidae in morphology and habit but smaller in size. They were not found in the same high numbers as the Zoropsidae. The species is found in rainforest throughout south-eastern Queensland.

Figure 56. A new genus and species of tengellid from the TISR.

Very Rare and Unusual Species

Two species deserve critical mention.

Diaprograpta sp. nov. (Miturgidae). This is simply an incredibly rare animal. A single male of this undescribed species was taken from Chelsea Road Reserve near Lota. The genus is known from a single species in Western Australia (WA). Present research (Raven) on the genus in all of the collections of museums in Australia has discovered more specimens of the WA species but only one male from each of South Australia and Victoria, and one female from western Queensland; all are new species. The specimen from Chelsea Road constitutes the first record of the genus so far east and the fifth species known in the genus. The spider was taken in a pitfall trap and is a ground hunting spider. Needless to say, intensive trapping at the site is ongoing.

Gnaphosidae sp. 67 (family placement uncertain, here listed in the Gnaphosidae). Another rare animal based only on a single female taken from Boombana. This species is challenging world authorities about the family to which it should belong.

Rediscoveries

Two species were discovered that had been thought to have disappeared, at least from the Brisbane area.

A tiny litter spider *Malkara loricata* (Malkaridae), was described by Davies (1980) from the lower slopes of Mt Coot-tha where it was taken under *Lantana* bushes.
Until now, material of that species has not be recaptured in the original area (the *Lantana* at the original site was removed) or in lowland areas around Brisbane. It did show that the *Lantana* was serving a purpose in maintaining a tiny pocket of deep moister leaf litter in which the species was surviving through the dry periods. However, fresh material was here taken at Belmont.

The second rediscovery is somewhat more spectacular as the trapdoor species, *Arbanitis longipes* (Koch, 1873) (Idiopidae), has been misinterpreted for over 130 years. That is partially because the original specimen was considered lost. In 1998, Raven recognised the long lost male holotype in Hamburg while examining other Australian material collected in the 1870's. *Arbanitis longipes* is a trapdoor spider (Fig. 48) that was supposedly from Bowen but continual searches in the area yielded no matches. On recognition of the type it was soon apparent that the species was a common trapdoor in the Brisbane area.

Site Species Diversity

Despite differences in the number of spider species across all sites, the relative contribution of each site to total diversity varied only from 22-33%, with a mean of 25%. To some extent, this simply reflects the comparatively small sampled area of each site in combination with the wide dispersal abilities of spiders.

Three sites were substantially more diverse than all others: Buhot (187), Belmont (161), Gold Creek (152). Buhot's high diversity was predictable (see 'Site Endemicity'); however, the relatively high diversities of Gold Creek and Belmont Hills sites were not.

Gold Creek

Although Gold Creek is surrounded by and contiguous with native forest, the site itself was a dry ridge with thin soil and very thin layer of leaf litter. Two families (the Jumping Spiders and Crab Spiders, Salticidae and Thomisidae respectively) showed substantially higher diversity at Gold Creek than at other sites. In fact, Jumping Spider diversity at Gold Creek was second only to Illaweena, the most relatively diverse Jumping Spider site. Despite the thin litter, spider diversity in the litter was higher than any other microhabitat at the site. Sampling issues may bear partially upon the higher diversity of Jumping Spiders and Crab Spiders at Gold Creek and perhaps also at Belmont Hills: both sites had easily searchable shrubs and bushes up to 2m high.

The boundary between two distinct forest/habitat types (ecotone), e.g. margins of rainforest, often present substantially higher diversity than either of the two bordering habitats; that effect is presumably attributable to the mixing of the faunas of the two habitats. Gold Creek also includes rainforest. Rainforest in other sites in the Gold Creek reservoir (less than 1km from the site) were sampled by the QM from 1979 to 1980 and both diversity and endemicity were comparable to Boombana. However, no rainforest species were taken at Gold Creek in this survey so the ecotone effect did not obviously contribute to the high diversity at Gold Creek. Illaweena Street proved to be one of the least speciose sites.

Belmont Hills

As with the high diversity at Gold Creek, the high diversity of spiders at this site was not readily predictable and certainly rang strongly counter to the ants for which the site was least diverse. The site is on thin soil and the litter layer thin. As with Gold Creek, however, spider diversity in the litter was higher than any other microhabitat at the site. Unlike Gold Creek, Belmont Hills is surrounded by suburban development, albeit about 1km distant. That was also evidenced in the presence of two spiders that are known urban associates, the harmless Daddy Long-legs (*Pholcus phalangioides*) and the Redback (*Latrodectus hasseltii*).

Illaweena Street

Although low in total number of species this site was third highest in the number of endemic species. The site had a high diversity of ant mimicking (Corinnidae, and hunting spiders), but lacked one almost ubiquitous species of shielded microspiders (Oonopidae). However, the high site endemicity combined with the presence of rare web-building species such as *Celaenia distincta* (also found at Buhot), and *Carepalxis tuberculata* testifies strongly to the intrinsic value of the site.

Boombana NP, a rainforest site of low diversity

Unequivocally, the overall figures for Boombana are low and presumably reflect only the specific site vegetation architecture: the site is basically a pole forest with little low vegetation; the untapped diversity is in the canopy. The combined litter and subterranean diversity is high (46 species, cf 50 at Gold Creek and Belmont Hills); however, the diversity of aerial web builders and vegetation hunters is much lower than in comparable sites. If the survey areas are extended to include forest with more undergrowth and creeks, it is likely the rainforest will equal or exceed some of the open forest sites.

