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Ants (Hymenoptera: Formicidae) of Christmas Island (Indian Ocean): identification and distribution

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Abstract – The composition of the Christmas Island (Indian Ocean) ant fauna is reviewed, leading to the recognition of 52 species in 24 genera and 7 subfamilies. This account amalgamates previously published records and recent extensive surveys of Christmas Island's ant fauna. Eight species represent new records for Christmas Island: *Technomyrmex vitiensis*, *Camponotus* sp. (*novaehollandiae* group), *Cardiocondyla kagutsuchi*, *Monomorium orientale*, *M.* cf. *subcoecum*, *Tetramorium* cf. *simillimum*, *T. smithi* and *T. walshi*. Although some of these new species records represent recent taxonomic advances rather than new introductions, we consider four species to be true new records to Christmas Island. These include *Camponotus* sp. (*novaehollandiae* group), *M. orientale*, *T. smithi* and *T. walshi*. None of the 52 species reported here are considered endemic. In general, the Christmas Island ant fauna is composed of species that are regarded as worldwide tramps, or that are widespread in the Indo-Australian region. However, Christmas Island may fall within the native range of some of these species. We provide a key to the ant species of Christmas Island (based on the worker caste), supplemented by comprehensive distribution maps of these ants on Christmas Island and a short synopsis of each species in relation to their ecology and world-wide distribution. Because of the large number of world-wide tramp ants on Christmas Island, this key may also prove applicable for introduced species resident on other oceanic islands.

INTRODUCTION

The ant fauna of Christmas Island (Indian Ocean) has claimed dubious fame through the impact of the introduced Yellow Crazy Ant, *Anoplolepis gracilipes* (Smith, 1857), on the population of a keystone species, the Red Land Crab, *Gecarcoidea natalis* (Pocock, 1888). The continuing decline of the Red Land Crab population through direct aggression by *A. gracilipes* workers is changing the composition and structure of the rainforest, resulting in major ecosystem disruption and providing favourable conditions for secondary invasions (O'Dowd *et al.* 2003). What is less well known is that the island harbours a considerable number of additional tramp ant species (e.g. Taylor 1990), some of which have caused significant ecological damage in other regions of their introduced ranges (e.g. Holway *et al.* 2002; Ness and Bronstein 2004).

Using historical reports, it is difficult to determine how many species of tramp ants are currently established on Christmas Island, and what part of the fauna can be considered native. Records of the ant fauna of Christmas Island have been sporadic and are either published in old or obscure journals (e.g. Crawley 1915; Donisthorpe 1935; Kirby 1888, 1900) or listed in unpublished reports that do not necessarily target ants (e.g. Campbell 1964; Collingwood and Hedlund 1980; Taylor 1990). From the few location records published, it appears that these surveys were generally restricted by their sampling effort and location. The most recent and comprehensive survey undertaken by CSIRO more than 15 years ago resulted in a report of 40 ant species, of which 26 were new records to the island and 29 were considered tramp species (Taylor 1990). However, even this survey did not cover large areas of the island such as the north coast from North West Point to Smith Point and large areas of the south coast between Egeria point and Middle Point (Figure 1). As such, species with localised

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distribution or a cryptic nature would have certainly escaped attention. Furthermore, given the dynamic nature of species composition of transferred ants on oceanic islands (Morrison 1996; Wilson and Taylor 1967), it is highly probable that additional species have since established themselves on the island.

This study provides a comprehensive treatment of the ant fauna of Christmas Island. We combine the results of recent extensive surveys of Christmas Island's ant fauna, with data from historical records to compile an exhaustive species list. Illustrated keys to subfamilies, genera and species to all ants of Christmas Island allow accurate species identification. In addition, we provide detailed distribution maps of all ants and information on their worldwide distribution and, if applicable, their status as tramp species. By drawing on ecological information, in combination with the distribution of the species in the distinct Christmas Island habitats, we also aim to predict the possible spread and ecological impact of introduced species.

MATERIAL AND METHODS

Christmas Island

Christmas Island lies in the Indian Ocean, approximately 360 km south of Java and 2600 km north-west of Perth, Australia (Figure 1). Located in the humid tropics, the island experiences a monsoonal climate with distinct wet (December–May) and dry (June–November) seasons. The island covers approximately 135 km^2, with a coastline consisting predominantly of sheer rocky cliffs from 10–20 m high interspersed with a few small beaches. The interior is a slightly undulating plateau, from 160–360 m above sea level and predominantly covered by tall evergreen closed forest (Claussen 2005). A series of steep slopes or cliffs with intervening narrow terraces separate the central plateau from the shore. Unlike the evergreen tall forests of the plateau, many species on the terraces are deciduous, with the canopy usually being closed during the wet season but open to varying degrees during the dry season. On the terraces the understorey is generally sparser than the plateau, with fewer ferns and lilies (Claussen 2005).

Although 63% of the island is National Park, to date approximately 25% of the island's rainforest have been cleared to mine phosphate. Areas that fall within the current mine lease have variable vegetation cover, ranging in gradient from scorched earth (recently mined), through weed infested wasteland, to 40–50 year old native forest regrowth on stockpiles or areas that were cleared but not mined.

Collection Methods

This study is mainly based on an exhaustive survey of the ants of Christmas Island in 2005 ('Island Wide Survey', IWS 2005) and a survey that predominantly aimed to document the impact of the construction of a large Immigration Reception and Processing Center (IRPC) (see Figure 1) in the Northwestern part of the island ('Biodiversity Monitoring Program', BMP). Parks Australia North, Christmas Island (PANCI), undertook both programs. Results of these surveys are supplemented by collections made during cave surveys (CS) undertaken between 2004 and 2006 organised through the Western Australian Speleological Group, and opportunistic hand collections by PANCI staff. In addition, we critically reviewed published records of Christmas Island ants, since the recent comprehensive collections allowed an interpretation of previous misidentifications.

Island Wide Survey (IWS 2005)

The Island Wide Survey (IWS) is undertaken biennially in the dry months (May–July) as a management tool used by Parks Australia North, Christmas Island, to primarily gain information on the distribution and abundance of the Yellow Crazy Ant and the endemic Red Land Crab. The survey comprises 980 waypoints in a grid network across the entire island. Each waypoint is separated by at least 300 m from any other waypoint and has been accurately established by computerised GIS of Christmas Island. In 2005, we incorporated a sampling program into the IWS in order to obtain a comprehensive understanding of the common ant fauna of the island and its distribution.

A 10 min timed sampling of ants was undertaken at each waypoint. Ants were collected within approximately 100 m^2 area (50 m x 2 m) at each waypoint and searched for on the ground, in leaf litter, under rocks and logs and on tree trunks and low lying foliage. One person undertook ant sampling at each waypoint, but eleven people overall were involved in collecting during the survey. These people were trained to have similar search imagery prior to the commencement of the survey. Particular emphasis was placed on obtaining data on species diversity and not species abundance; therefore ants that were obviously the same species (i.e. from the same foraging trail) were sub-sampled. Ants were collected using either a paintbrush dipped in alcohol or a pair of soft forceps and preserved in EtOH until identified.

Biodiversity Survey (BMP)

The biodiversity survey was implemented as part of the Christmas Island Biodiversity Monitoring Program (BMP) run by PANCI. The survey was undertaken at three different sites near North West

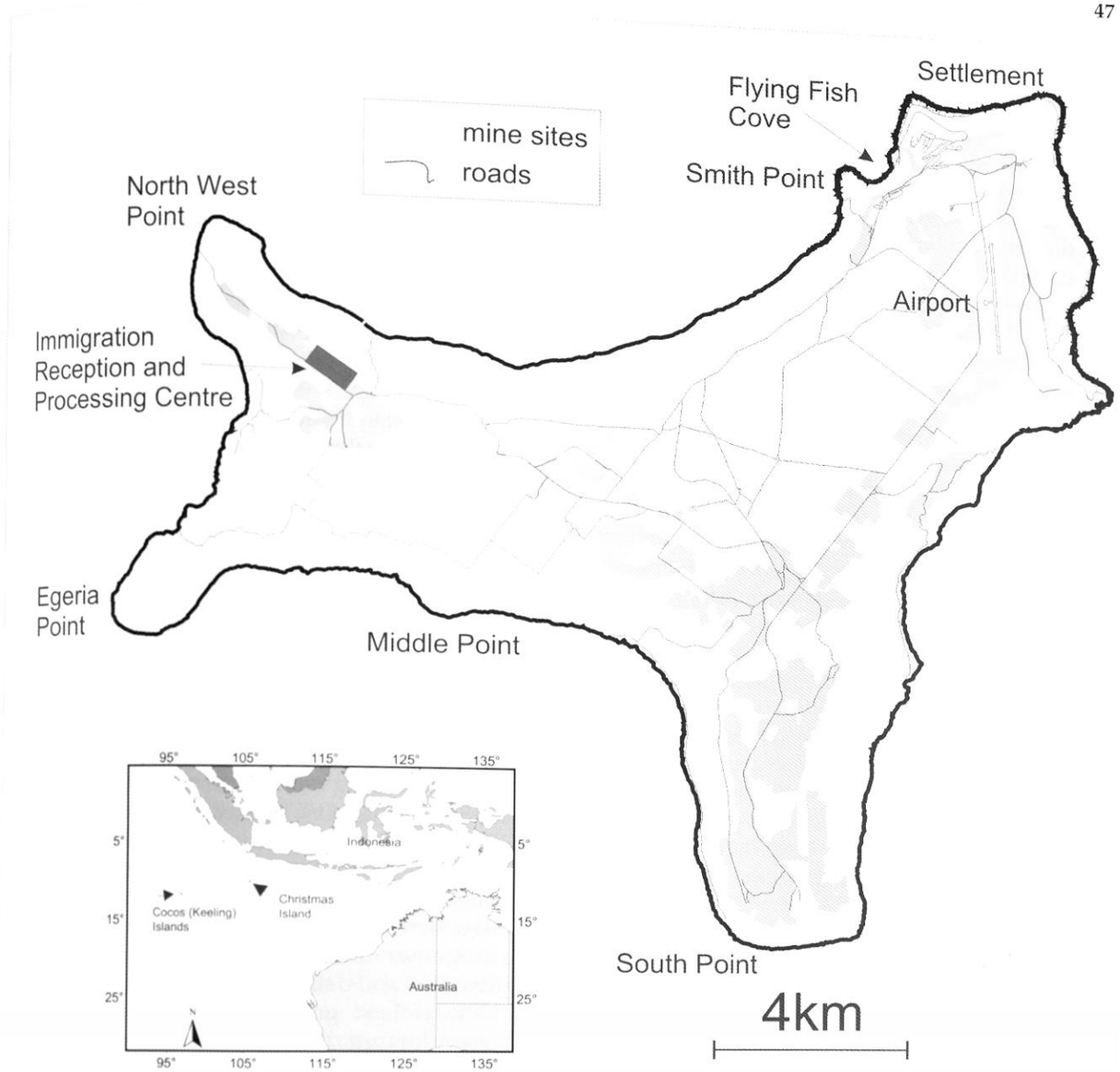


Figure 1 Map of Christmas Island illustrating major geographic features and location of mine sites.

Point, separated by at least 400 m. The sites included internal primary forest (a range of tall evergreen rainforest and tall semi-deciduous rainforest) and edge with varying degrees of disturbance. At each site, traps were placed at either end of two 100 m transects that were spaced 50 m apart (making a total of four trap locations per site). At each trap location two pitfall traps and one canopy malaise trap, intercept trap and light trap were placed. Pitfall, malaise and intercept traps were set for 7 days and nights at each sampling occasion and light traps were set for one night. Collections were made in January, April, July and October during 2004 and 2005. Examining the ants collected from this survey should improve the likelihood of encountering nocturnal, very small and cryptic species. However, specimens from all traps were bulk bottled immediately after collection in each trapping period, so a detailed analysis of which ants were successfully collected with which trap was not possible.

Cave Surveys (CS)

Ants of a recent survey of selected caves of Christmas Island were made available through Bill Humphreys (Western Australian Museum) and Tim Moulds (University of Adelaide). The survey, organised by Darren Brooks through the Western Australian Speleological Group and financed by PANCI, was conducted in April/May 2006. Pitfall traps were the primary method of collection, but hand collections were also made. The Western Australian Museum also holds a small number of ants from a previous cave collection on Christmas

Island undertaken in June 2004 (D. Brooks unpublished data). These ants were also made available for study by Bill Humphreys.

Species Identification

Species identification was based on available printed keys, Internet publications or the opinion of expert ant taxonomists (see Acknowledgements). It was beyond the scope of this study to compare the material collected on Christmas Island with respective type specimens. The knowledge of the taxonomy and systematics of a large number of genera or species groups of ants collected on Christmas Island is rudimentary and requires extensive revision. Therefore, species identification must be taken cautiously and in many cases, definite species names must be considered 'species groups' pending a taxonomic revision of these groups. These include *Anochetus graeffei, Paratrechina bourbonica, Paratrechina minutula, Ochetellus glaber, Tapinoma minutum* and others (see Table 1). Species group designation follows Andersen (2000a, personal communication). Particularly problematic groups include the genera *Paratrechina* and *Camponotus*. In many cases, we have consulted ant specialists currently working on specific taxa (see Acknowledgements) for identification or confirmation of our identifications.

Generic and species group identification followed Bolton (1994), Shattuck (1999) and Andersen (2000a). Species level identification often followed Wilson and Taylor (1967), but more detailed species keys for genera were employed if available. These are listed under the respective taxon headings below. Internet identification tools that were of particular help were the Australian Ant Image Database (available at: http://ant.edb.miyakyo-u.ac.jp/AZ/index.html; verified 11 October 2007), which contains a number of images of ants collected on Christmas Island, and AntWeb (Agosti and Johnson 2005). Some species previously reported from Christmas Island were not found during the current survey. For these species, we have relied on secondary publications for the compilation of keys.

Voucher specimens of species collected during the IWS 2005 are deposited with PANCI and the Western Australian Museum, Perth. Some ants remain with the consulted specialist: Alan Andersen (CSIRO Darwin, various taxa), Barry Bolton (*Technomyrmex, Tetramorium*), Archie MacArthur (South Australian Museum, *Camponotus*), and John LaPolla (Smithsonian Institute, Washington; *Paratrechina*). Collections, in particular the reference collection of the Western Australian Museum, also include a large number of sexuals (e.g. queens and males) for future systematic study; however, sexuals do not form part of our identification key. Previous significant collections of ants from Christmas Island have been lodged with the Australian National Insect Collection (CSIRO, Canberra) (e.g. Taylor 1990).

Subfamilies, genera within subfamilies and species within genera are listed alphabetically. The nomenclature of all species, except *Technomyrmex vitiensis*, follows Bolton (1995).

Abbreviations

ANIC – Australian National Insect Collection, CSIRO, Canberra; PANCI – Parks Australia North, Christmas Island; WAM – Western Australian Museum, Perth.

IWS – Island wide survey; BMP – Biodiversity monitoring program; CS – Cave survey

TL – total length (measured laterally along the extended body of an ant)

RESULTS

General features of the ant fauna of Christmas Island

The ant fauna of Christmas Island comprises 52 species, representing 24 genera in 7 subfamilies (Table 1). The majority of these species were recorded during the IWS (39 species; 76%), with the BMP recording 51% of species (26) and the CS only 25% (13). The cave surveys recorded two cryptic species (*Hypoponera punctatissima* and *Pachycondyla* (*Trachymesopus*) *darwinii*) that were not collected during the IWS 2005 or BMP (Table 1). Altogether over 15,000 ants were individually identified and databased during this study.

The richest genera on Christmas Island are *Tetramorium* (8 species), *Monomorium* (6), *Paratrechina* (5) and *Camponotus* (3). The most commonly recorded species (those recorded from more than 200 of the 980 sites) during the IWS 2005 were: *Paratrechina* sp. (*bourbonica* group) (489 waypoints), *Anoplolepis gracilipes* (478), *Tetramorium insolens* (462), *Pheidole* sp. (*variabilis* group) (314), *Paratrechina* sp. (*minutula* group) (294), *Odontomachus simillimus* (289), *Tapinoma melanocephalum* (279) and *Camponotus melichlorus* (268). These eight species represent 65% of records from the IWS 2005.

The ants of Christmas Island together occupy all habitat types on the island. Although most species are found predominantly in forested sites, a few species such as *Cardiocondyla kagutsuchi, Paratrechina longicornis, Solenopsis geminata*, and *Tetramorium bicarinatum* are restricted to disturbed habitats such as mine sites. It appears that modification of the environment on Christmas Island due to mining activities has produced patches suitable for these species to become established.

DISCUSSION

Of the 52 known ant species on Christmas Island, eight species represent new records for the island: *Technomyrmex vitiensis, Camponotus* sp. (*novaehollandiae* group), *Cardiocondyla kagutsuchi, Monomorium orientale, M.* cf. *subcoecum, Tetramorium* cf. *simillimum, T. smithi*, and *T. walshi*. Some of these new records are based on advances in taxonomy rather than new species to the island. These include *T. vitiensis*, which is here considered a valid species (B. Bolton, personal communication) and not a junior synonym of *T. albipes*, as apparently reported previously. *Monomorium* cf. *subcoecum* and *Cardiocondyla kagutsuchi* are almost certainly the same as *M. talpa* and *C. nuda*, respectively (reported in Taylor 1990, see Heterick 2001; Seifert 2003). Lastly, *Tetramorium* cf. *simillimum* is extremely similar to *T. simillimum* and may have been included in previous reports as *T. simillimum*. Therefore, only four species are here considered as true new records for Christmas Island: *Camponotus* sp. (*novaehollandiae* group), *M. orientale, T. smithi* and *T. walshi*.