Site endemicity

The two sites with significantly high endemicity were Boombana NP and Buhot Creek both with about 60 endemic species which comprised 50% of the species at the less speciose Boombana but only 30% at Buhot, the most diverse site (Fig. 57).

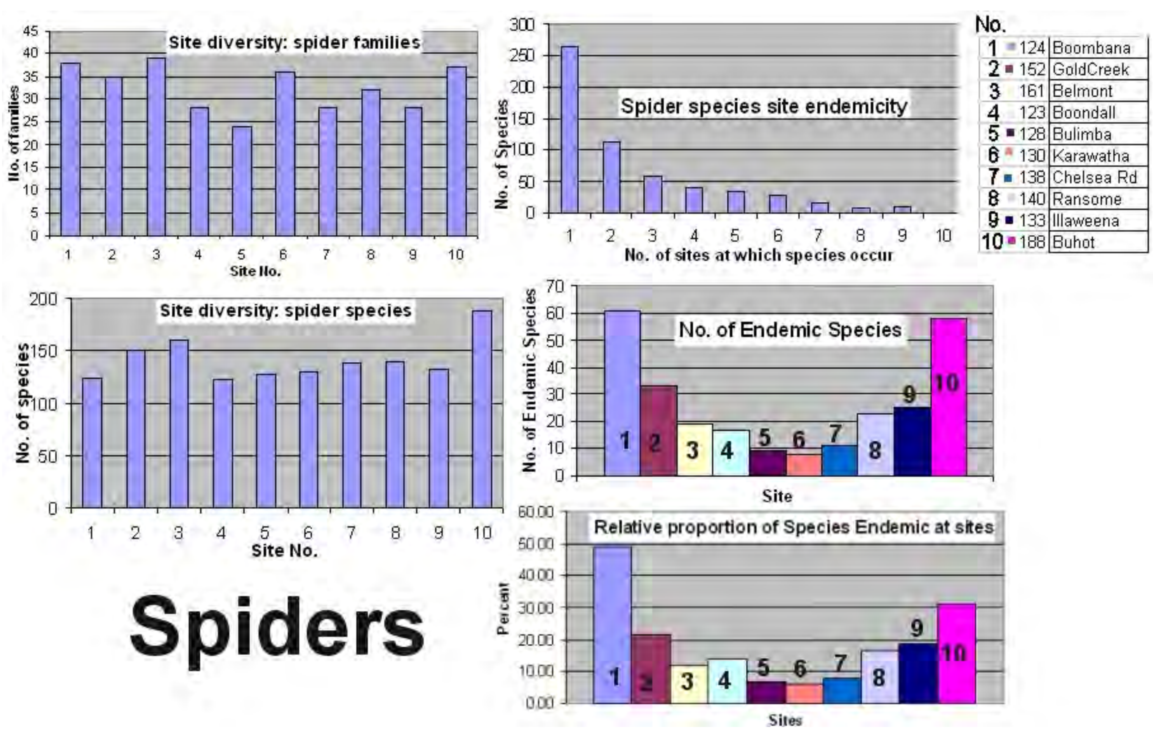


Figure 57. Site diversity and site endemicity of araneomorphs across the ten survey sites.

In terms of habitat types, that is hardly surprising as they both are the only sites in the survey that are either rainforest or include floristic components of rainforest. Hence, they are both floristically and faunistically the outliers or outgroups of the sites surveyed. Apart from those very highly unusual and endemic sites, relative endemicity across the remaining eight sites varied from 5-6% (Karawatha, Bulimba; 9 and 8 species, respectively) to 22% (Gold Creek, 33 species), with a mean across all sites of 13% (18 species).

Site similarity

Measured by Jaccard similarity index (Table 13).
Boombana : 6-15, mean 10; highest similarities with Buhot (15) & Bulimba (14), i.e., it is the most unusual site.
Gold Creek varied between 10 (Boombana) and 28, mean 20; highest similarities with Karawatha (27) & Belmont (24).
Belmont : 11-28, highest similarities with Karawatha (34) & Bulimba (31).
Boondall: 8-32; highest similarities with Chelsea (32) & Bulimba (28).
Bulimba: 14-31; highest similarities with Belmont (31) & Chelsea/Karawatha (30).
Karawatha: 9-34; highest similarities with Belmont (34) & Bulimba (30).
Chelsea: 7-32; highest similarities with Boondall (32) & Bulimba (30).
Ransome: 9-29; highest similarities with Karawatha (29) & Chelsea (29).
Illaweena: 6-24; mean 20; highest similarities with Karawatha & Chelsea (24).
Buhot: 15-25, mean 19; highest similarities with Belmont (25) & Boondall (22).

Table 13. Shared species (top right) and Jaccard index values (bottom left) for all spiders across all sites. The higher the Jaccard value the more similar the sites.

		SPIDERS									
Species	568	GoldCreek	Belmont	Boondall	Bulimba	Karawatha	Chelsea R	Ransome	Illaweena	Buhot	
124	Boombana	24	28	19	30	20	17	22	14	40	
152	GoldCreek	9.52	60	47	46	61	53	50	49	45	
161	Belmont	10.89	23.72	56	68	73	63	57	51	69	Species
123	Boondall	8.33	20.61	24.56	55	53	63	46	48	44	shared
128	Bulimba	13.51	19.66	30.77	28.06	59	61	52	48	57	
130	Karawatha	8.55	27.6	33.49	26.5	29.65	55	61	51	51	
138	Chelsea Rd	6.94	22.36	26.69	31.82	29.76	25.82	58	53	49	
140	Ransome	9.09	20.66	23.36	21.2	24.07	29.19	26.36	48	55	
133	Illaweena	5.76	20.76	20.99	23.08	22.53	24.06	24.31	21.33	46	
188	Buhot	14.76	15.31	24.73	16.54	22.09	19.62	17.75	20.22	16.79	
			Jaccard Site Similarity								

Spider Microhabitats

Spiders from the survey were grouped according to their "microhabitat" preference in order to place the many species collected in ecological context: the term 'microhabitat' here being more broadly defined as both microhabitat and habit. The following broad concepts were utilised:

1. aerial webs built in open spaces. These include larger spiders of the families Araneidae, Tetragnathidae and to a lesser extent Uloboridae and Linyphiidae, Pholcidae, Cyatholipidae and Theridiidae which are usually taken by night or day hand collecting & sweeping vegetation.
2. cursorial hunters. These are primarily active both on the forest floor but also may hunt over bark and low vegetation and include medium sized spiders of many families that may be taken by night or day hand collecting, sweeping vegetation but most commonly are taken by pitfall traps, leaf litter processed through Berlese funnels or 4x4 vibration (which was not successfully used to any extent herein).
3. litter spiders. These are usually very small (total length 0.8-3mm) and include Anapidae, Micropholcommatidae, Mysmenidae, Oonopidae, Orsolobidae, Sternodidae, Tetrablemmidae, Theridiosomatidae. Many build very tiny webs in the tiny spaces between the fallen leaves; the spiders are usually taken by pitfall traps or leaf litter processed through Berlese funnels.
4. low vegetation web (low veg. web). These are small spiders that build webs in low vegetation and include some Araneidae, Tetragnathidae, Uloboridae, Linyphiidae, Pholcidae, Cyatholipidae and Theridiidae. The spiders are usually taken by night or day hand collecting or sweeping vegetation.
5. on trees. These are typically spiders that are rarely found away from tree trunks and hunt on the trunk during the day (e.g., Hersiliidae) or night (e.g., Huntman spiders, family Sparassidae). They span the size ranges from the very small to the very large. Most are taken only by hand collecting by day or night.
6. subterranean. These are true burrowing spiders and usually only include the Mygalomorphae but in some cases may also include Lycosidae & Zodariidae. Most are taken by focussed searching and digging but may also be taken at night by hand or pitfall trapping.
7. kleptoparasites on webs. This specifically applies only to species of the comb-footed spiders *Argyrodes* that live exclusively on the webs of other spider hosts and steal food from the host web or, more spectacularly, feed at the mouth of the host. Their hosts are the often gigantic females of the Golden Orb Weavers (*Nephila* species, family Tetragnathidae).
8. hollow twig webs. Two groups of spiders (*Paramatachia*, family Desidae, and *Ariadna*, family Segestriidae (known but not taken herein) are known to utilise these spaces.
9. aquatic. A number of spider groups live in association with water, semipermanent or otherwise. These include the biggest spiders in the region (*Megadolomedes australianus*, family Pisauridae, known but not taken) and a number of smaller related species of the genus *Dolomedes*. Also associated with water are the elegant and harmless Four-jawed Spiders (*Tetragnatha*, family Tetragnathidae) and smaller Wolf Spiders (family Lycosidae).

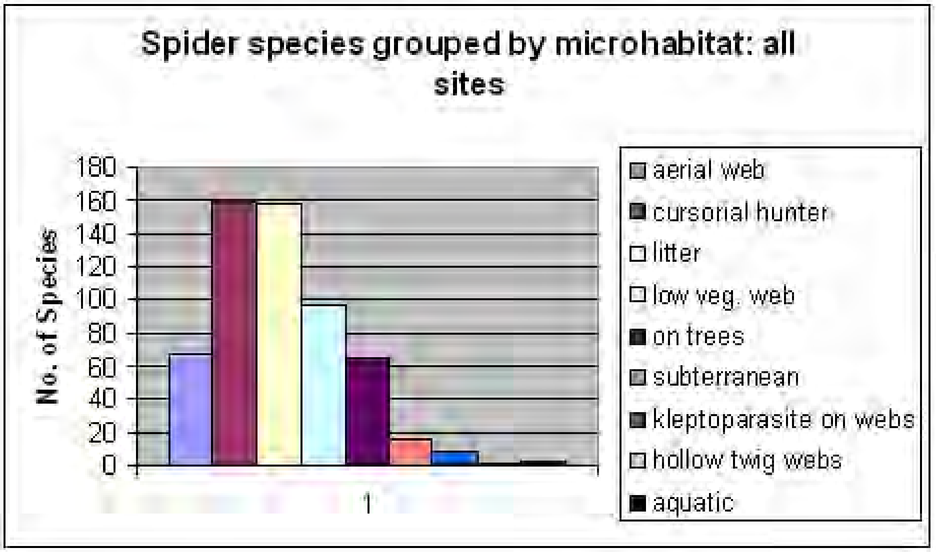


Figure 58. Relative occurrence of 'microhabitat' types in survey total.