A recent immigration to Christmas Island is supported for three of these new species by their distribution pattern. *Monomorium orientale, Camponotus* sp. (*novaehollandiae* group), and *T. smithi* are all found at a limited number of sites (1, 5, and 11 waypoints respectively) that are grouped close to the port of entry (Flying Fish Cove). While *T. walshi* was also found at a small number of waypoints (four), it is more widely distributed across the island. However, this species close association with disturbed habitats (such as roads and minefields) suggests that it may have reached this more extensive distribution through human vectors. Alternatively, given its small size and limited distribution, *T. walshi* could have simply been overlooked in previous surveys.

We consider nine species that have been previously reported from Christmas Island but not found during the current surveys to be part of the Christmas Island ant fauna. These include: *A. zwaluwenburgi, Cerapachys biroi, Plagiolepis alluaudi, P. exigua, Leptanilla* sp., *Monomorium destructor, M. pharaonis, Pyramica membranifera*, and *Hypoponera opaciceps*. Most of these species were reported relatively recently by Taylor (1990) and their absence during the recent surveys most likely reflects limitations in our collecting techniques rather than their extinction from the island. For example, the transect samples of the IWS 2005 almost certainly overlooked small and cryptic species such as *Hypoponera punctatissima, H. opaciceps*, and *Leptanilla* sp. that are known only from single specimens on Christmas Island (Taylor 1990). While the methodology used during the BMP survey would be more likely to reveal these species, the small number and location of sites posed limitations to this survey. Other species not detected, such as *M. destructor*, show very close association with houses in other parts of their introduced ranges (Collingwood et al. 1997) and may have also been overlooked using the current methodology. In other cases, it is difficult to decide without recourse to the original material if a misidentification or sample bias caused the absence of a species in the current survey. For example, *M. pharaonis* has only been reported once (Donisthorpe 1935) and a misidentification is possible. All other species not listed here, which have been previously reported from Christmas Island, have been attributed to misidentifications or taxonomic changes, i.e. they represent junior synonyms of other reported species (see Table 1).

In accordance with previous reports of the ant fauna from Christmas Island (e.g. Collingwood and Hedlund 1980; Taylor 1990), we do not consider any of the species reported here to be endemic. In general, most species are widespread globally or form part of the Indo-Australian fauna (Table 1). The three species that were originally described from Christmas Island (*Camponotus melichloros* Kirby, 1888, *Leptogenys harmsi* (Donisthorpe, 1935), and *Pachycondyla christmasi* (Donisthorpe, 1935)) have subsequently been collected in other parts of the Indo-Pacific region (Taylor 1990). A further subspecies initially described from Christmas Island, *Odontomachus haematodes* var. *breviceps* Crawley, 1915, has subsequently been synonymised with a worldwide tramp, *O. simillimus*.

Although it is evident that none of the ants of Christmas Island are endemic, it is difficult to determine if the island falls within any of the species' native ranges. The first exploration of the island was undertaken in 1887 (Kirby 1888), a year before human settlement in 1888 (see http://www.deh.gov.au/parks/christmas/islehistory.html; accessed 10 October 2007). During this mission, and a survey undertaken 10 years later, only two ant species were collected; *C. melichloros* and *L. harmsi* (see Table 1). Both of these species are widespread in the Indo-Australian region (Taylor 1990), and Christmas Island may fall within their native ranges. Other species, such as *O. simillimus* and *P. christmasi*, could also have a similar status, but were not reported on Christmas Island until 1915 and 1935 respectively. Species reported subsequent to these surveys were most likely introduced onto the island through human commerce. Obvious introductions include species such as *A. gracilipes* (but see Wetterer 2005), *P. megacephala* and *S. geminata*, all of which are well known invasive ants.

The total number of introduced species on Christmas Island at least equals, if not surpasses the

Table 1 Ant species recorded from Christmas Island. IWS – Island Wide Survey, in brackets the number of waypoints at which each species was found (out of 980); BMP – Biodiversity Monitoring Program; CS – Cave Surveys 2004/2006. **Previous records from Christmas Island:** Species name given as in the original publication only if it deviates from the name given in first column. † indicates a junior synonym of listed species; [5] indicates a presumed misidentification or putative synonymy (see under respective species listing in main text). Origin according to Trager (1984)[1], Taylor (1990)[2], Reimer (1994)[3], Morrison (1996)[4], McGlynn (1999)[5], Shattuck and Bennett (2001)[6], Holway *et al.* (2002)[7], Seifert (2003)[8], ABRS (2006)[9], pers. comm.. B. Bolton* IA (Indo-Australian) = widespread in the Indo-Australian region; T (Tramp) = widespread distribution around the globe; I (Invasive) = considered one of the most ecologically damaging introduced ants.

Species	Survey	Previous records from Christmas Island	Origin
Amblyoponinae			
Amblyopone zwaluwenburgi (Williams, 1946)	–	Taylor (1990), known from one queen specimen only	T [2]
Cerapachyinae			
Cerapachys biroi Forel, 1907	–	Taylor (1990)	T [2, 5]
C. longitarsus (Mayr, 1879)	IWS (1)	Taylor (1990)	IA [2, 6]
Dolichoderinae			
Ochetellus sp. (*glaber* (Mayr, 1862) group)	IWS (9)	Taylor (1990; *Iridomyrmex glaber* (Mayr))	T [2, 3]
Tapinoma melanocephalum (Fabricius, 1793)	IWS (279), BMP, CS	Donisthorpe (1935); Taylor (1990); Abbott (2006)	T [2, 4, 5]
Tapinoma sp. (*minutum* Mayr, 1862 group)	IWS (4)	Campbell (1964; *Tapinoma minutum*)	IA [4]
Technomyrmex vitiensis Mann, 1921	IWS (87), BMP	Taylor (1990; *Technomyrma* [sic] *albipes* (Fr. Smith)†)	T*
Formicinae			
Anoplolepis gracilipes (Smith, 1857)	IWS (478), BMP, CS	Donisthorpe (1935; *Anoplolepis longipes* Jerd.†); Taylor (1990; *Anoplolepis longipes* (Jerdon)†); O'Dowd *et al.* (2003); Abbott (2005, 2006)	I [7]
Camponotus sp (*reticulatus* Roger, 1863 group)	IWS (34), BMP	Taylor (1990; *Camponotus* sp. (widespread Indo-Australian))	IA [2]
C. melichloros Kirby, 1888	IWS (268), BMP, CS	Kirby (1888, **new species**); Kirby (1900); Donisthorpe (1935; *Camponotus* (*Tanaemyrmex*) *melichloros* Kirby); Collingwood & Hedlund (1980; *Camponotus chloroticus* Emery, 1897[5]); Taylor (1990; *Camponotus* sp. (widespread Indo-Australian)); Abbot (2006; *Camponotus maculatus*)	IA [2]
Camponotus sp. (*novaehollandiae* Mayr, 1870 group)	IWS (9)		
Paratrechina bourbonica (Forel, 1886)	IWS (489), BMP, CS	Donisthorpe (1935); Taylor (1990)	IA [6]
P. longicornis (Latreille, 1802)	IWS (68), BMP	Tweedie (1933); Donisthorpe (1935); Taylor (1990); Abbott (2006)	T [2, 4]
Paratrechina sp. (*minutula* (Forel, 1901) group)	IWS (294), BMP	Taylor (1990; *Paratrechina minutula* (Forel)); Abbott (2006; *Paratrechina minutula*)	T [2, 4, 5]
Paratrechina sp. (*vaga* (Forel, 1901) group)	IWS (12)	Collingwood & Hedlund (1980; *Paratrechina vaga*)	T [2]
P. vividula (Nylander, 1846)	IWS (22)	Crawley (1915; *Prenolepis vividula* Nyl.); Donisthorpe (1935)	T [5]
Plagiolepis alluaudi Forel, 1894	–	Collingwood & Hedlund (1980)	T [1]
P. exigua Forel, 1894	–	Collingwood & Hedlund (1980)	T [4]
Leptanillinae			
Leptanilla sp.	–	Taylor (1990; *Leptanilla* sp. 1), known from one male specimen only	
Myrmicinae			
Cardiocondyla kagutsuchi Terayama, 1999	IWS (23)	Taylor (1990; *Cardiocondyla nuda* (Mayr)[5])	IA [8]
C. wroughtonii (Forel, 1890)	IWS (31), BMP	Taylor (1990)	T [2, 4, 5]
Monomorium destructor (Jerdon, 1851)	–	Donisthorpe (1935); Collingwood & Hedlund (1980)	T [5]
M. floricola (Jerdon, 1851)	IWS (16), BMP	Donisthorpe (1935); Taylor (1990)	T [2, 4, 5]
M. latinode Mayr, 1872	IWS (5)	Bolton (1987); Taylor (1990)	
M. orientale Mayr, 1879	IWS (1)		
M. pharaonis (Linnaeus, 1758)	–	Donisthorpe (1935)	T [5]
M. cf. *subcoecum* Emery, 1894	BMP, CS	Taylor (1990; *Monomorium talpa* Emery†)	
Pheidole megacephala (Fabricius, 1793)	IWS (37), BMP	Donisthorpe (1935); Collingwood & Hedlund (1980); Taylor (1990)	I [5, 7]
Pheidole sp. (*variabilis* group)	IWS (314), BMP, CS	Collingwood & Hedlund (1980; *P. oceanica* Mayr, 1866); Taylor (1990); *Pheidole* sp. (widespread Indo-Australian))	IA [2]
Pyramica membranifera (Emery, 1869)	–	Taylor (1990; *Trichoscapa membranifera* (Emery))	T [2, 5]
Solenopsis geminata (Fabricius, 1804)	IWS (111), BMP	Crawley (1915; *S. geminata* F. var. *rufa* Jerd.); Tweedie (1933; *Solenopsis geminata rufa* Jerd.); Donisthorpe (1935; *S. geminata* F. subspecies *rufa* Jerd.); Collingwood & Hedlund (1980); Taylor (1990)	I [7]
Strumigenys emmae (Emery, 1890)	BMP	Taylor (1990; *Quadristruma emmae* (Emery))	T [2, 4, 5]
S. godeffroyi Mayr 1866	IWS (1)	Taylor (1990)	T [2, 4]
Tetramorium bicarinatum (Nylander, 1846)	IWS (34), BMP	Donisthorpe (1935; *Tetramorium guineensis* F.†); Collingwood & Hedlund (1980); Taylor (1990)	T [2, 4, 5]
T. insolens (Fr. Smith, 1861)	IWS (462), BMP, CS	Taylor (1990)	T [2]
T. lanuginosum Mayr, 1870	IWS (128), BMP	Crawley (1915; *Triglyphothrix striatidens* Em.); Donisthorpe (1935; *Triglyphothrix striatidens* Emery); Taylor (1990)	T [2, 5]
T. pacificum Mayr, 1870	IWS (17), BMP	Taylor (1990)	IA [4, 5], T [2]
T. simillimum (Smith, 1851)	IWS (163), BMP, CS	Donisthorpe (1935); Taylor (1990)	T [2, 4, 5]
T. cf *simillium* (PF2,2)	IWS (4)		
T. smithi Mayr, 1879	IWS (11)		
T. walshi Forel,1890	IWS (5)		
Ponerinae			
Anochetus sp. (*graeffei* Mayr, 1870 group)	IWS (17), BMP	Taylor (1990; *Anochetus graeffei* Mayr)	IA [4], T [2]
Hypoponera confinis (Roger, 1860)	IWS (14), BMP	Taylor (1990)	IA [2]
H. opaciceps (Mayr, 1887)	–	Taylor (1990), known from one worker only	T [2, 4, 5]
H. punctatissima (Roger, 1859	CS	Taylor (1990), known from one worker only	T [2, 5]
Leptogenys falcigera Roger, 1861	IWS (6)	Taylor (1990)	T [2]
L. harmsi Donisthorpe, 1935	IWS (68), BMP	Kirby (1888, 1900; *Lobopelta diminuta* (Smith)[5]); Donisthorpe (1935, **new species**); Collingwood & Hedlund (1980; *Leptogenys pequeti* [sic] (André)[5]); Taylor (1990)	IA [2]
Odontomachus simillimus Smith, 1858	IWS (289), BMP	Crawley (1915; *Odontomachus haematoda* L. var. *breviceps*, **new subspecies**†.); Tweedie (1933; *Odontomachus haematodes* L.[5]); Donisthorpe (1935; *Odontomachus haematoda* L. var. *breviceps*†); Campbell (1964); Taylor (1990); Abbott (2006)	IA [2]
Pachycondyla (Brachyponera) *christmasi* (Donisthorpe, 1935)	IWS (192), BMP, CS	Donisthorpe (1935; *Euponera* (*Mesoponera*) *christmasi*, **new species**); Collingwood & Hedlund (1980; *Pachycondyla solitaria* Mayr[5]); Taylor (1990; *Brachyponera christmasi* (Donisthorpe)); Abbott (2006; *Brachyponera christmasi*)	IA [2]
Pachycondyla (*Trachymesopus*) *darwinii* (Forel, 1893)	CS	Taylor (1990) (*Trachymesopus* considered junior synonym of *Pachycondyla* in Bolton 1995)	IA [2]
Platythyrea sp. (*parallela* (Smith, 1859) group)	IWS (25), CS	Taylor (1990; *Platythyrea wroughtonii* Forel†)	IA [2]
Ponera swezeyi (Wheeler, 1933)	IWS (2), BMP, CS	Taylor (1990)	T [2]

known number of ant species introduced to Hawaii (45 species, Reimer 1994) and nearly every other biogeographical region of the world (McGlynn 1999). This is true, even when taking into account the possibility that a few of the species recorded on Christmas Island may be native, and that a few species reported here were not collected during the current survey and possibly no longer occur. Oceanic islands are reputed for supporting large numbers of introduced species, and their depauporate native ant fauna is thought to contribute to this condition (Simberloff 1995; Wilson and Taylor 1967). In addition, the proximity of Christmas Island to Indonesia (300km), and the fragmentation of Christmas Islands landscape through phosphorus mining may have facilitated the establishment of exotic ants. Studies investigating the species richness of non-native taxa have shown that anthropogenic factors, such as the degree of disturbance, fragmentation and proximity to the edge of the habitat fragment are often important factors influencing non-native species richness (Brooks 1999; Byers 2002; With 2002).

Perhaps the greatest concern relating to the introduced ant fauna on Christmas Island is the potential for endemic species extinction. On Hawaii, the lack of co-evolved defenses of the endemic terrestrial fauna against exotic alien ants has resulted in drastic reductions in the native invertebrate fauna (Reimer 1994). Similarly, on Christmas Island the Yellow Crazy Ant is having a devastating impact on the endemic Red Land Crab (O'Dowd *et al.* 1999), and is possibly affecting populations of the endemic subspecies of the ground foraging Emerald Dove *Chalcophaps indica natalis* Lister, 1889 and the endemic Christmas Island Thrush *Turdus poliocephalus erythropleurus* Sharpe, 1887 (Davis 2002). With the exception of the Red Land Crab, the impact of *A. gracilipes* and other exotic ants on the native invertebrate fauna of Christmas Island is unknown, but the potential lack of co-evolved defenses could make them particularly vulnerable to extinction. For example, two potentially endemic spiders (*Ariadna natalis* Pocock, 1900 and *Heteropoda listeri* Pocock, 1900) have not been found during recent targeted collections, although they were considered common when originally described (Pocock 1900). Undoubtedly, more experimental and observational evidence is required to determine the effect of these exotic ants on the native terrestrial fauna, in particular in relation to invertebrates.

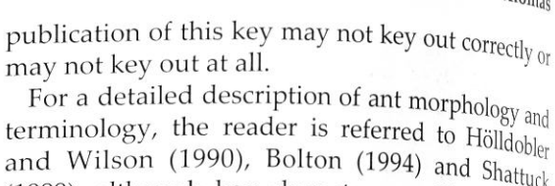
KEY TO THE ANTS (WORKERS) OF CHRISTMAS ISLAND

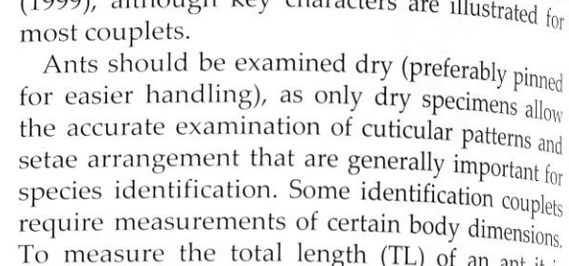
The identification keys presented here will only work for ants considered part of the Christmas Island fauna (Table 1). Species introduced after the publication of this key may not key out correctly or may not key out at all.

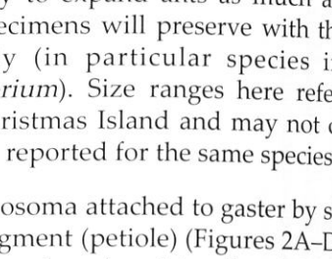
For a detailed description of ant morphology and terminology, the reader is referred to Hölldobler and Wilson (1990), Bolton (1994) and Shattuck (1999), although key characters are illustrated for most couplets.