It is clear that overall the biggest microhabitat contribution to species diversity in the Brisbane area are spiders which are either cursorial hunters or litter spiders (Fig. 58). However, the relative contributions of these 'ecological' groups is not equivalent across the survey sites and most likely reflects the idiosyncracies of survey plots and survey techniques (Fig. 59).

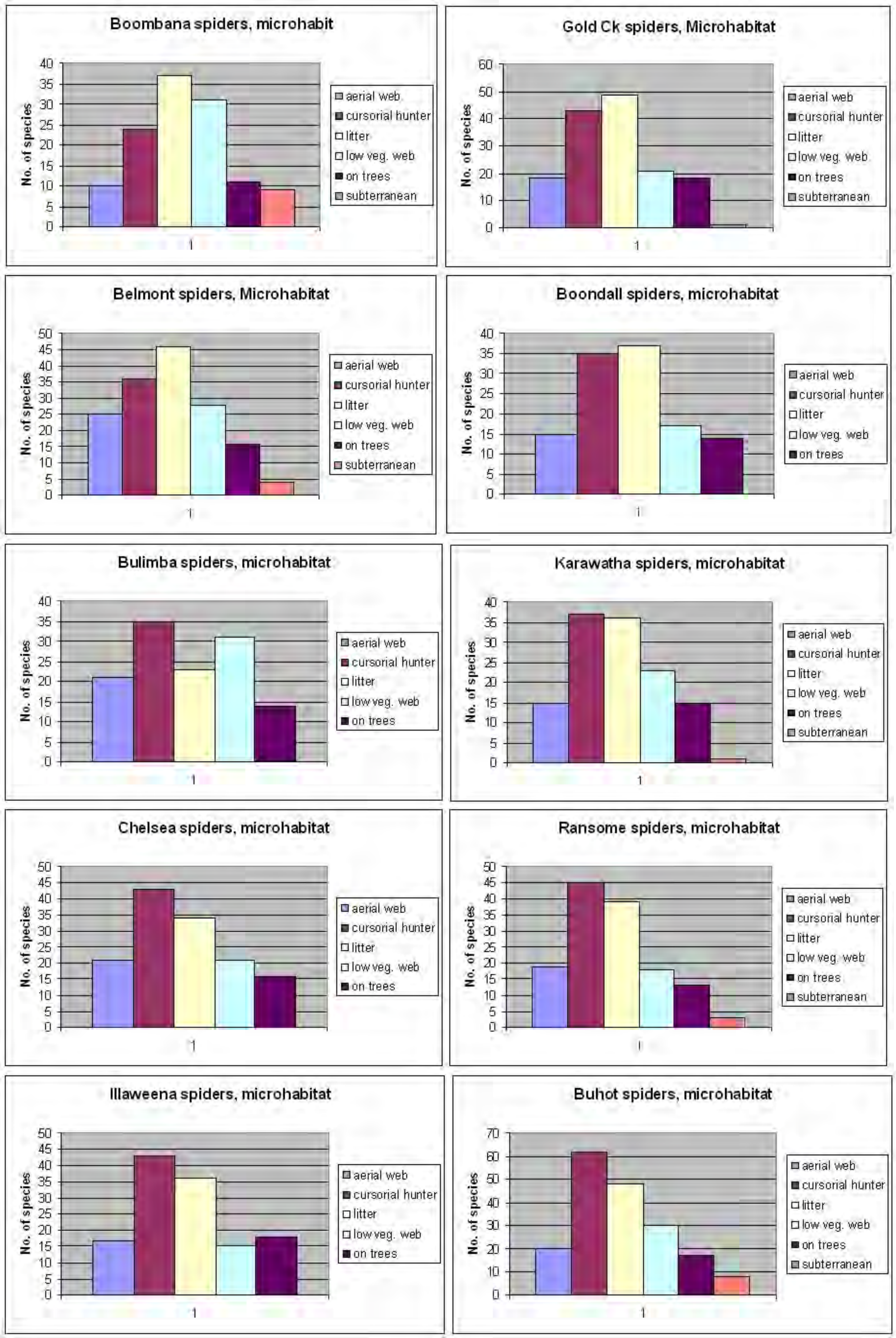


Figure 59. Relative occurrence of spider 'microhabitat types' at each survey site.

Cursorial hunters tend to be more widely distributed and not so informative about site specifics; they do however provide significant contributions both as prey of smaller birds and lizards, especially when logically combined with "on trees" species.

Litter spiders tend to be endemic to small regions and apparent high site endemicity of these spiders in this survey is likely to be an artefact of the sites sampled.

Web builders in open spaces (aerial webs) combined with low veg. web builders also contribute a major component both in terms of diversity and hence in terms of predators of air-borne insects and ants which because of their numerical dominance are the prey of many spider species including the Redback Spider, *Latrodectus hasseltii*. Significantly, in the "pole rainforest" habitat at Boombana low vegetation was limited and orb weavers which would be abundant in such forests were the most depauperate of all sites (10 species). In most sites, the number of cursorial species or litter spiders was 2-3 times that of the aerial web weavers. However, at Bulimba, the low vegetation web builders were the most diverse (presumably because of the dominant grass understorey), litter spiders were only as diverse as the aerial web builders.

As discussed with the Mygalomorphae, the relative number of species of subterranean spiders may be small but the indicator value of these spiders is significant.

Conclusions

- With a total of 568 species collected and a possible total of 658 predicted, the spiders represent one of the larger groups of invertebrates surveyed during the TISR;
- The most informative groups in terms of diversity, endemicity, site integrity and surrogates of site similarities are those families surveyed by pitfall traps and include the trapdoor and funnelweb spiders, Zodariidae, Zoridae, Miturgidae and Corinnidae and account for more than half the species taken;
- Highest periods of productive activity of adult spiders (and hence optimum trapping period) are the summer months. An exception is the trapdoor group of spiders which can be visually surveyed year long and need to be trapped at wider intervals also outside summer; and
- Three sites, Chelsea Road, Illaweena Street and Boondall Wetlands include rare spiders and need to be re-sampled for taxonomic studies of these species.

LAND SNAILS OF BRISBANE CITY

A total of 43 species of land snail belonging to 12 families were collected (Table 16). Five of these species were introductions that are well established in the Brisbane area. Compared with insects and spiders the land snails are a comparatively small group of invertebrates in Brisbane City. It is somewhat axiomatic within the snail world that as suburbia moves in native land snails move out. Only a few hardy native species manage to survive together with a range of adaptable introductions. However, experience has shown that native land snails do not require a large area of greenspace in which to eke out a living and the small patches of Brisbane bushlands that remain are more than adequate to maintain a robust land snail fauna. The land snails of Brisbane City may not be as numerically dominant as the insects and spiders but they nonetheless provide a unique guide to the integrity of the ten TISR sites.

In eastern Australia land snails number approximately 1200 species with almost 900 requiring formal description (Stanisic, unpubl.). Here they are particularly diverse in rainforest with relatively few species living in drier sclerophyll communities (Stanisic 1994). Rainforest species usually are obligate in their habitat preference so that these species would not be expected to be found at any of the drier sclerophyll sites. Those species living in the drier sites are regarded as having greater environmental tolerance and hence in some cases range over vast distances. Single site diversities in rainforest can range to 40 species. However, on average most rainforest sites range from 15-20 species while drier sclerophyll sites range 5-10 species. Most of the BCC sites fall into the drier forest category with only Boombana having true rainforest. Buhot Creek contains rainforest floristic elements while Gold Creek site is adjacent to stands of dry rainforest. Interestingly, but not surprisingly, the suite of snail species collected from each of these sites closely reflects the floristic idiosyncrasies of the sites.

Land snails are most active in wet periods and typically aestivate in the winter months. Hence, the results of the BCC survey are probably somewhat below expectations in regard to abundance and species richness due to the extreme dryness that was affecting the whole of the east coast of Australia during the survey period. In these conditions land snails will tend to be short-term active in response to short-term rain events and spend most of the time aestivating (cf. hibernating) deep in the litter zone of the forests.

Figure 60. The Red-Triangle Slug (left); feeding tracks (centre); eggs (right).

Species such as the Red-Triangle Slug (Fig. 60) are often seen in Brisbane associated with rainfall. These species feed on tree trunks, brick and concrete walls and even concrete driways where ther favaourite food, microscopic algae, accumulates.

Land Snail Diversity

Three families dominate the eastern land fauna. These are the Charopidae, Camaenidae and Helicarionidae and they also dominate the TISR survey.

Charopidae

The Charopidae are a family of very tiny litter snails (shell width < 7mm) that are very diverse in rainforests and usually have very small and circumscribed ranges. They are very difficult to collect except through litter sorting and do not usually display great abundance in the landscape. Their small size and lack of dispersal ability (low vagility) makes them particularly powerful indicators of historical connections between sites and the long-term persistence of relatively stable environmental moisture regimes. Areas where charopids are abundant (e.g. rainforest) are usually areas with high biodiversity, and hence, high conservation value.

Twelve species of charopid were taken in the survey and they showed variable distributions across sites. Boombana was the richest site for these with four species, all obligate rainforest inhabitants. One of these (*Nautiliropa omicron*) was also found at Buhot Creek (Fig. 61). An unusual find was the relatively rare rainforest species *Ngairea corticicola* at Buhot Creek (Fig. 62). This species lives almost exclusively under the bark of fallen rotting trees.

Figure 61. *Nautiliropa omicron*.

Figure 62. *Ngairea corticicola*.

While many charopids do have narrow rainforest-bound distributions, those in the drier scrubs (dry rainforest, eucalypt forest and woodland) can occur over the relatively wider area within the same broad vegetational biotype e.g. Charopidae BR 28 (Fig. 63).

Figure 63. Charopidae BR 28 from Bulimba Creek. Shell width approx 2mm.

Figure 64. The widespread *Discocharopa aperta*. Shell diameter approx 1mm.

In contrast the exceptional and extremely tiny *Discocharopa aperta* encompasses a distribution that includes much of northern Australia and ranges to the Philippines and the Kermadec Islands (Fig. 64).

Two previously unrecorded species (Charopidae BR 44 and BR 45) were collected during the survey and this probably reflects both the localised distribution of these tiny snails and the lack of collecting work by the QCB in drier forests over the years.