Ants should be examined dry (preferably pinned for easier handling), as only dry specimens allow the accurate examination of cuticular patterns and setae arrangement that are generally important for species identification. Some identification couplets require measurements of certain body dimensions. To measure the total length (TL) of an ant it is necessary to expand ants as much as possible, as most specimens will preserve with the gaster bent ventrally (in particular species in the genus *Tetramorium*). Size ranges here refer to material from Christmas Island and may not correspond to the sizes reported for the same species elsewhere.

1. Mesosoma attached to gaster by single, distinct segment (petiole) (Figures 2A–D); petiole can be reduced and hardly visible (Figure 2C); gaster may be depressed between first and second segment, appearing like petiole and postpetiole (Figure 2D) 2
– Mesosoma attached to gaster by two distinct segments (petiole and postpetiole), gaster always unconstricted between first and second segment (Figure 3) 30

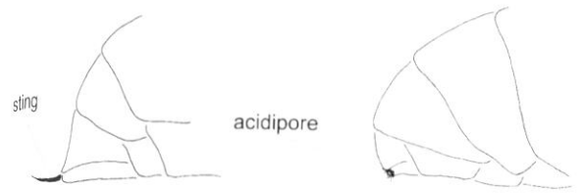




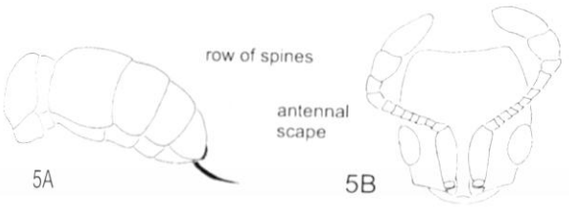


2. Petiole with distinct rear face (Figures 2A, D) or reduced (Figure 2C) 3
– Petiole with distinct front and top faces, but no separate rear face as the rear face is attached to the gaster (gaster separated from petiole only by a shallow impression) (Figure 2B), small ants (< 2 mm in length), eyeless .... *Amblyopone zwaluwenburgi* (Amblyoponinae)

3. Sting well developed and functional, and visible in dead specimen (Figure 4A) 4
- Sting absent, tip of gaster with a circular or semicircular opening (acidipore) which is often fringed with short setae (Figure 4B), or tip of gaster slit-like without fringe of setae 16

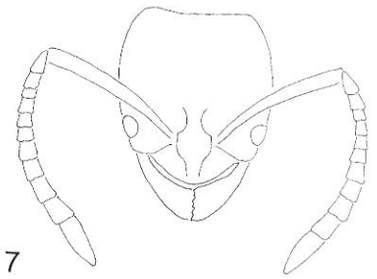


4. Upper surface of tip of gaster (pygidium) with a row of small spines (Figure 5A); antennal scape short, only reaching about halfway along head (Figure 5B) .... 5 (Cerapachyinae: *Cerapachys*)
- Upper surface of the tip of the gaster without a row of spines; scape longer than halfway along head ..... 6 (Ponerinae)

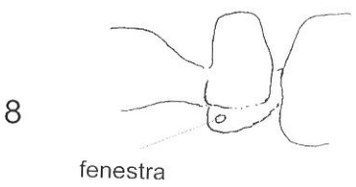


5. Eyeless, unicolourous reddish-brown .... *Cerapachys biroi*
- Well-developed compound eyes, bicoloured (head and gaster, excluding first segment, dark brown; trunk and petiole light brown; first segment of gaster bicoloured with posterior end dark brown) (Figure 24) .... *Cerapachys longitarsus*

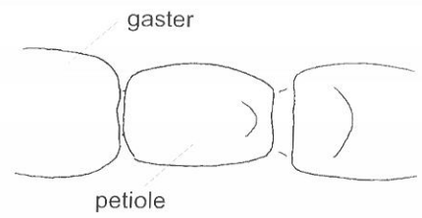
6. Head of bizarre, sculptured form (Figures 6A–B) with mandibles linear and inserted near its midline 7
- Head not deeply sculptured, mandibles inserted at side of head (e.g. Figure 7) 8



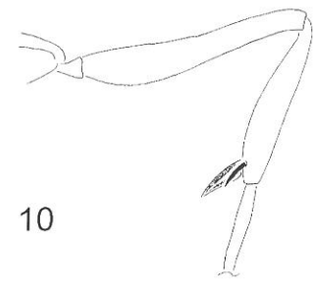
7. Large ant (TL ca. 8.0 mm), petiole dorsally drawn into acute spine (Figure 74) .... *Odontomachus simillimus*
– Medium sized (TL ca. 3.0 mm), petiole summit a narrow transverse ridge .... *Anochetus* sp. (*graeffei* group)
8. Small ant (< 2mm in length), lower surface of petiole with translucent spot (fenestra) towards the front when viewed from the side (Figure 8) ..... *Ponera swezeyi*
– Larger (> 3.0 mm), lower surface without fenestra 9



9. Petiole cylindrical, in dorsal and lateral view longer than wide (Figure 9) .... *Platythyrea* sp. (*parallela* group)
– Petiole not cylindrical, generally wider than long in dorsal view 10



10 Tibia of hind leg with a single, comb-like (pectinate) spur ..... 11 (*Hypoponera*)
– Tibia of hind leg with two spurs, one small, and a larger, comb-like (pectinate) one (Figure 10) 13



11. Antennal scapes short; when laid back along head they fail to attain median occipital border by a distance greater than their maximum diameter ..... *Hypoponera punctatissima*

– Antennal scapes longer, clearly attaining or surpassing median occipital border 12

12. Dorsum of pronotum strongly shining and lacking punctuation; petiolar node in side view distinctly narrowing dorsally (Figure 68) ..... *Hypoponera confinis*

– Dorsum of pronotum dully shining, with a close cover of very fine punctures; anterior and posterior faces of petiolar node in side view almost parallel ..... *Hypoponera opaciceps*

13. Eyes inconspicuous, less than 5 ommatidia ..... *Pachycondyla* (*Trachymesopus*) *darwinii*

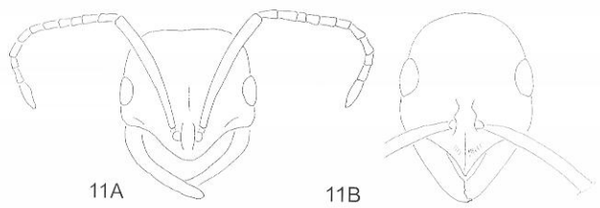
– Eyes conspicuous, more than 10 ommatidia 14

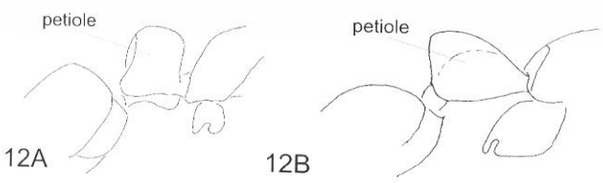
14 Claws on hind-legs without teeth ..... *Pachycondyla* (*Brachyponera*) *christmasi*

– Inner margin of claws on hind-legs with teeth ..... 15 (*Leptogenys*)

15. Mandibles slender and strongly curved at base (Figure 11A); petiole of similar height along its whole length (Figure 12A) ..... *Leptogenys falcigera*

– Mandibles wider and not curved at base (Figure 11B); petiole distinctly higher towards the rear when viewed from the side (Figure 12B) ..... *Leptogenys harmsi*





16. Tip of gaster with a circular or semicircular opening (acidipore), often fringed with short setae (Figure 4B) ..... 17 (Formicinae)

– Tip of gaster slit-like, never with fringe of setae ..... 27 (Dolichoderinae)

17. Antennae with 10 or 11 segments (including scape) 18

– Antennae with 12 segments (including scape). 20

18. TL ca. 5 mm; scape surpassing the rear margin of the head by two thirds their length or more; yellow to light brown ants, body elongate, pronotum (first segment of trunk) longer than wide in dorsal view (Figure 33). ..... *Anoplolepis gracilipes*

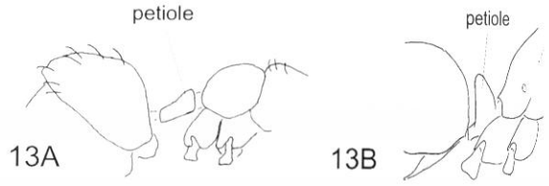
– TL < 3 mm; scape surpassing the rear margin of the head by less than one quarter of their length, body compact, pronotum shorter than wide viewed dorsally ..... 19 (*Plagiolepis*)

19. Antennal scape exceeds the occipital corner by at least the length of the first two funicular segments combined ..... *Plagiolepis alluaudi*

– Antennal scape exceeds the occipital corner by less than the length of first furnicular segment ..... *Plagiolepis exigua*

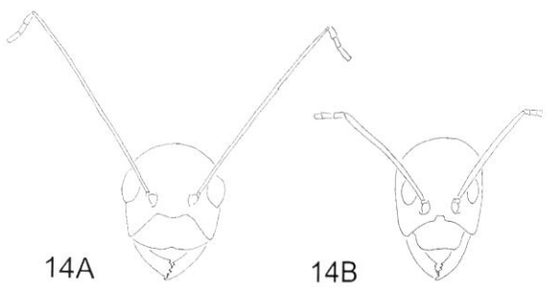
20. TL < 3 mm; head, trunk [except propodeum (= third segment of trunk)] and gaster with dorsally prominent standing dark setae (only the small *P. minutula* has two setae on propodeum), petiolar node inconspicuous, with only a low frontal face (Figure 13A) ..... 21 (*Paratrechina*)

– TL > 3 mm; head, trunk (including propodeum) and gaster with long, white but less prominent setae, petiolar node conspicuous (Figure 13B) ..... 25 (*Camponotus*)



21. Scapes surpassing occipital margin of the head by two-thirds their length or more (best viewed from the side) (Figure 14A; also Figure 42), body elongate and thin ..... *Paratrechina longicornis*

– Scapes surpassing the rear margin of the head by less than half their length (Figure 14B; also Figure 40) 22



22. Small (TL = 1.3 mm), propodeum (third segment of trunk) with two setae, unicolourous light yellow-brown ..... *Paratrechina* sp. (*minutula* group)

- Larger ants (TL = 1.5 mm), propodeum without setae 23

23. TL ca. 1.5 mm; body brown (gaster might be somewhat darker), coxae of leg 2 and 3 distinctly lighter than trunk ..... *Paratrechina vividula*

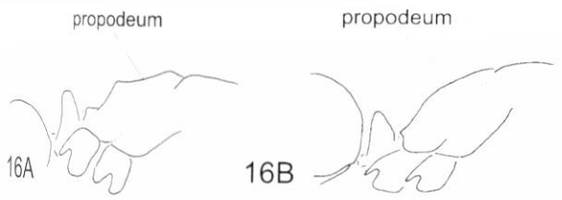
- Body light brown to black (gaster might be darker), coxae of leg 2 and 3 not distinctly lighter than trunk 24

24. TL ca. 2.5 mm, body uniformly dark brown to black or light brown with darker gaster, katepisternum (cp. Figure 15) with short setae ..... *Paratrechina* sp. (*bourbonica* group)

- TL ca. 1.6 – 2.0 mm; body uniformly light brown, katepisternum without setae ..... *Paratrechina* sp. (*vaga* group)

25. TL < 4 mm; dorsal profile of propodeum concave (Figure 16A); apical segments of antennae darker than rest of antennae including scape *Camponotus* sp. (*reticulatus* group)

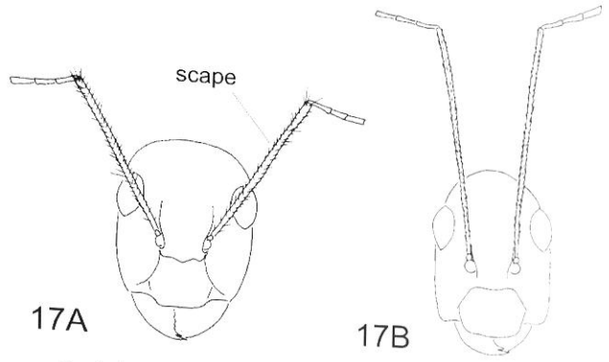
- TL > 5 mm; dorsal profile of propodeum convex (Figure 16B); scape darker than apical segments of antennae 26



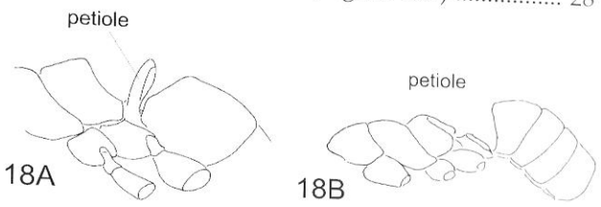
26. Length of antennal scape ca. 1.8–2.0 mm, setae on antennae erect, single setae somewhat longer (Figure 17A) ..... *Camponotus melichloros*

- Length of antennal scape ca. 2.3–2.5 mm; setae on scape shorter, appressed and all of similar lengths (Figures 17B) ..... *Camponotus* sp. (*novaehollandiae* group)

27. Petiolar node well developed, with distinct frontal and rear faces, TL ca. 2 mm (Figure 18A) ..... *Ochetellus* sp. (*glaber* group)



– Petiolar node greatly reduced, its forward face absent or indistinct (Figure 18B) 28



28 Larger ants (TL ca. 3 mm), unicolorous dark brown to black ..... *Technomyrmex vitiensis*

– Very small ants (TL = 1.8 mm), light yellow-brown or bicoloured with dark brown head and trunk and light gaster (Figure 28) ..... 29 (*Tapinoma*)

29. Head and trunk dark brown in contrast to light gaster, legs and antennae (trunk sometimes lighter dorsally) (Figure 28), TL ca. 1.5 mm .. .. *Tapinoma melanocephalum*

– Unicolorous light yellow-brown, minute (TL ca. 1 mm) ..... *Tapinoma* sp. (*minutum* group)

30 Eyes absent ..... *Leptanilla* sp. (Leptanillinae)

– Eyes present, generally conspicuous and with many facets (ommatidia) (rarely with one or two ommatidia) ..... 31 (Myrmicinae)

31. Antennae with 10–12 segments (including scape) 32

– Antennae with a maximum of 6 segments (including scape) 50

32. Antennae 10-segmented, antennal club 2-segmented ..... *Solenopsis geminata*

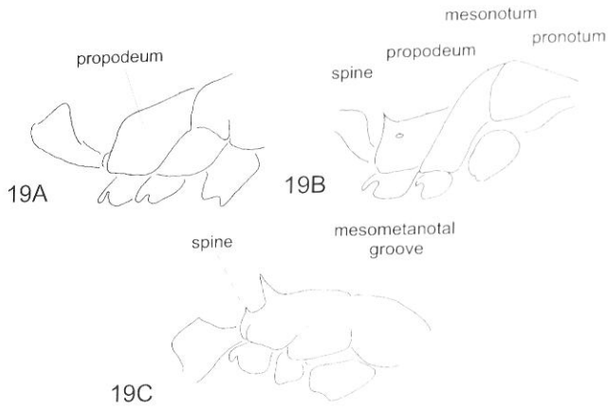
– Antennae 11- or 12-segmented, antennal club 3-segmented or no distinct club 33

33. Propodeum without spines (Figure 19A) ..... 34 (*Monomorium*)

– Propodeum with one or two pairs of distinct spines (Figures 19B–C) 39

34. Very small ants, TL < 1.3 mm 35

– Larger ants, TL > 1.5 mm 37



35. Head and gaster distinctly darker than mesosoma ..... *Monomorium floricola*
– Head and gaster of similar colour as mesosoma 36

36. Reduced eyes with only 1–2 ommatidia ..... *Monomorium* cf. *subcoecum*
– Eyes normally developed, eyes with > 10 ommatidia ..... *Monomorium orientale*

37. Mandibles with 5 teeth . *Monomorium latinode*
– Mandibles with 4 teeth 38

38 TL ca. 2 mm, head and trunk heavily punctuate ..... *Monomorium pharaonis*
– TL ca. 3 mm, head and trunk not punctuate ..... *Monomorium destructor*

39 Pro- and mesonotum prominently rounded and markedly higher than propodeum in lateral view (Figure 19B) ..... 40 (*Pheidole*)
– Profile of trunk straight with at most a small mesometanotal groove (Figure 19C) 41

40. Pronotum and top of head shiny ..... *Pheidole megacephala*
– Pronotum and top of head strongly punctured and rugose ..... *Pheidole* sp. (*variabilis* group)

41. Mesosoma and gaster with standing setae; distinct frontal carinae (longitudinal ridges originating above antennae) extending almost to the posterior margin of head ..... 42 (*Tetramorium*)
– No standing pilosity on head, mesosoma and gaster (setae appressed to body); frontal carina shorter ..... 49 (*Cardiocondyla*)

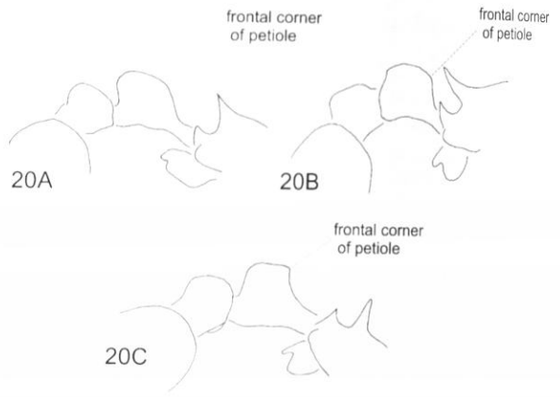
42. Antennae 11-segmented, postpetiole in dorsal view wider than petiole and its upper surface smooth and shiny ..... *Tetramorium smithi*
– Antennae 12-segmented, postpetiole in dorsal view ca. as wide as petiole and its upper surface with pits 43

43. Fairly dense cover of silvery setae, some of which are bifid or trifid (i.e. ends are split in two or three) 44
– Body pilosity less dense, setae never bifid or trifid 45

44. Gaster black, distinctly darker than head and trunk and with single setae that can be easily recognized individually ..... *Tetramorium lanuginosum*
– Gaster dark brown, of similar colour or slightly darker than head and trunk and covered with dense, almost fur-like bifid and trifid setae that can hardly be recognised individually ... *Tetramorium walshi*

45. Larger ants (TL > 2.0 mm); setae on trunk slender and acute 46
– Smaller ants (TL < 2.0 mm), setae on trunk short, thick and blunt 48

46. Body uniformly dark brown, frontal corner of petiole without a distinct edge (Figure 20A) ..... *Tetramorium pacificum*
– Body uniformly yellow-brown or yellow-brown and with darker gaster; frontal corner of petiole more pronounced (Figures 20B–C) 47

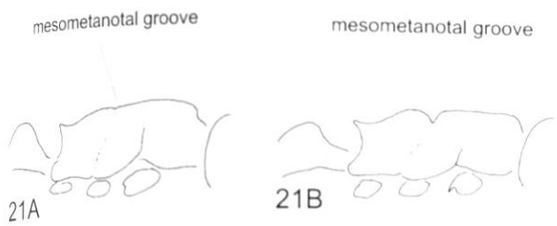


47. Body uniformly yellow-brown (very shiny in dried specimens), petiole frontal face with indistinct frontal corner (Figure 20B); some setae on front of head distinctly longer than diameter of eyes ..... *Tetramorium insolens*
– Gaster darker than body (body not very shiny in dried specimens); frontal corner of petiole distinct (Figure 20C); setae on front of head shorter than diameter of eyes ..... *Tetramorium bicarinatum*

48. Body uniformly yellow-brown, palp formula (number of segments) 4,3 ..... *Tetramorium simillimum*
– Gaster darker than body, palp formula 2,2 ..... *Tetramorium* cf. *simillimum*

49. In lateral view, mesometanotal groove absent or very weak (Figure 21A), antennal club darker than scape; gaster black ..... *Cardiocondyla kagutsuchi*

– In lateral view, mesometanotal groove distinct (Figure 21B); antennae uniformly coloured; gaster light brown ..... *Cardiocondyla wroughtonii*



50. Mandibles linear, meeting only at their tips, inner margins without teeth ..... 51 (*Strumigenys*)
– Mandibles triangular, meeting along their inner margins which are toothed ..... *Pyramica membranifera*

51. Antennae with 4 segments (including scape) ... *Strumigenys emmae*
– Antennae with 6 segments (including scape) ... *Strumigenys godeffroyi*

ANTS OF CHRISTMAS ISLAND

All currently reported ant species are listed here with comments on their identification, ecology, and distribution on Christmas Island and worldwide. Subfamilies, genera within subfamilies and species within genera are listed in alphabetical order.

Family Formicidae Latreille, 1809

Subfamily Amblyoponinae Bolton, 2003

Genus *Amblyopone* Erichson, 1842

Members of the genus *Amblyopone* are specialist predators on certain arthropods; some show a strong preference for centipedes (Shattuck 1999). They live in soil or leaf litter (Wilson and Taylor 1967).

Amblyopone zwaluwenburgi (Williams, 1946)

Identification

Very small (TL < 2mm); eyeless (Figure 22); single petiole is attached to gaster with its whole rear face (Figure 2B).

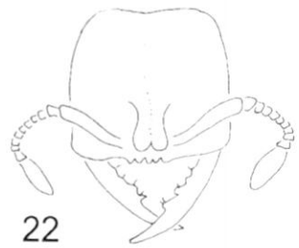


Figure 22 Head of *Amblyopone zwaluwenburgi* (redrawn after Wilson and Taylor 1967).

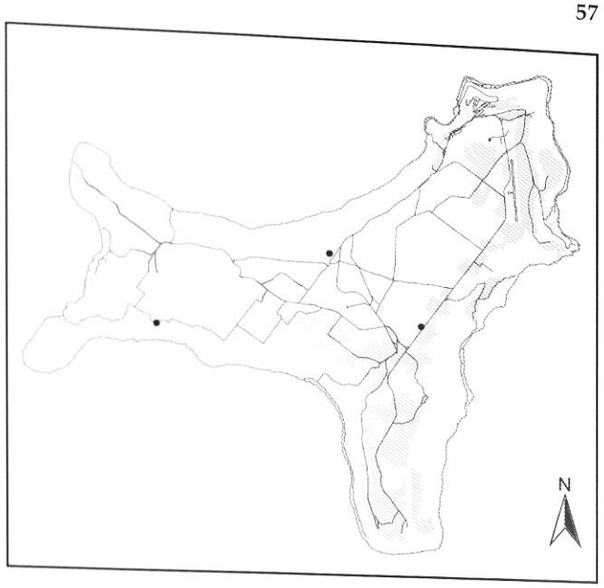


Figure 23 Records of *Amblyopone zwaluwenburgi* on Christmas Island.

Distribution

Christmas Island: The presence of *A. zwaluwenburgi* on Christmas Island is based on the report of a single winged queen collected in 1989 without precise locality data (Taylor 1990) and some recent (2001–2002) collections at the Central Area Workshop, Stuart Hill and Western Circuit Road (Figure 23) (D. O'Dowd personal communication). Given that *A. zwaluwenburgi* is a tiny cryptobiotic species that is especially difficult to collect (Wilson and Taylor 1967), the absence of it in the current surveys probably reflects the collection methodology rather than its disappearance from the island.

Worldwide: Prior to the record from Christmas Island, *A. zwaluwenburgi* was only known from Hawaiian sugar cane fields (Taylor 1990). However, this species is a likely introduction to Hawaii and Christmas Island and is possibly native to Melanesia or the East Indies (Brown 1960; Wilson and Taylor 1967).

Subfamily Cerapachyinae Forel, 1893

Genus *Cerapachys* Smith, 1857

Species of *Cerapachys* are specialist predators of other ants. During raids on ant nests, larvae in the attacked nest are stung and paralysed but not killed. When returned to the host nest, paralysed larvae can remain in this state for extended periods of time without increasing in size or pupating (Shattuck and Bennett 2001). Nests are generally small, normally containing only a few hundred workers or less. Most species will disperse quickly when disturbed (Shattuck 1999).

Cerapachys biroi Forel, 1907

Identification

TL ca. 2.5 mm; eyeless; unicolorous reddish-brown.

Biology

In colonies of *C. biroi* collected in Japan and Taiwan, there are no queens or sterile caste (Ravary and Jaisson 2004). Instead, unmated female individuals lay diploid eggs (thelytoky) (e.g. Ravary and Jaisson 2004). Reproduction is linked to a temporal polyethism, in which older workers cease to lay as they become foragers, and a morphological polyethism, illustrated by two morphological types that are differentiated by differences in task allocation and ovary capacities (Ravary and Jaisson 2004).

Distribution

Christmas Island: The distribution of *C. biroi* on Christmas Island remains obscure. It was reported by Taylor (1990) without detailed locality data and not collected during the recent surveys.

Worldwide: *Cerapachys biroi* is widespread in tropical Asia and has also been introduced to Polynesia and the West Indies (e.g. Ravary and Jaisson 2004).

Cerapachys longitarsus (Mayr, 1879)

Identification

TL ca. 2.0 mm; eyes well developed; distinctly bicoloured, with darker head and posterior parts of gaster (Figure 24).

Biology

In general, species of *Cerapachys* nest directly in the soil with single, small, simple entrance holes.

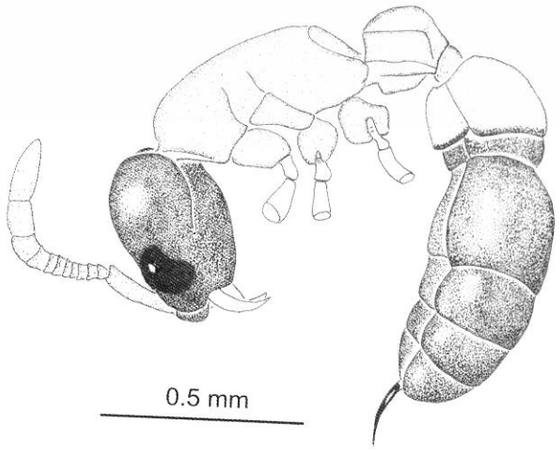


Figure 24 Worker of *Cerapachys longitarsus*.

Figure 25 Record of *Cerapachys longitarsus* on Christmas Island.

However, *Cerapachys longitarsus* commonly nests in hollow twigs (Brown 1975) and this nesting behaviour may have facilitated its dispersal.

Distribution

Christmas Island: A single male was reported by Taylor (1990) without locality data. During the IWS 2005, two workers from a single waypoint in the southern part of the island were collected in cleared land (Figure 25).

Worldwide: *Cerapachys longitarsus* is widespread in the Indo-Australasian region (Shattuck and Bennett 2001).

Subfamily Dolichoderinae Forel, 1878

Genus *Ochetellus* Shattuck, 1992

Ochetellus sp. (*glaber* group)

Nominal species

Ochetellus glaber (Mayr, 1862) (Black House Ant)

Identification

TL ca. 2 mm; petiolar node well developed and very narrow in lateral view (Figures 18A, 26). The taxonomy of *O. glaber* and allied species is not solved and therefore this species must be regarded as representing a species group.

Biology

In New Zealand, *O. glaber* has been reported to forage primarily arboreally (Manaki Whenua Landcare Research 2006), although this appears to be an exception to its generally epigaeic life style (A. Andersen personal communication).

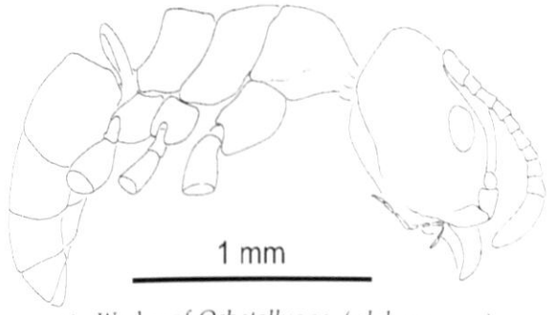


Figure 26 Worker of *Ochetellus* sp. (*glaber* group).

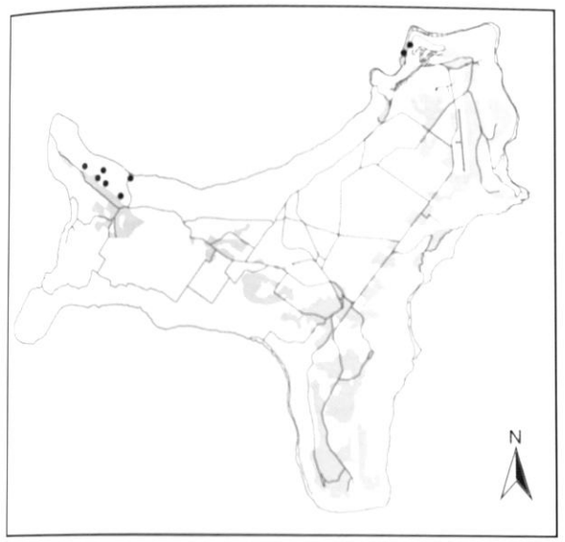


Figure 27 Records of *Ochetellus* sp. (*glaber* group) on Christmas Island.

Distribution

Christmas Island: *Ochetellus* sp. (*glaber* group) was only found around the main settlement area and near the new Immigration Reception and Processing Center (IRPC) in the northwestern part of the Island (Figure 27). This restricted distribution may reflect a relatively recent introduction to Christmas Island.

Worldwide: The nominal species, *O. glaber*, is most likely native to Australia, and has been introduced to the Pacific islands (including Hawaii) (Reimer 1994), North America (Smith 1979) and New Zealand (Brown 1958).

Genus *Tapinoma* Förster, 1850

Tapinoma melanocephalum (Fabricius, 1793) (Ghost Ant)

Identification

Easily recognised by its small size (TL ca. 1.5 mm) and peculiar colouration: head and trunk are deep dark brown (trunk sometimes lighter dorsally) with gaster and legs opaque or milky white (Figure 28).

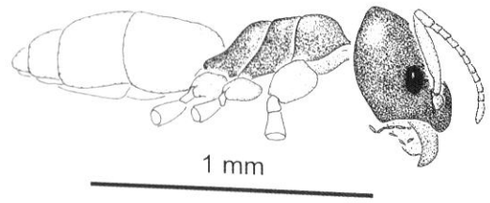


Figure 28 Worker of *Tapinoma melanocephalum*.

Biology

This species is an opportunistic nester utilising almost any crack or crevice, such as tufts of dead but temporarily moist grass, plant stems, and cavities beneath detritus in open, rapidly changing habitats (Hölldobler and Wilson 1990). *Tapinoma melanocephalum* is unlikely to have any significant ecological impact (A. Andersen personal communication), but can be a general nuisance in urban areas (ISSG 2004). Its ecological impact in more natural environments is unknown.

Distribution

Christmas Island: Despite its small size and somewhat cryptic colouration, *T. melanocephalum* was recorded at nearly 30% of the sites visited during the IWS 2005 (Figure 29). It was one of the earliest recorded species on Christmas Island (Table 1). The Ghost Ant was collected in both disturbed areas, such as mine sites, and more natural forested environments.

Worldwide: *Tapinoma melanocephalum* is a tramp ant and is widely distributed in the tropical and subtropical regions of the world. It is probably of African or Oriental origin (Wheeler 1910).

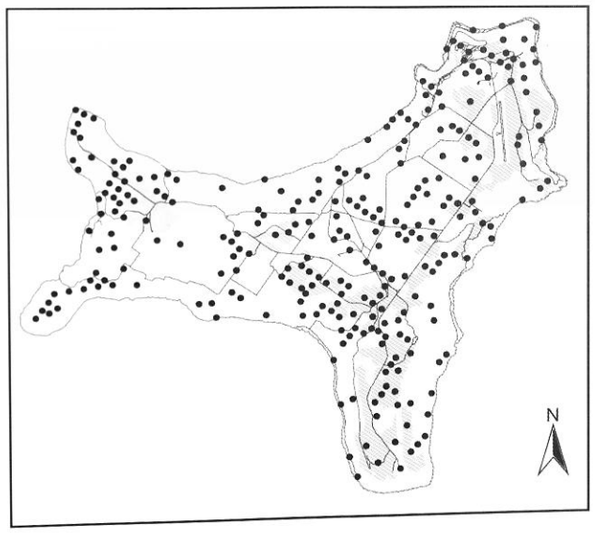


Figure 29 Records of *Tapinoma melanocephalum* on Christmas Island.

Tapinoma sp. (*minutum* group)

Nominal species
Tapinoma minutum Mayr, 1862 (Tiny Ghost Ant)

Identification
Easily distinguished from *T. melanocephalum* by the uniform yellowish-brown colour pattern. Shattuck (1999) lists the nominal and three subspecies of *T. minutum* in Australia suggesting that this species group requires taxonomic revision. There are several to many species of the *Tapinoma minutum* group in Australia (A. Andersen personal communication).

Distribution
Christmas Island: This species was recorded at only four sites during the IWS 2005 (Figure 30). These sites are widely distributed across the island, but three out of the four are very close to roads, suggesting that its dispersal on Christmas Island may be primarily through human means. However, this species is very inconspicuous and it is highly probable that it was overlooked at a large number of sites.

Worldwide: The nominal species, *T. minutum*, was originally described from Sydney (New South Wales) and must be considered an Australian native (Shattuck and Bennett 2001). Wilson and Taylor (1967) report this species from Queensland (Australia), Samoa, New Guinea, Solomon Islands, Fiji and Micronesia.

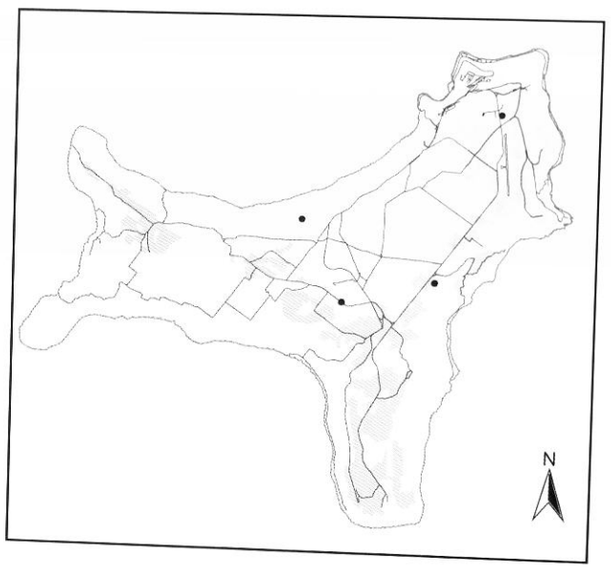


Figure 30 Records of *Tapinoma* sp. (*minutum* group) on Christmas Island.