Camaenidae

Together with the Charopidae this family is one of the two most speciose in Australia. While camaenids are relatively diverse in eastern Australia, the family's greatest diversity is in the arid and semi-arid areas of central and Western Australia. Seven species were collected during the survey including the rare arboreal species Camaenidae SQ2 from Boombana (Fig. 65). The large *Sphaerospira fraseri* (Fig.66) prefers rainforest but can also be found in wet sclerophyll forest and along drainage lines (riparian). This species can also do well in suburban backyards where these are adjacent to natural bushland and where suitable micro-environments have been created by humans.

Figure 65. Camaenidae SQ 2.

Figure 66. *Sphaerospira fraseri*

The family includes both rainforest obligates (*Ramogenia challengeri*, Camaenidae BR 5 [Fig.67]) and others that are more widely distributed through drier habitats (*Ventopelita mansueta*). The small *Trachiopsis mucosa* is known to prefer dry vine thickets and open forest situations (Fig. 68).

Figure 67. Camaenidae BR 5.

Figure 68. *Trachiopsis mucosa*.

Helicarionidae

This is the third most speciose family in eastern Australia and second most diverse family in the TISR. It includes a group of curious snails, the semislugs, which are renowned for their very reduced shells and their sometimes spectacular colours. One very common species in the Brisbane area is *Fastosarion virens*. The species is particularly prone to capture in pitfall traps, hence the large numbers of individuals recorded. A second species, *Fastosarion aquila* (Fig. 69), is an obligate rainforest dweller. A third, undescribed species, Helicarionidae BR 5 (Fig. 70), is semi-arboreal, often living and feeding on low shrubs. Its large numbers in the survey are largely attributable to the sweeping program designed to capture insects on plants and shrubs. This species prefers wetter sites, such as rainforest and riparian situations.

Figure 69. The rainforest semi-slug *Fastosarion aquila*.The extra flaps of tissue that cover the shell when the animal is active act as secondary breathing surfaces. These snails can absorb oxygen direct from the atmosphere much like frogs. *F. aquila* is restricted to rainforest and was only recorded at Boombana. The more common species, *Fastosarion virens* is present in many of the sites.

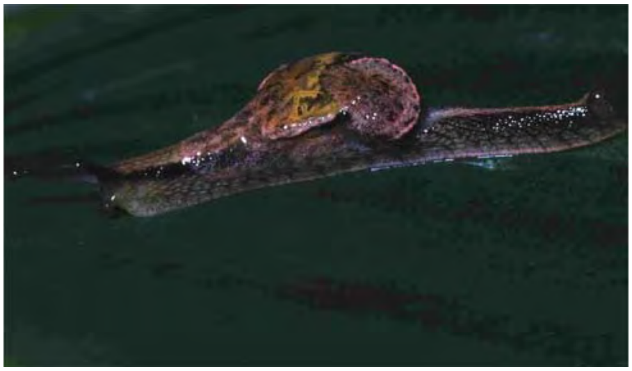


Figure 70. Helicarionidae BR 5.

Figure 71. *Nitor pudibunda*.

Among the more traditionally shelled species, *Nitor pudibunda* (Fig. 71) and the related Helicarionidae BR 7 are both obligate rainforest dwellers, often living among the leaves of the forest floor. Their large numbers in the TISR reflect both their habitat preference and the use of pitfall traps in the survey.

Other families of interest

Caryodidae

This family includes our largest regional snail and one of the largest in Australia, *Hedleyella falconeri* (Giant Panda Snail) [Fig. 72]. This is an obligate rainforest species and is common in the D'Aguilar Range NP. This family also includes the Flat-coiled Snails, *Pedinogyra* spp., which can be found at Mt Glorious but are absent from Mt Nebo.

Figure 72. The very large Giant Panda Snail, *Hedleyella falconeri*. This species occurs in rainforest from the central coast area of New South Wales to Mt Mee, north of Brisbane. It lays the largest known eggs of any Australian land snail with the eggs measuring almost 2cm in diameter.

Rhytididae

A group of predatory carnivores that feed on a range of invertebrates including other snails. While some are quite large e.g. Rhytididae MV 3 (Fig 73), others are very small (*Echotida starngeoides*, Rhytididae BR 1 [Fig. 74]). Most are obligate rainforest dwellers

Figure 73. The large carnivore, Rhytididae MV 3 (left), dining out on the introduced Asian Snail *Bradybaena similaris***.**

Figure 74. Rhytididae BR 1. A small carnivorous species (maximum shell width 10 mm) from Brisbane City bushlands.

Tramp species

While the majority of eastern Australian land snails have fairly localised or at most regionalised distributions, some are more widespread over the landscape. These are a community of species that survive mainly in the archipelago of dry rainforests that pepper the east Australian landscape. These drier forests are often small, sometimes reduced to remnants by land clearing. Often they are physiographic isolates surviving on less rich soils and drier ridges amidst more tropical forest types. A number of the species that typically inhabit these vegetation communities were recorded in the Brisbane survey and indicate historical links with more widespread rainforest communities in the past when climatic conditions were more conducive to survival of these vegetation communities. Their presence may also reflect a level of synanthropic change that has affected the landcape in more recent times e.g land clearing and fire.

These species include the pupillids *Cylindrovertlla hedleyi*, *Gastrocopta pediculus*, *Imputegla circumlitum;*the subulinid *Eremopeas tuckeri*; the charopid *Discocharopa aperta*; and the punctids *Paralaoma caputpinulae* and *Iotula microcosmos*. The camaenid *Trachiopsis mucosa* is another such species.