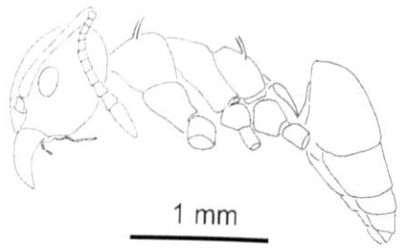


Figure 31 Worker of *Technomyrmex vitiensis*.

Genus *Technomyrmex* Mayr, 1872

Technomyrmex vitiensis Mann, 1921

Identification
TL ca. 3 mm; its larger size and uniform dark brown to black colouration distinguish this species from *Tapinoma* sp. (Figure 31).

Technomyrmex vitiensis is currently listed as junior synonym of *T. albipes* (Wilson and Taylor 1967); however a forthcoming revision of the genus *Technomyrmex* recognises it as a valid species (B. Bolton personal communication). Therefore, we list the species here in its new unpublished combination. Previous records of *T. albipes* from Christmas Island must be attributed to *T. vitiensis* (see Table 1).

Biology
One of the characteristics of the species group to which *T. vitiensis* belongs is the development of worker-queen intercastes. These are worker-like individuals, which exhibit a series of increasingly gyne-like morphological developments, such as the presence of ocelli, spermathecae and a gradually more gyne-like mesosomal structure. These intercastes can undertake reproductive behaviour (Yamauchi *et al.* 1991).

Figure 32 Records of *Technomyrmex vitiensis* on Christmas Island.

Distribution
Christmas Island: Although it is well dispersed across the island, *T. vitiensis* was recorded at less than 10% of waypoints (Figure 32). During the IWS 2005, it was collected primarily at the edge of disturbed habitats.

Worldwide: It is currently difficult to establish the worldwide distribution of *T. vitiensis* due to the confusion of this species with *T. albipes*. However, it appears to be a very successful tramp species and has colonised many islands in the Pacific and Indian Oceans (B. Bolton personal communication).

Subfamily Formicinae Latreille, 1809

Genus *Anoplolepis* Santschi, 1914

Anoplolepis gracilipes (Smith, 1857)

(Yellow Crazy Ant, Long-Legged Ant) (not to be confused with the Black Crazy Ant, *Paratrechina longicornis* (see further below)).

Identification
TL ca. 5 mm; unmistakable (Figure 33); long slender gracile body with long legs, yellow-brownish colouration, gaster usually somewhat darker than head and thorax; workers monomorphic.

Remarks
Anoplolepis gracilipes was probably introduced onto Christmas Island some time between 1915 and 1934 (Donisthorpe 1935; O'Dowd *et al.* 1999), but its distribution was unknown until populations exploded in the early 1990s causing devastating effects on the Red Land Crab population. Since 1996, efforts have been made to locate high-density sites of the Yellow Crazy Ant for management purposes. This species is currently the focus of a multi-million dollar control program administered by PANCI. Curiously, *A. gracilipes* was not reported between 1935 and 1989, suggesting low numbers on Christmas Island during this period. Note that most literature on *A. gracilipes* is under its junior synonym *A. longipes*.

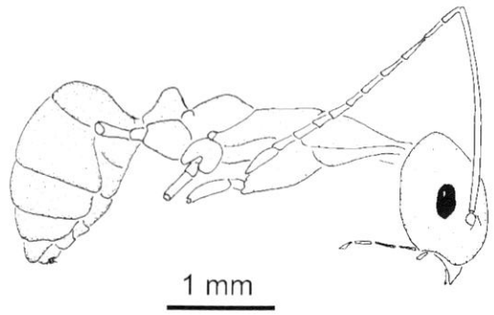


Figure 33 Worker of *Anoplolepis gracilipes*.

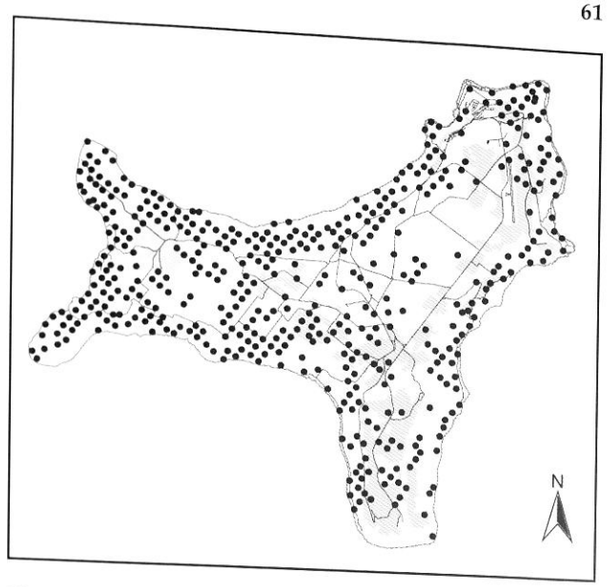


Figure 34 Records of *Anoplolepis gracilipes* on Christmas Island.

Distribution
Christmas Island: Although *A. gracilipes* is generally associated with human-modified environments in other parts of its introduced range, on Christmas Island it also thrives in (previously) undisturbed native forest habitats. It is widespread and common on the island (Figure 34).

Worldwide: *Anoplolepis gracilipes* has been introduced widely across the globe (McGlynn 1999). However, it remains poorly studied and even its native range is not certain. It may have originated from Africa or Asia (Holway *et al.* 2002; Wetterer 2005). The center of diversity for this genus is Africa and *A. gracilipes* is the only species distributed beyond that continent.

Genus *Camponotus* Mayr, 1861

Species of *Camponotus* are polymorphic and can show considerable size variation within single species. Foraging times vary, with some species foraging nocturnally or noctidiurnally (Shattuck 1999). As it is difficult to obtain detailed information on the biology of most *Camponotus* species found on Christmas Island, it is possible that the distribution of these species is underrepresented by the collection methodology used in the IWS 2005. *Camponotus* species may forage predominantly at night (e.g. *C. variegatus* in Hawaii (Reimer 1994)).

Camponotus sp. (*reticulatus* group)

Nominal species
Camponotus reticulatus Roger, 1863

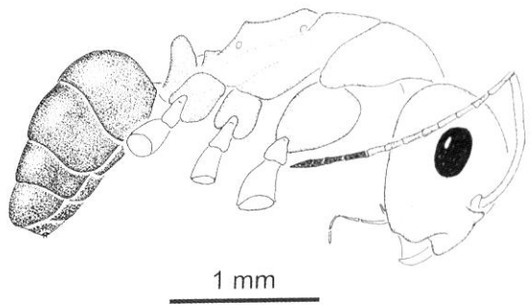


Figure 35 Worker of *Camponotus* sp. (*reticulatus* group).

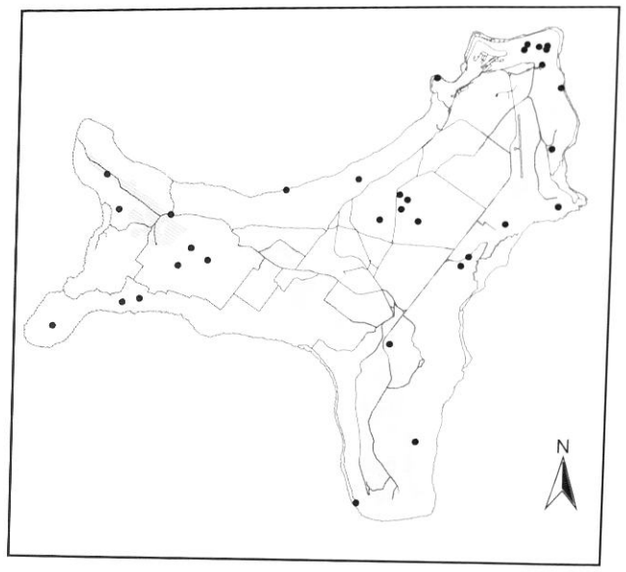


Figure 36 Records of *Camponotus* sp. (*reticulatus* group) on Christmas Island.

Identification

Smallest *Camponotus* on Christmas Island (TL ca. 3.5 mm) and easy to recognise; propodeum concave dorsally (Figures 16A, 35). Workers of this species are very similar to *Camponotus mackayensis* (see for example McArthur and Shattuck 2001), however soldiers differ considerably (A. Andersen personal communication).

Distribution

Christmas Island: Although well dispersed across the island, this species is not common and was found at only 3% of waypoints (Figure 36). *Camponotus* sp. (*reticulatus* group) does not appear to show any particular preference for certain habitats, but is not found in highly disturbed mine sites.

Worldwide: Unknown.

Camponotus melichloros Kirby, 1888

Identification

TL ca. 6–8 mm; easily confused with *Camponotus*

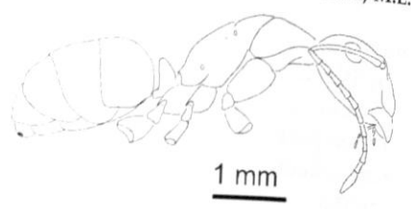


Figure 37 Worker of *Camponotus melichloros*.

sp. (*novaehollandiae* group), but differs by the setae on the antennal scape which are more erect than in *Camponotus* sp. (*novaehollandiae* group); *C. melichloros* is also somewhat smaller than *C.* sp. (*novaehollandiae* group) and with an overall lighter head (but the latter two characters are not reliable in differentiating both species) (see Figure 37).

Camponotus melichloros was originally described from Christmas Island. It is the only species of the *C. maculatus* group on Christmas Island. Minor workers of this group have wider heads at the front than at the back whereas the head of major workers is wider at the back than at the front. Previous listings from Christmas Island for species of this group include *C. chloroticus* (Collingwood and Hedlund 1980) and *C. maculatus* (Abbot 2006). Collingwood and Hedlund (1980) discuss the identity of this species on Christmas Island: '*Camponotus chloroticus* listed above may well be the same as *C. melichloros* [...] but with a generalised description that would equally fit both *C. chloroticus* and the widespread *C. variegatus*. We list this widespread species of the *maculatus* group from Christmas Island as *C. melichloros* pending a revision of the *maculatus* group for the Indo-Australian region.

Distribution

Christmas Island: *Camponotus melichloros* is one

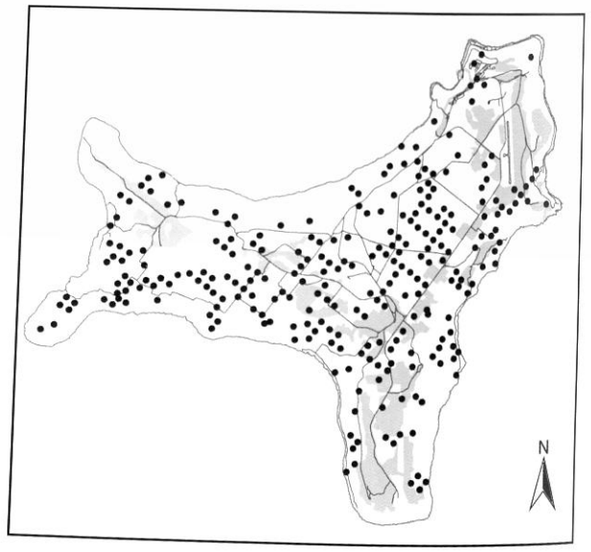


Figure 38 Records of *Camponotus melichloros* on Christmas Island.

of the most common ants of Christmas Island, having been found at 27% of sites surveyed (Figure 38). It is distributed widely across the island, but appears to prefer forested sites to open disturbed habitats such as minefields.

Worldwide: This species appears to be common in the Indo-Australian region (Taylor 1990).

Camponotus sp. (*novaehollandiae* group)

Nominal species

Camponotus novaehollandiae Mayr, 1870 (Northern (Common) Sugar Ant)

Identification

TL ca. 7–9 mm; easily confused with *C. melichloros*, but differs by the orientation of the setae on the scape, which are less erect than in *C. melichloros*, the relatively larger size (but sizes overlap) and overall darker colour of the head (but colour may overlap).

Remarks

In Australia, the nominal species of this group, *C. novaehollandiae*, forages noctidiurnally, so its distribution may be underrepresented by the methodology used in the current study (Shattuck and Bennett 2001).

Distribution

Christmas Island: This is the first record of a *Camponotus* species of the *novaehollandiae* group on Christmas Island. This species is relatively uncommon, found at only eight waypoints. Its current distribution appears to reflect a recent introduction, being found exclusively in the North East region of the island near the main port of entry, Flying Fish Cove (Figure 39).

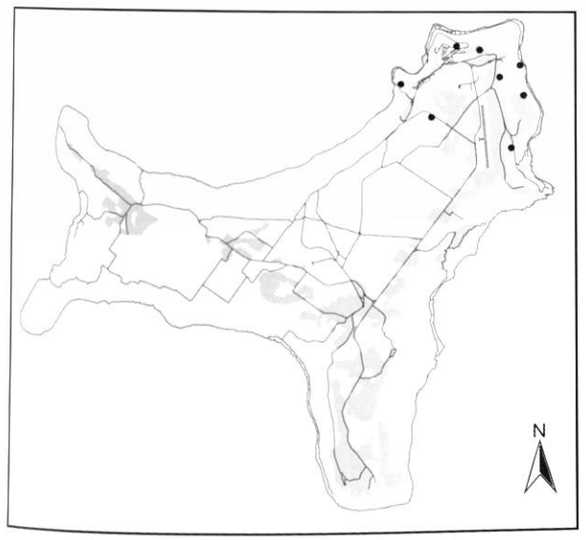


Figure 39 Records of *Camponotus* sp. (*novaehollandiae* group) on Christmas Island.

Worldwide: Members of this species group are also known from throughout northern Australia (Shattuck and Bennett 2001), and Papua New Guinea (Edwards and Thornton 2001).

Genus *Paratrechina* Motschoulsky, 1863

With the exception of *P. minutula* (to species group level) and *P. longicornis*, the identification of workers in the genus *Paratrechina* is notoriously difficult, in particular as the systematics and taxonomy of this genus are not well resolved (B. Bolton personal communication). Species identification must be treated cautiously and in particular, those that key out to *P. bourbonica* may represent a different species. A worldwide revision of the genus that will consider material from Christmas Island is in progress (J. LaPolla personal communication).

Paratrechina sp. (*bourbonica* group)

Nominal species

Paratrechina bourbonica (Forel, 1886)

Identification

TL ca. 2.5 mm. The more common *Paratrechina* sp. (*bourbonica* group) (Figure 40) and fairly rare *Paratrechina* sp. (*vaga* group) are very difficult to distinguish, in particular when only single individuals are available. Wilson and Taylor (1967) diagnosed *P. bourbonica* and *P. vaga* occurring on Pacific Islands merely by size and, to some extent colouration, but admitted that these characters may overlap. Newly eclosed *Paratrechina* sp. (*bourbonica* group) may be lighter in colouration and resemble *Paratrechina* sp. (*vaga* group). It is suggested, that for identification, whole nest series should be considered. Reimer (unpublished) used an additional character to differentiate both species in Hawaii, namely the presence (*P. bourbonica*) and absence (*P. vaga*) of setae on the katepisternum which was used here to distinguish between the two species groups. On Christmas Island, it appears that there may be more than one species in what keys out to *Paratrechina* sp. (*bourbonica* group).

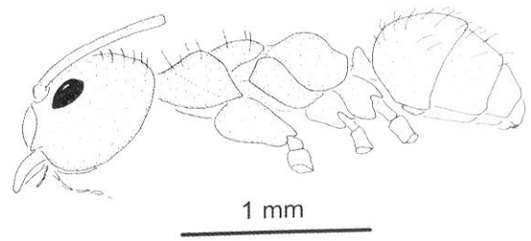


Figure 40 Worker of *Paratrechina* sp. (*bourbonica* group).

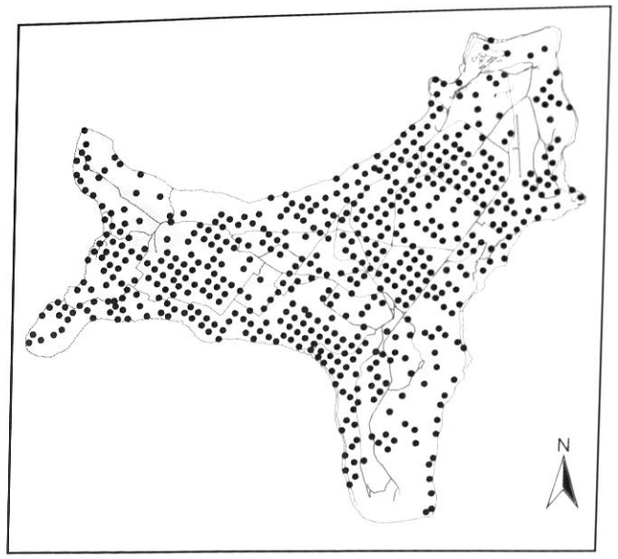


Figure 41 Records of *Paratrechina* sp. (*bourbonica* group) on Christmas Island.

Some specimens are unicolourous dark black, whilst other are lighter with a darker gaster. However, pending a revision of *Paratrechina* (J. LaPolla personal communication), we have not differentiated between these forms.