Introduced Species

These are often a very broad measure of the relative disturbance of areas, especially in urban situations. Surprisingly very few were recorded during the survey. The most common was the almost cosmopolitan European field slug *Deroceras panormitanum* (Fig. 75). This species lives among the grass and is particularly prone to capture in pitfall traps. The less common *Zonitoides arboreus* is a pest in orchid nurseries (Fig. 76).

Figure 75. *Deroceras panormitanum*.

Figure 76. *Zonitoides arboreus*.

A number of introduced species known to inhabit much of the suburban landscape e.g. *Laevicaulis alte* (Fig. 77), *Vaginulus plebeius*, *Lehmannia nyctelia*, and the common garden snail, *Cantareus aspersus* (Fig. 78), were not collected. Many of these can be inadvertently spread to bushland through the illicit dumping of garden rubbish. However, there is a belief (yet to be fully substantiated) that the sclerophyllous vegetation is not suitable food for these vegetarians.

Figure 77. *Laevicaulis alte*.

Figure 78. *Cantareus aspersus*.

Nonetheless, it speaks well for the health of the Brisbane bushlands that so few snail introductions were taken. On the other hand the presence of even a few species in the sites is cause for some concern.

Site diversity

Site diversities fell largely within the range of expectations. The site with highest diversity was Boombana NP with 15 species. Floristically this site differed most from all others in the survey in being a rainforest site and from a land snail perspective it differed most from all others by the fact that 10 of the 15 species found there were not found at any of the other sites. These ten species are obligate rainforest dwellers. The QCB database records 33 species from the Mt Nebo area. However, Mt Nebo is floristically diverse and the database records are derived from a number of different forest types, some of which are not present in the Boombana site. Land snails have an ability to segregate along very fine environmental gradients and hence differ in community structure within very small areas. This characteristic makes them particularly useful as bio-indicators.

Other BCC sites varied in diversity from 5-11 species. Among these Buhot Creek was exceptional in that it contained several rainforest species (*Nautiliropa omicron*, *Ngairea corticicola* and *Echotrida strangeoides*) and a previously unrecorded species of charopid (Charopidae BR 44).

Although Bulimba Creek was a very disturbed site in terms of the presence of many weeds and other floristic introductions it recorded the second highest diversity. This can be ascribed to both its riparian situation (an important habitat for land snails and probably used as a dispersal corridor) and the presence of some dense litter.

Boondall Wetlands displayed signs of regular inundation (presence of several freshwater species in the litter) but still was able to support a community of land snails. These lived mainly on the higher ground within the wetlands. The disturbed nature of this site including dense grass cover was highlighted the presence of the introduced slug, *Deroceras panormitanum*.

Site similarities

Jaccard indices (Table 14) show that Boombana is the most distinctive site with most similarity to Buhot Creek due to the sharing of some rainforests species. Buhot Creek is also quite distinctive from all other sites. The high similarity of Chelsea Road and Ransome Reserve were expected on the basis of broadly similar habitat and geographic proximity. However, the Chelsea Road-Ransome Reserve-Gold Creek alliance was less predictable. Reasons for this are not obvious. The close alliance of Karawatha and Illaweena Street was also to be expected given their location.

Table 14. Jaccard indices for snail data.

	GoldCreek	Belmont	Boondall	Bulimba	Karawatha	Chelsea	Ransome	Illaweena	Buhot
Boombana	4	11	4	4	5	5	4	5	28
GoldCreek		27	13	11	27	50	38	27	6
Belmont			8	23	25	22	17	11	18
Boondall				25	8	15	20	27	6
Bulimba					7	13	18	14	6
Karawatha						22	27	43	8
Chelsea Rd							50	38	8
Ransome		**Jaccard Site Similarity**						40	6
Illaweena		**Molluscs Only**							8

Interestingly, the land snails segregate the TISR sites quite differently to the arthropods surveyed. Comparison of Figure 80 with Table 6 (ants) and Table 13 (spiders) show that site associations based on arthropods only are quite different to the profile generated by molluscs.

A combination of arthropods and molluscs (Table 15) still very much reflects the arthropod picture. Hence, these two broad groups are not suitable surrogates for each other and the results re-inforce the notion that among the invertebrates surveyed the land snails are idiosyncratic in their interpretation of the Brisbane landscapes. However, there is a strong indication that they closely reflect the floristic peculiarities of the sites.

Table 15. Jacaard indices combining land snails, insects and spiders.

	GoldCreek	Belmont	Boondall	Bulimba	Karawatha	Chelsea	Ransome	Illaweena	Buhot
Boombana	9	12	10	13	9	10	10	7	17
GoldCreek		26	26	26	31	30	24	26	18
Belmont			26	35	34	31	26	23	27
Boondall				31	30	33	26	28	20
Bulimba					30	36	29	25	23
Karawatha						33	32	33	22
Chelsea Rd							33	29	21
Ransome		**Jaccard Site Similarity**						25	23
Illaweena		**Arthropods & Molluscs**							18

Factors affecting land snail distribution in the Brisbane City

Land clearing (habitat removal) is the biggest threat to land snail populations. Snails need shelter to reduce the risk of dessication. Maintenance of natural bushland will result in the persistence of snail populations. This has been shown by the results of the TISR.