Biology

On Hawaii, *P. bourbonica* has been found in disturbed montane habitats such as roadsides or urban development sites, but never in undisturbed sites (Reimer 1994). On Samoa it favors more disturbed habitats than either *P. minutula* or *P. vaga* (Wilson and Taylor 1967). These habitat preferences contrast strongly with this species' widespread distribution in natural forested areas on Christmas Island.

Distribution

Christmas Island: *Paratrechina* sp. (*bourbonica* group) is one of the most common and widespread species on Christmas Island (Figure 41), but it is generally not found in mine sites.

Worldwide: Probably originating from the Old world tropics (Asia) (Deyrup *et al.* 2000; Wilson and Taylor 1967), the nominal species, *P. bourbonica*, has been spread by commerce throughout the Indian and Pacific Oceans and the New World tropics (Trager 1984; Wilson and Taylor 1967). However, a proper assessment of *P. bourbonica's* global spread may have to await taxonomic revision of this species.

Paratrechina longicornis (Latreille, 1802)
(Black Crazy Ant)

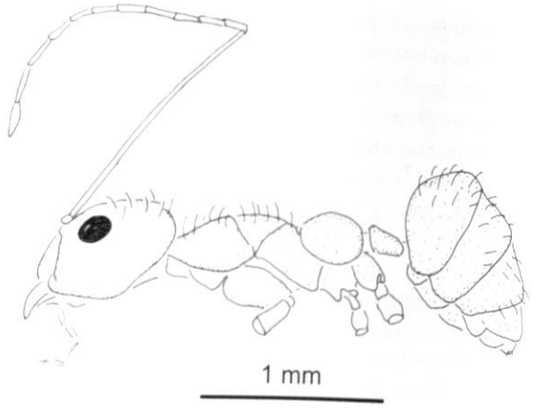


Figure 42 Worker of *Paratrechina longicornis*.

Identification

TL ca. 2.5 mm. *Paratrechina longicornis* is easily distinguished from other *Paratrechina* species on Christmas Island by its extremely long antennal scapes (Figure 42) and legs.

Biology

Paratrechina longicornis is an extremely hardy species that is highly adaptable and can live in both very dry and highly moist environments (Manaki Whenua Landcare Research 2006). Its ability to invade different habitats, together with its capacity to displace other ants and possibly other invertebrates (ISSG 2004), makes this species a serious threat to Christmas Island's ecosystems. On Christmas Island it currently appears to be restricted to disturbed areas, but has the potential to spread into more natural environments. Unfortunately, this species has proven relatively difficult to control because workers forage long distances and their nests are difficult to locate (ISSG 2004).

Figure 43 Records of *Paratrechina longicornis* on Christmas Island.

Distribution

Christmas Island: On Christmas Island, *P. longicornis* is primarily associated with disturbed habitats such as mine fields and near human settlements and roads (Figure 43).

Worldwide: *Paratrechina longicornis* is either of Asian or African origin (Smith 1965; Trager 1984). It is one of the most common tramp ants in the tropics and subtropics, and has probably achieved one of the widest distributions of all the tramp ants (Manaki Whenua Landcare Research 2006).

Paratrechina sp. (*minutula* group)

Nominal species

Paratrechina minutula (Forel, 1901)

Identification

Smallest of all *Paratrechina* species from Christmas Island (TL ca. 1.0 – 1.2 mm); Wilson and Taylor (1967) considered *Paratrechina minutula* as a species complex with 'the only character showing variation of possible species significance [...] is size". However, differences in head width of different populations did not appear to warrant specific separation. Andersen (2000a) reported the *minutula* group distributed throughout Australia, with about a dozen species occurring in the monsoonal region. Therefore, this species must be considered to represent a species complex pending revision of the group.

Distribution

Christmas Island: *Paratrechina* sp. (*minutula* group) is one of the most common species on Christmas Island. It is widespread across the island, but appears to show a preference for forested habitats on the plateau (Figure 44).

Worldwide: It is difficult to judge the worldwide distribution of *P. minutula* and allied species, as it represents a complex of species. However, this group is most likely native to the Indo-Australian region (Wilson and Taylor 1967). The type locality of the nominal species is New South Wales, but it appears to occur throughout Australia.

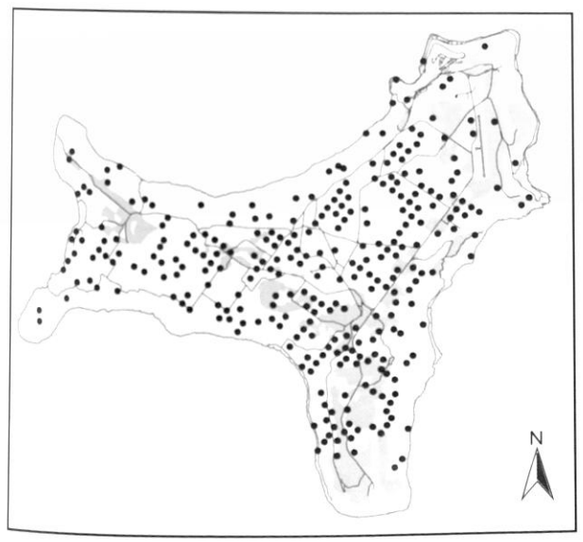


Figure 44 Records of *Paratrechina* sp. (*minutula* group) on Christmas Island.

Paratrechina sp. (*vaga* group)

Nominal species

Paratrechina vaga (Forel, 1901)

Identification

Differs from *Paratrechina* sp. (*bourbonica* group) in size (TL ca. 1.6 – 2.0 mm) and colouration (see above). The coxae of legs 2 and 3 are of similar colour as the trunk (brown), not distinctly lighter (as in *P. vividula*).

Distribution

Christmas Island: *Paratrechina* sp. (*vaga* group) is widely dispersed across the island, but was not commonly found as part of the ant fauna during the IWS 2005 (Figure 45)

Worldwide: The nominal species, *P. vaga*, is reported to be native to New Guinea and the Western Pacific (Manaki Whenua Landcare Research 2006). Species of this complex are reported from tropical Australia (Andersen 2000a) and various Pacific Islands, including Hawaii (Wilson and Taylor 1967). Also reported from Madagascar and Galapagos (Manaki Whenua Landcare Research 2006).

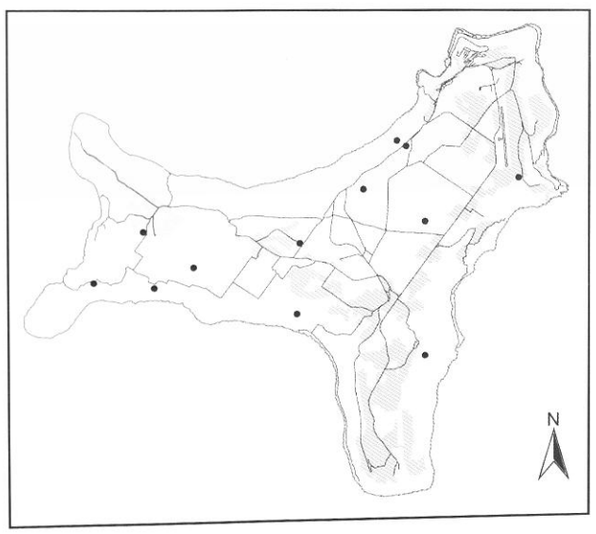


Figure 45 Records of *Paratrechina* sp. (*vaga* group) on Christmas Island.

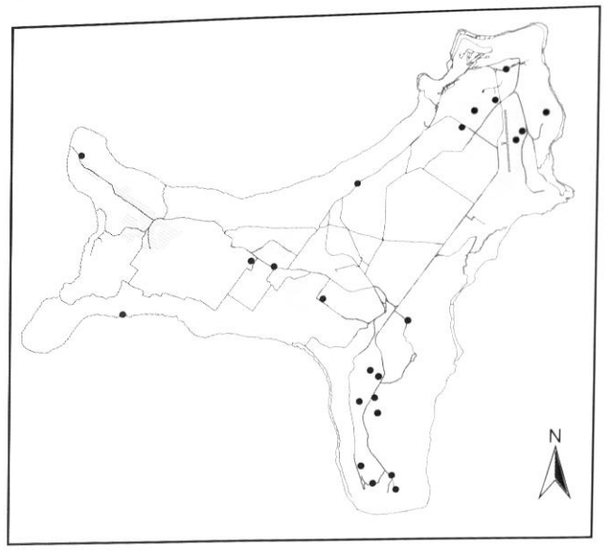


Figure 46 Records of *Paratrechina vividula* on Christmas Island.

Paratrechina vividula (Nylander, 1846)

Identification

Workers relatively small (TL ca. 1.5 mm), weakly bicoloured with the head and gaster yellowish-brown to black and alitrunk, legs and antennae yellow to dark reddish-brown. *Paratrechina vividula* differs from other *Paratrechina* of Christmas Island, in particular the similar sized *Paratrechina* sp. (*vaga* group), by the light colouration of the coxae of legs 2 and 3.

Distribution

Christmas Island: On Christmas Island this species is primarily found on the plateau near disturbed areas such as roads or mine fields (Figure 46).

Worldwide: Native to North America this species has spread relatively widely outside its native range (Trager 1984).

Genus Plagiolepis Mayr, 1861

Plagiolepis include small, inconspicuous ants that nest in soil and under rocks or logs or in rotten wood on the ground. Two *Plagiolepis* species have been recorded from Christmas Island, *P. alluaudi* and *P. exigua* (Collingwood and Hedlund 1980), but were not encountered during the recent surveys. It is possible they were overlooked because of their inconspicuous nature and small size (Shattuck 1999) and their preference to nest in or around human dwellings. *Plagiolepis* are similar in general appearance to the dolichoderine *Tapinoma*, but have only 11 antennal segments instead of 12. Both *Plagiolepis* listed here are well-known tramp species (Wilson and Taylor 1967).

Plagiolepis alluaudi Forel, 1894

Identification

TL ca. 1.5 – 2.0 mm; differs from *P. exigua* by a longer scape that exceeds the occipital corner by at least the length of the first two funicular segments combined (by less than the length of the first furnicular segment in *P. exigua*)

Distribution

Christmas Island: The presence of this species on Christmas Island is based on an unpublished report without precise locality data (Collingwood and Hedlund 1980). *Plagiolepis alluaudi* was not found during the recent surveys.

Worldwide: *Plagiolepis alluaudi* is a pantropical tramp species with an increasing range through transport by human commerce. It appears to be native to Africa (Wilson and Taylor 1967).

Remarks

In Hawaii it is commonly found in the dry, mesic, and wet lowland communities (Reimer 1994).

Plagiolepis exigua Forel, 1894

Identification

TL ca. 1.5 – 2.0; differs from *P. alluaudi* by its shorter scape (see above), sparser pilosity (presence of setae) and shinier body surface (Wilson and Taylor 1967).

Distribution

Christmas Island: Similar to *P. alluaudi*, the presence of *P. exigua* on Christmas Island is based on the report by Collingwood and Hedlund (1980). It was not collected during recent surveys.

Worldwide: It is known from India, western China, Hong Kong, Madagascar and Ethiopia (Wilson and Taylor 1967). Early records from Hawaii are possibly erroneous (Wilson and Taylor 1967).

Subfamily Leptanillinae Emery, 1910

The subfamily Leptanillinae includes only seven genera and is entirely absent from the New World and has not yet been discovered in the Malagasy region (Bolton 1994). These ants are very rarely encountered and little is known about their biology.

Genus *Leptanilla* Emery, 1870

Leptanilla sp.

Identification

Minute ants (Taylor 1990), eyes absent (Brady and Ward 2005); petiole and postpetiole present.

Biology

The majority of species within *Leptanilla* are described from either isolated males or workers (Brady and Ward 2005). Most males are caught in traps or by sweeping, suggesting that they leave the nest for mating (Masuko 1990). *Leptanilla* queens have an unusual feeding behaviour in which they imbibe hemolymph from a pair of specialised duct organs on the larvae. Larval hemolymph feeding by this genus may be an adaptation to unstable food conditions (Masuko 1990).

Distribution

Christmas Island: A *Leptanilla* sp. was reported by Taylor (1990) from a single male specimen. No locality data was given. Workers of this genus have never been collected from Christmas Island. We did not find any *Leptanilla* sp. in the current survey; however this is not surprising given the subterranean nature of this genus (Masuko 1990).

Worldwide: *Leptanilla* sp. are known from workers collected in North Africa, the Indo-Australian area and Japan (Taylor 1990).

Subfamily Myrmicinae Lepeletier, 1835

Remarks

Representatives of the Myrmicinae are distinguished from all other ants of Christmas Island by the presence of two segments, a petiole and a postpetiole, connecting the trunk and the gaster. The only other subfamily with similar morphology on Christmas Island is the Leptanillinae, small cryptic and blind ants that are known from Christmas Island only from a single male specimen of *Leptanilla* (Taylor 1990). All other ant subfamilies with petiole and postpetiole (Aenictinae, Ecitoninae, Leptanilloidinae, Myrmeciinae, Pseudomyrmecinae) do not currently occur on Christmas Island.

Genus *Cardiocondyla* Emery, 1869

Species of this genus are most easily recognised by their dorsoventrally flattened, wide postpetiole. When viewed from above it is much wider than long and broader than the petiole. A recent revisionary study of *Cardiocondyla* allows accurate species identification for the representatives of this genus on Christmas Island (Seifert 2003).

The males of some *Cardiocondyla* species are unusual. In most ants, males are fully winged. However, in both *Cardiocondyla* species found on Christmas Island, males can be wingless (ergatoid) and worker-like (Seifert 2003).

Cardiocondyla kagutsuchi Terayama, 1999

Identification

TL ca. 1.5 – 1.8 mm; mesometanotal groove in

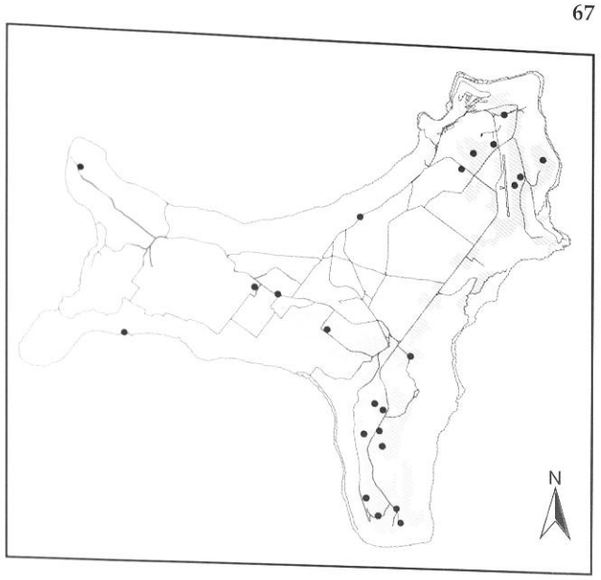


Figure 47 Records of *Cardiocondyla kagutsuchi* on Christmas Island.

lateral view absent or only very shallow (Figure 21A). On Christmas Island, this species has previously been misidentified as *C. nuda* (Taylor 1990; Table 1), which differs in the relative height of petiole and postpetiole (Seifert 2003). It is a sister species of, and may be conspecific with, *C. mauritanica* Forel, 1890, a common cosmotropical tramp species (Seifert 2003).

Distribution

Christmas Island: *Cardiocondyla kagutsuchi* can be found interspersed across the island but is primarily restricted to disturbed habitats such as minefields and roads (Figure 47).

Worldwide: The range of *C. kagutsuchi* extends over East India, Sri Lanka, Nepal, Bhutan, southern China and South Korea, southern Japan, Guam, Singapore, Malaysia, Indonesia, the Philippines, Hawaii and Papua New Guinea (Seifert 2003).

Remarks

The distribution of *C. kagutsuchi* on Christmas Island agrees with the habitat preferences described in the literature, i.e. 'in shallow soil in open, disturbed areas with bare or weakly herbaceous ground' (Seifert 2003).

Cardiocondyla wroughtonii (Forel, 1890)

Description

TL ca. 1.3 – 1.5 mm; differs from *C. kagutsuchi* by the presence of a distinct mesometanotal groove (Figure 21B) and the colour pattern (see key above). The postpetiolar sternite has a prominent anterolateral corner that is absent in *C. kagutsuchi*.

Figure 48 Records of *Cardiocondyla wroughtonii* on Christmas Island.

Distribution

Christmas Island: *Cardiocondyla wroughtonii* is widespread across the plateau of the island and also found on the northern terraces (Figure 48). This species appears to prefer more forested habitats than *C. kagutsuchi* on Christmas Island.

Worldwide: *Cardiocondyla wroughtonii* is a pantropical tramp species. It was thought to have originated in tropical Africa and to have extended its range very widely in the tropics and subtropics through human agency (Wilson and Taylor 1967), but more recent evidence suggest it to be native to Australia (A. Andersen personal communication).

Genus *Monomorium* Mayr, 1855

Five species of *Monomorium* have been previously reported from Christmas Island; *M. australicum* (as *M. talpa*), *M. destructor*, *M. floricola*, *M. latinode* and *M. pharaonis* (Table 1). Only two of these, *M. floricola* and *M. latinode*, and two additional species (*M. orientale* and *M.* cf. *subcoecum*) were collected during the recent surveys. The absence of *M. destructor* and *M. australicum* could be based on misidentification by past researchers. *Monomorium destructor* is very similar to *M. latinode*, and *M. australicum* is almost certainly the species that is here identified as *M.* cf. *subcoecum* (see Heterick 2001). However, we have included *M. destructor* here, since it is a well-known cosmopolitan tramp species. The absence of *M. pharaonis* in recent surveys is not so easily explained. This species is a well-known tramp that was reported fairly early from Christmas Island (Donisthorpe 1935). Since there have been no subsequent reports of this species on Christmas Island, it is likely that it either never occurred on the island, has become locally extinct, or is only present in and around houses (as in other parts of its introduced range) and was therefore not collected during the recent surveys. Accurate species identification of members of *Monomorium* is possible by applying the keys of Bolton (1987) and Heterick (2001).

Monomorium destructor (Jerdon, 1851)

(Singapore Ant)

Identification

Size variable (TL ca. 1.8 – 3.5mm). This species was not collected during the current survey. It is possible that the two reported cases of *M. destructor* on Christmas Island (Collingwood and Hedlund 1980; Donisthorpe 1935) were misidentifications, since *M. destructor* is very similar to *M. latinode* in both size and coloration. *Monomorium destructor* is distinguished from *M. latinode* by the presence of 4 teeth on each mandible (versus 5 in *M. latinode*), the distinct metanotal groove (shallow and indistinct in *M. latinode*) and the narrower postpetiole (1.5 times as long as broad in *M. latinode*) (Manaki Whenua Landcare Research 2006). *Monomorium destructor* is also highly polymorphic, with minor workers 2 mm or less in length (A. Andersen personal communication).

Distribution

Christmas Island: Unknown, based on previous reports without precise locality data (Table 1).

Worldwide: *Monomorium destructor* is most likely of Indian origin and has been introduced throughout the tropical zone, and increasingly into temperate regions (Bolton 1987).

Remarks

Monomorium destructor has been considered a pest species in Australia since the 1970s (Davis *et al.* 1993). This species is known to cause significant commercial damage. It can gnaw holes in fabric and rubber goods and is able to remove insulation from power and phone lines and damage polyethylene cable (Bolton 1987). Several fires are attributed to these ants (Davis and van Schagen 1993). There are even reports of people being bitten or stung fiercely while in bed (Smith 1965).

Monomorium floricola (Jerdon, 1851)

Identification

Monomorphic, TL ca. 1.4 mm; bicoloured with light brown trunk, and much darker head and gaster. Its small size and striking coloration easily distinguishes this ant from other ant species on Christmas Island.

Figure 49 Records of *Monomorium floricola* on Christmas Island.

Distribution

Christmas Island: Despite this species being reported on the island since 1935 (Table 1), its distribution is largely restricted to areas adjacent to roads (Figure 49). This pattern is consistent with its distribution in other parts of its introduced range, where colonies seem unable to penetrate undisturbed native forests (Wilson and Taylor 1967). However, it should be noted that this species is primarily arboreal (Smith 1965; Wilson and Taylor 1967) and may have been overlooked at many forested sites using the hand collection method utilised in the IWS 2005.

Worldwide: *Monomorium floricola* is possibly native to tropical Asia (Wilson and Taylor 1967), but is an extremely successful tramp species that is widespread in tropical and subtropical regions.

Monomorium latinode Mayr, 1872

Identification

TL ca. 2.5 mm; postpetiolar node viewed from above wider than petiole. This species is similar to *M. destructor* in size and coloration, but the 5-toothed mandibles and shallow mesometanotal groove distinguish *M. latinode* (Figure 50).

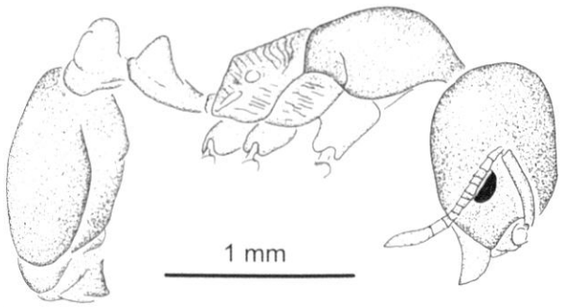


Figure 50 Worker of *Monomorium latinode*.

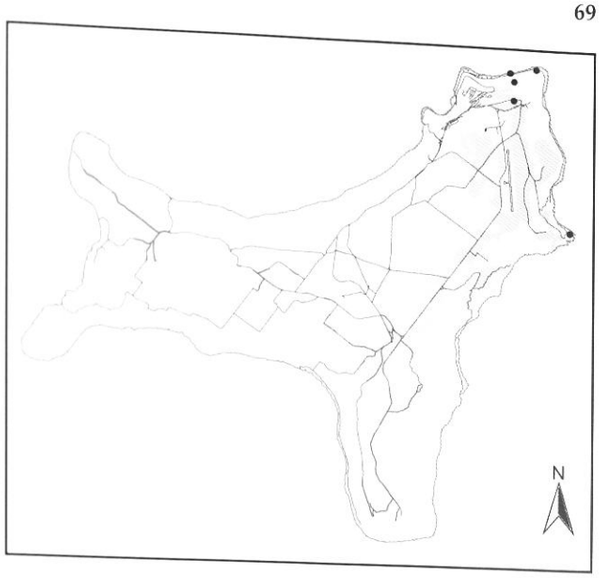


Figure 51 Records of *Monomorium latinode* on Christmas Island.

Distribution

Christmas Island: The current distribution of this species is restricted to the northeastern region of the island (Figure 51). This distribution appears to reflect a relatively recent introduction (Table 1).

Worldwide: *Monomorium latinode* is most likely native to the Indian subcontinent (Bolton 1987), although Wilson and Taylor (1967) report its native range as 'Sri Lanka to Taiwan and south to Java and Sumatra'. It is known from several countries bordering the Indian Ocean (Bolton 1987). Its presence in Borneo, Tanzania and New Zealand indicates its potential as a tramp species.

Monomorium orientale Mayr, 1879

Identification

Very small ant (TL ca. 1.1 mm); could be confused with *M.* cf. *subcoecum*, but the latter has very reduced eyes, whereas the eyes of *M. orientale* are fully developed with more than 10 ommatidia.

Distribution

Christmas Island: This is the first record of this species on Christmas Island. It was only reported from one waypoint in the northeastern corner of the island (Figure 52).

Worldwide: *Monomorium orientale* has originally been described from India (McGlynn 1999). It has subsequently been reported from Australia (B. Heterick, personal communication) and New Zealand but the latter records may be erroneous (see Gunawardana 2005).

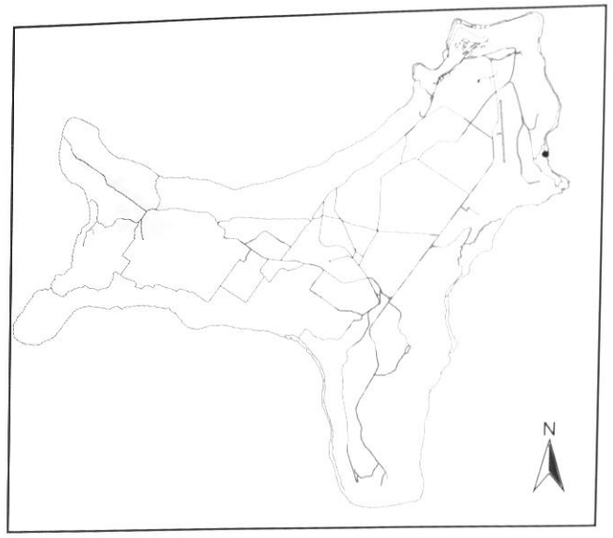


Figure 52 Records of *Monomorium orientale* on Christmas Island.

Figure 53 Records of *Monomorium* cf. *subcoecum* on Christmas Island.

Monomorium pharaonis (Linnaeus, 1758)
(Pharaoh Ant)

Identification

Size variable (TL ca. 1.3 – 1.8 mm); antennae 12-segmented; head and trunk densely punctuated.

Distribution

Christmas Island: This species was not collected during the current survey. In fact, *M. pharaonis* has not been reported from Christmas Island since Donisthorpe (1935).

Worldwide: *Monomorium pharaonis* is native to West Africa and has been introduced into Asia (including Japan, India and Saudi Arabia), Australia, North, Central and South America, Europe and some islands in the Indian Ocean (including Madagascar) and the Pacific Ocean (including New Zealand and some islands in the Hawaiian and Galapagos archipelagoes) (ISSG 2004; McGlynn 1999).

Remarks

Monomorium pharaonis frequently nests inside human structures but rarely displaces native species outside urban environments (Holway *et al.* 2002; McGlynn 1999). This species is a pest in many regions of the world. Its presence in hospitals is of particular concern as it is a vector for the transmission of certain human bacterial pathogens (ISSG 2004).

Monomorium cf. *subcoecum* Emery, 1894

Identification

Very small (TL ca. 1.1 mm); as part of the *fossolatum*-group it is apparently very similar to *M. australicum* (junior synonym *M. talpa*), which it was most likely reported as previously from Christmas Island. Workers of *M.* cf. *subcoecum* lack the domed promesonotum and deeply impressed metanotal groove found in *M. australicum* (Heterick 2001). Differs from *M. orientale* by its reduced eyes.

Distribution

Christmas Island: This cryptic species has only been found in the traps of the BMP in the northeastern parts of Christmas Island and in Whip Cave (CS) (Figure 53).

Worldwide: This appears to be the same species as reported by Heterick (2001) from a series collected in Cannon Vale (Queensland).

Genus *Pheidole* Westwood, 1839

Pheidole is one of the world's most diverse ant genera with many hundreds of species, but the taxonomy and systematics of this genus in Australia remain rudimentary (Andersen 2000a). Workers of *Pheidole* are dimorphic (majors and minors) and major workers have very large heads. The genus is easily identified by the raised pronotum and mesonotum that are much higher than the propodeum (Figure 19B).

Only *P. megacephala* and one species belonging to the *P. variabilis* group were found during the current survey. A further species, *P. oceanica*, has been previously recorded from Christmas Island. Given the widespread distribution of *P. variabilis* group, it is possible that *P. oceanica* has been misidentified. However, this cannot be verified without recourse to previously collected material.

Pheidole megacephala (Fabricius, 1793)
(Big Headed Ant, Coastal Brown Ant)

Identification

TL ca. 3.5 mm (majors), ca. 2.5 mm (minors); differs from *Pheidole* sp. (*variabilis*) group, amongst other characters, by the smooth and shiny top of the head and pronotum (punctured in *Pheidole* sp. (*variabilis* group)). *Pheidole megacephala* is also somewhat larger although sizes may overlap.

Distribution

Christmas Island: *Pheidole megacephala* is not common on Christmas Island and appears to be distributed close to disturbed areas. It is particularly common around the main settlement area and in forests adjacent to mine sites and roads in the Southeast of the Island (Figure 54).

Worldwide: Evidence of the origin of *P. megacephala* derived from historical human records is scarce (Wheeler 1922), but South Africa has generally been accepted as its native range (Haskins and Haskins 1965; Vanderwoude *et al.* 2000; Wilson and Taylor 1967). This species has been spread to almost all of the more humid parts of the tropics via commerce.

Remarks

Pheidole megacephala represents one of the most threatening exotic ant species worldwide and is listed as one of the world's 100 worst invasive species (ISSG 2004). In its introduced range, the Big-Headed Ant is a serious threat to biodiversity (Haskins and Haskins 1965; Heterick 1997; Hoffmann *et al.* 1999; Lieberburg *et al.* 1975; Majer 1985), a pest to agriculture (Bach 1991; Jahn and Beardsley 1994), and a domestic nuisance (Schagen *et al.* 1994). Although its current distribution on Christmas Island is somewhat limited, this species' preference for shady, humid environments (Greenslade 1972; Hoffman *et al.* 1999; Majer 1994) suggests that it has the potential to spread across large portions of Christmas Island's rainforest.

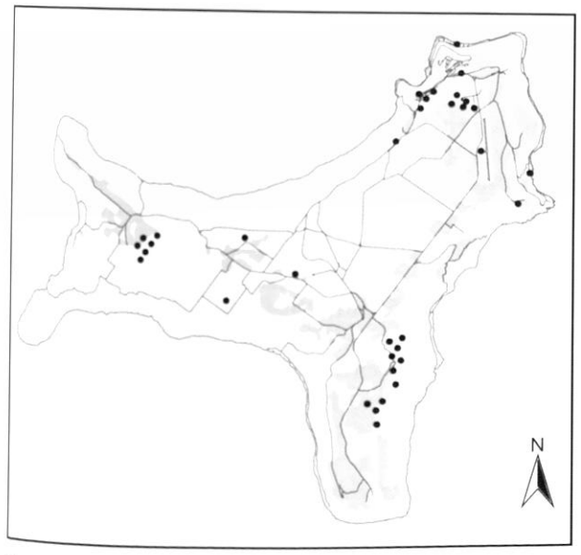


Figure 54 Records of *Pheidole megacephala* on Christmas Island.

Pheidole sp. (*variabilis* group)

Nominal species

Pheidole variabilis Mayr, 1876

Identification

TL ca. 2.8 mm (majors), ca. 1.5 mm (minors); differs from *P. megacephala* by the punctuated pronotum and top of head, and its smaller size.

Distribution

Christmas Island: *Pheidole* sp. (*variabilis* group) is widely distributed across the island, but this species appears to be less common in mine sites (Figure 55).

Worldwide: Based on the collections of the ANIC, this species appears to be a common Indo-Australian representative of *Pheidole* (Taylor 1990).

Remarks

This species may be the same as the previously reported *P. oceanica* (see *Pheidole* section).

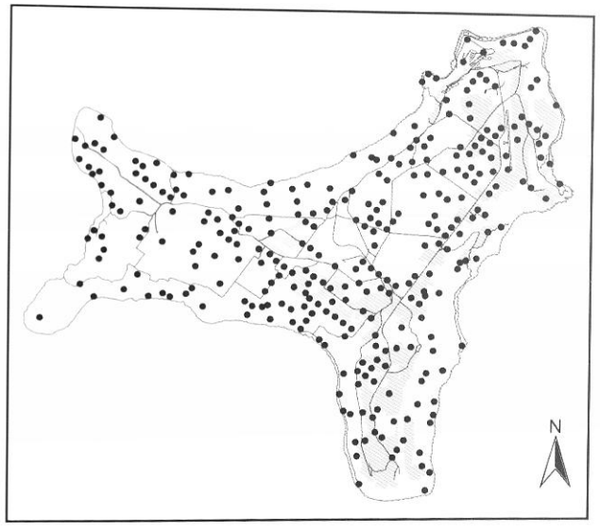


Figure 55 Records of *Pheidole* sp. (*variabilis* group) on Christmas Island.

Genus *Pyramica* Roger, 1862

Pyramica membranifera (Emery, 1869)

Identification

TL ca. 2 mm; body colour yellowish-brown. Except for a pair of erect scale-like hairs on posterior portion of the head, pilosity almost lacking in this species.

Biology

Pyramica membranifera is found in the soil of rather open habitats and is predaceous on a wide variety of small, soft-bodied arthropods (Wilson and Taylor 1967).

Distribution

Christmas Island: The distribution of *P. membranifera* on Christmas Island remains obscure as the only record was without precise locality data (Taylor 1990). This species was not recorded during the current surveys.

Worldwide: *Pyramica membranifera* is an accomplished tramp species. It has been recorded widely from tropical and warm temperate regions of the world, including Fiji, eastern China, West Indies and the southeastern US (Wilson and Taylor 1967). Brown and Wilson (1959) suggested an African origin, but this was questioned by Bolton (1983).

Genus *Solenopsis* Westwood, 1840

The genus *Solenopsis* includes two of the most notorious worldwide invasive species, *S. geminata* (Fabricius, 1804) (Tropical Fire Ant) and *S. invicta* Buren, 1972 (Red Imported Fire Ant). Only *S. geminata* has been recorded on Christmas Island. However, all identifications of this species should be carefully verified against the diagnostic characters of *S. invicta* to allow an early detection of this problematic invasive species. Major workers of both species differ by the vertex of the head in frontal view (*geminata*: strongly bi-convex, *invicta*: weakly biconvex), the length of the antennal scape in lateral view (*geminata*: short, not reaching top of occipital margin; *invicta*: longer, almost reaching the occipital margin), and the absence (*geminata*) and possible presence (*invicta*) of a central clypeal tooth.

Solenopsis geminata (Fabricius, 1804)

(Tropical Fire Ant)

Identification

TL ca. 3.0 – 3.5 mm (majors), 2.2 – 2.5 mm (minors); currently unmistakable on Christmas Island: the only species of which the antennal club consists of only two segments.

Distribution

Christmas Island: On Christmas Island, this species shows a strong preference for open disturbed habitats, primarily recorded from mine fields and along roads (Figure 56).

Worldwide: *Solenopsis geminata* is native to some tropical and temperate regions of the New World (McGlynn 1999; Wilson and Taylor 1967).