Land snail distribution in the urban situation will also be affected by fire. All sites with the exception of Boombana are prone to fire either as part of bushland management or as the result of fires deliberately lit by vandals or 'concerned' locals. The snail communities will take considerable time to rebuild populations after fire, particularly hot fires which destroy most of the forest floor debris. This repopulation will result initially in the explosion of numbers of certain species prior to dispersing over the landscape at both the macro and microhabitat level. This phenomenon was evident in both the Illaweena Street and Karawatha SF where charopids, the species probably most prone to fire were present in unusually high numbers in the little microhabitat that was present. Both sites showed evidence of recent 'hot' fires. The judicious use of fire for management rather than relying on an *ad hoc* approach will do much to preserve these local snail communities.

The infiltration of the native bushland by introduced species is also a concern because these may eventually displace the native species. The illegal dumping of garden rubbish is a major factor in the spread of these species.

Conclusions

- land snail communities are still flourishing in the Brisbane City bushlands with a minor presence of introduced species;
- land snails communities are reflecting important differences between sites suggesting that they are useful bio-indicators, in particular this is so of the Charopidae;
- land snail communities show good correspondence with vegetation communities and appear to provide a secondary basis for assessing the integrity of the Brisbane bushlands.

TABLE 13. Results of land snail collecting. An asterisk denotes introduced species.

Scientific name	Boondall Wetlands	Gold Ck	Chelsea Rd	Ransome Res	Bulimba Ck	Belmont Hills	Buhot Ck	Illaweena St	Karawatha Forest	Boombana NP
Family Pupillidae										
Cylindrovertilla hedleyi	2				9					
Gastrocopta pediculus			1	1						
Imputegla circumlitum				1						
Pupillidae MV 1										1
Family Subulinidae										
*Lamellaxis clavulinus**					4					
Eremopeas tuckeri	1	6	5	5	10	3				
Family Rhytididae										
Echotrida strangeoides							1			
Rhytididae BR 1						1	1			10
Rhytididae MV 3										4
Family Caryodidae										
Hedleyella falconeri										
Family Punctidae										
Paralaoma caputspinulae	7				2					
Iotula microcosmos					1					
Family Charopidae										
Nautiliropa omicron							10			16
Ngairea corticicola							1			
Discocharopa aperta					1					
Rotacharopa densilamellata										
Coenocharopa parvicostata										3
Coenocharopa sordidus										5
Coenocharopa multiradiata										4
Charopidae BR 28	5			9	9			9		
Charopidae BR 29		3				2			3	
Charopidae BR 32									7	
Charopidae BR 44							7			
Charopidae BR 45		1	6	3						

Scientific name	Boondall Wetlands	Gold Ck	Chelsea Rd	Ransome Res	Bulimba Ck	Belmont Hills	Buhot Ck	Illaweena St	Karawatha Forest	Boombana NP
Family Athoracophoridae										
Triboniophorus graeffei					1					
Family Helicarionidae										
Fastosarion virens		15	1	5	53	14		24	54	
Fastosarion aquila										5
Nitor pudibunda										49
Wilhelminaia mathilde					1					
Coneuplecta calculosa	1						1			4
Liardetia scandens					5					
Helicarionidae BR 5					40	79	14			117
Helicarionidae BR 7										52
Family Zonitidae										
*Zonitoides arboreus**	1									
Family Agriolimacidae										
*Deroceras panormitanum**	65	1	5					62		
Family Bradybaenidae										
*Bradybaena similaris**	12									
Family Camaenidae										
Sphaerospira fraseri		12	1	7			2	1	2	8
Ventopelita mansueta	14			28				7	13	
Trachiopsis mucosa		1		1						
Austrochloritis separanda		1								
Ramogenia challengeri										3
Camaenidae BR 5		5								
Camaenidae SQ 2										1

CONCLUSIONS

The results of the TISR have been extraordinary in regard to the quantity of material recovered. Specimen and species numbers are high by any standards. Most importantly, all the invertebrates targeted as possible bio-indicators have shown that they have a strong foothold in the bushland patches. And in terms of assessing ongoing ecological processes and functions there is every indication that these are also fully represented by the target groups collected.

Thus for the first time, there is a significant database of invertebrate animals for Brisbane City and this information can be used to address the key issue of managing the River City's biodiversity. There is now an opportunity to monitor the presence of locally significant invertebrate species, species richness and species abundance as well as the ability to measure the health of Brisbane ecosystems through invertebrates and their involvement in fundamental ecological processes. But for this to happen, a number of additional steps need to be taken.

Results of the TISR show that the BCC study sites all have a healthy population of invertebrates. Results also show that individual sites display quite inherent differences from each other in terms of both species richness and abundance of invertebrates. However, in terms of the future monitoring of biodiversity health using these invertebrates it is essential that more focussed scientific studies now be carried out. There is a need to more accurately determine the integrity of study sites in regard to ecosystem definition (finer scale mapping) and then to test the fidelity of invertebrate assemblages across these ecosystems through more rigorous sampling procedures (replication). Results also suggest that the addition of more sites, representing a more varied range of ecosystems, would add more species to the inventory. Hence, surveying more sites would increase the breadth of the baseline data and make monitoring programs more reliable.

In the absence of prior knowledge the BCC project has been a baseline data gathering exercise. But opportunity to progress the findings of the study for urban biodiversity conservation, through the application of science, is now a real possibility.

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