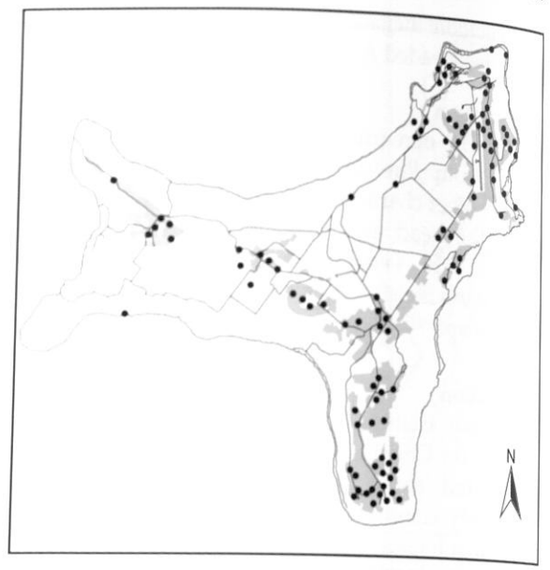


Figure 56 Records of *Solenopsis geminata* on Christmas Island.

Remarks

Solenopsis geminata is classified as a 'hot climate specialist' (Anderson 2000b) and, as such, resides only in hot arid regions. It is therefore unlikely to spread into Christmas Island's forested areas. There is evidence that *S. geminata* reduces native invertebrate fauna (McGlynn 1999), can have a negative effect on plant life because of its association with honey-dew producing insects (Lit and Caasi-Lit 2004), and is a threat to land vertebrates such as lizards and tortoises (Williams and Whelan 1991). In urban areas it can cause chewing damage to PVC coatings of electrical wiring (Prins 1985) and the sting can cause painful postules (Schmidt and Hoffmann 1999) with a low risk of anaphylactic shock (Collingwood *et al.* 1997; Hoffmann 1997).

Genus *Strumigenys* Smith, 1860

Species of *Strumigenys* are difficult to find other than when encountered in leaf litter samples (Shattuck 1999). Species in this genus are mostly specialised hunters of Collembola and have long, linear mandibles with a few large teeth at the apex. When waiting for prey the mandibles are widely opened and specialised trigger setae at the ant's mouthparts will initialise the long mandibles to snap shut with explosive force when prey is encountered. The initial strike itself usually kills the prey, and stinging is not necessary (Deyrup and Deyrup 1999).

Strymigenys emmae (Emery, 1890)

Identification

Very small (TL ca. 1.2–1.5 mm); differs from *S. godeffroyi* by the smaller number of antennal segments (4 instead of 6).

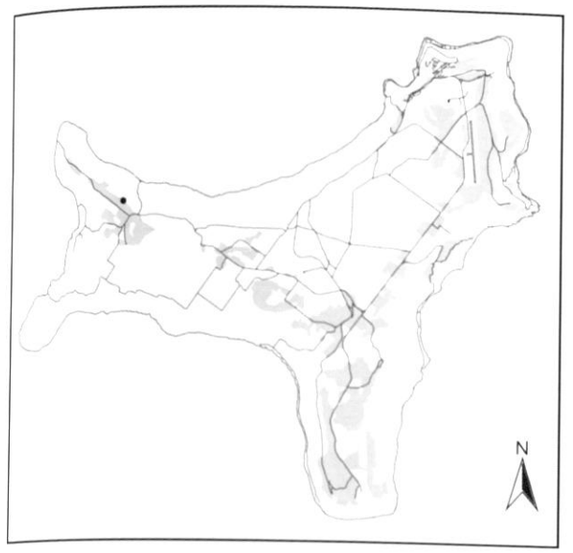


Figure 57 Record of *Strumigenys emmae* on Christmas Island.

Distribution

Christmas Island: This small cryptic species was only collected in traps of the BMP in the Northwestern part of the island (Figure 57). However, due to its cryptic behaviour and small size it is likely that this species is more widespread than reported here.

Worldwide: *Strumigenys emmae* is a pantropical tramp species known from tropical regions throughout the world (Bolton 1983). The geographic origin of *S. emmae* is apparently Australia, where several related species occur (Bolton 2000). However, Africa has also been suggested as its native range (Deyrup and Deyrup 1999; Wilson and Taylor 1967)

Strumigenys godeffroyi Mayr, 1866

Identification

TL ca. 1.2 – 1.5 mm; differs from *S. emmae* by the number of antennal segments (6 instead of 4).

Distribution

Christmas Island: Only one specimen was collected during the IWS 2005 in the northeastern part of the island (Figure 58). This species was also found in a previous survey (Taylor 1990), suggesting that it is more common than implied by the IWS 2005.

Worldwide: *Strymigenys godeffroyi* is believed to be native to tropical southeastern Asia (Wilson and Taylor 1967). It is widely distributed from the Pacific, East Indies, New Guinea, Solomon Islands tropical mainland of Asia, the Philippines, and northern Australia and across the Indian Ocean as far as Madagascar (W.L. Brown personal communication in Wilson and Taylor 1967).

Figure 58 Record of *Strumigenys godeffroyi* on Christmas Island.

Genus *Tetramorium* Mayr, 1855

Members of the genus *Tetramorium* are fairly distinctive. The area of the clypeus immediately below the antennal socket is raised into a sharp-edged ridge that forms the lower section of the pit around the base of the antennae (see Shattuck 1999, Figure 584). However, this character is difficult to identify and therefore not used in this key. The surface of the body of the ants is generally deeply sculptured with pits. The front of the head displays distinct raised edges (carinae) (except in *T. walshi*). Accurate species identification is possible when applying the keys of Bolton (1976, 1977).

With eight species present on Christmas Island, *Tetramorium* is the most speciose genus and one species, *T. insolens*, is particularly abundant.

Tetramorium bicarinatum (Nylander, 1846)

Identification

TL ca. 2.3 mm. This species is very similar to *T. insolens*, but is distinguished by the sharper frontal angle of the petiole in lateral view (see Figures 20B vs. 20C), the shorter setae on the head and the darker gaster (see Bolton 1977 for a detailed identification table to distinguish both species).

Distribution

Christmas Island: *Tetramorium bicarinatum* is mainly found in disturbed habitats such as mine sites and near roads (Figure 59).

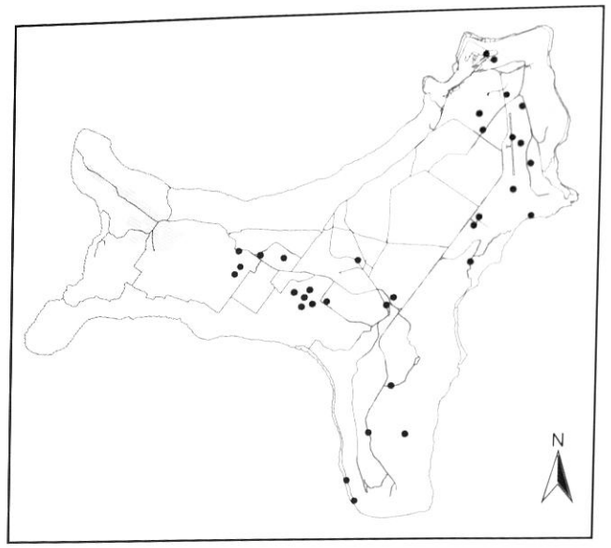


Figure 59 Records of *Tetramorium bicarinatum* on Christmas Island.

Worldwide: *Tetramorium bicarinatum* has been considered native to South-East Asia (Bolton 1977) and Africa (Ingram *et al.* 2006), but has been widely distributed to many parts of the tropics by human commerce. This species dominates some habitats of the New World (Ingram *et al.* 2006).

Tetramorium insolens (Fr. Smith, 1861)

Identification

TL ca. 2.3 mm. Very similar to *T. bicarinatum*, but distinguished by the less sharp anterior angle of the petiole in lateral view (Figure 20C *vs.* 20B), and generally lighter gaster and longer setae on the head (see Bolton 1977 for an identification table to distinguish both species).

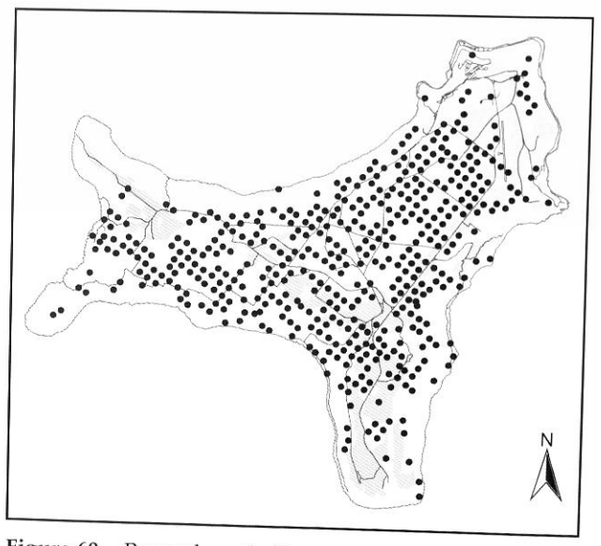


Figure 60 Records of *Tetramorium insolens* on Christmas Island.

Distribution

Christmas Island: This species was one of the most commonly collected ants during the recent surveys, but appears to be absent from areas on the lower terraces (Figure 60). The widespread distribution of *T. insolens* on Christmas Island is somewhat surprising given that it was recorded for the first time on the island in 1989 (Taylor 1990) (although it may have been confused with *T. bicarinatum* by Donisthorpe (1935)).

Worldwide: Widespread; Bolton (1977) reported it from Sri Lanka, Flores, Sulawesi, the Philippines, Solomon Island, New Guinea, Pacific Islands, and it has been introduced into hot houses in Europe.

Tetramorium lanuginosum Mayr, 1870

Identification

TL 1.5 – 2.1 mm; within *Tetramorium* of Christmas Island most similar to *T. walshi* due to the presence of bifid or trifid setae, however differs in the darker colour and much less dense pilosity, in particular on the gaster.

Distribution

Christmas Island: Widespread and common on Christmas Island (Figure 61).

Worldwide: Probably native to tropical Asia (Wilson and Taylor 1967) and northern Australia (A. Andersen personal communication), and spread by commerce to Africa and the Pacific coast of Mexico (Wilson and Taylor 1967).

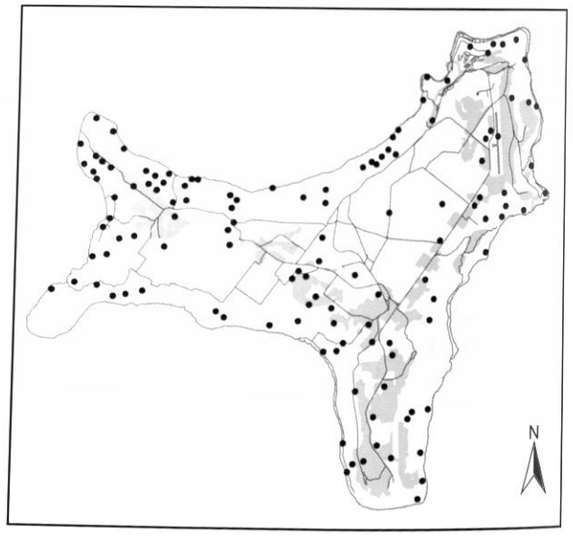


Figure 61 Records of *Tetramorium lanuginosum* on Christmas Island.

Tetramorium pacificum Mayr, 1870

Identification

TL ca. 2.0 – 2.5 mm; easily distinguished from other *Tetramorium* on Christmas Island by the uniformly dark brown to blackish-brown colouration and the shape of the petiolar node (Figure 20A).

Figure 62 Records of *Tetramorium pacificum* on Christmas Island.

Distribution

Christmas Island: *Tetramorium pacificum* appears to be predominantly found on the plateau rainforest (Figure 62).

Worldwide: *Tetramorium pacificum* is probably native to the Indo-Australian region, i.e. Southeast Asia, most of Melanesia, including New Caledonia, Micronesia, Polynesia east to the Marquesas and North Queensland (Wilson and Taylor 1967). It is one of the most common ants of the Pacific region and has probably been introduced to North America (Creighton 1950), and some islands, including the Society Islands (Morrison 1996) and Niue (Collingwood 2001).

Tetramorium simillimum (Smith, 1851)

Identification

Small (TL 1.3 – 1.8 mm); the short, stout pilosity on mesonoma easily distinguishes this and *T.* cf. *simillimum* from the other species of *Tetramorium* on Christmas Island. In contrast to *T.* cf. *simillimum*, this ant is uniformly yellow-brown (darker gaster in *T.* cf. *simillimum*) and the palp formula is 4,3 (2,2 in *T.* cf. *simillimum*).

Distribution

Christmas Island: *Tetramorium simillimum* is well dispersed across the island (Figure 63). It is a very small species and may be more common than indicated by the hand collections of the IWS 2005.

Worldwide: *Tetramorium simillimum* is a pantropical tramp species originating from the old world tropics (Africa) (Bolton and Collingwood 1975; Bolton 1977, 1980). It has been spread by commerce throughout the Americas and the Caribbean, Indian and Pacific Oceans (Bolton 1977, 1979, Clark *et al.* 1982; Wetterer and Wetterer 2004; Wilson and Taylor 1967).

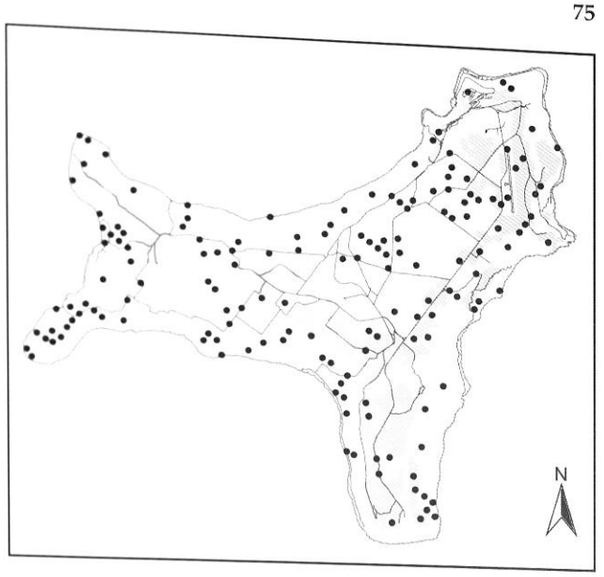


Figure 63 Records of *Tetramorium simillimum* on Christmas Island.

Remarks

Tetramorium simillimum occurs to about 1100 m altitude in dry and mesic habitats in Hawaii (Reimer 1994). There, it is limited to disturbed habitats. The species appears to be most active during the morning and evenings (Whitcomb *et al.* 1982).

Tetramorium cf. *simillimum*

Identification

Small (TL 1.3 – 1.8 mm); see above to distinguish this species from *T. simillimum*.

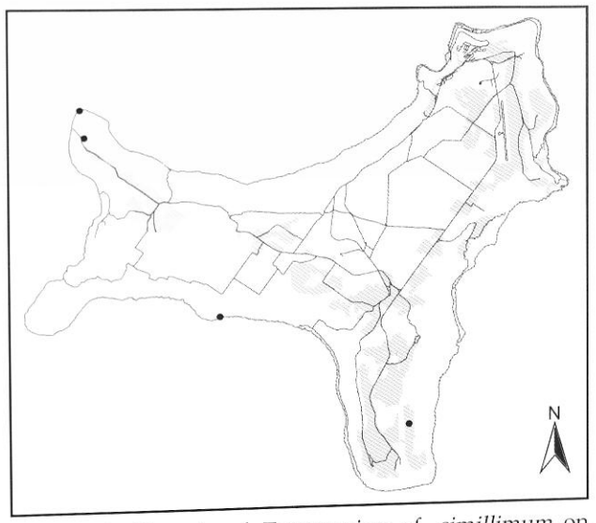


Figure 64 Records of *Tetramorium* cf. *simillimum* on Christmas Island.

Distribution

Christmas Island: This species was found at only four sites distributed from the northwest to the southeast of Christmas Island (Figure 64).

Worldwide: Worldwide distribution unclear (under revision by B. Bolton).

Tetramorium smithi Mayr, 1871

Identification

Tetramorium smithi is the only *Tetramorium* on Christmas Island with 11-segmented antennae (all other are 12-segmented).

Distribution

Christmas Island: *Tetramorium smithi* was encountered at only a few sites during the IWS 2005 that are all clustered in the north-east corner of the island (Figure 65). This distribution potentially reflects a recent introduction. All of these sites are adjacent to disturbed habitats such as roads or mine sites.

Worldwide: *Tetramorium smithi* is an Indo-Malayan species, reported from Sri Lanka, India, Myanmar, Thailand, Vietnam, Malaya, Borneo and Sulawesi (Bolton 1977).

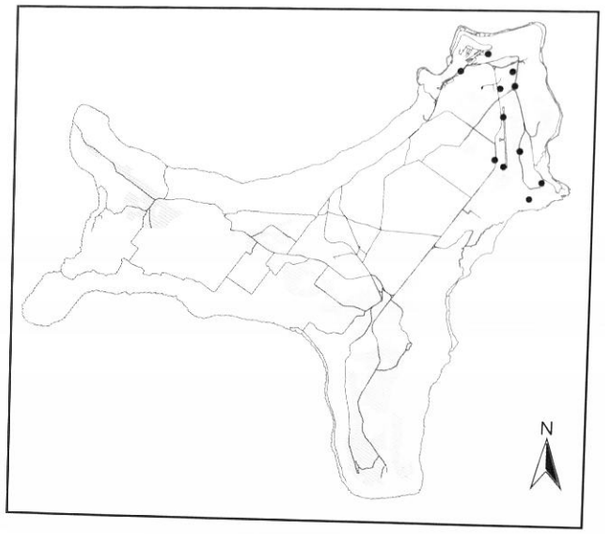


Figure 65 Records of *Tetramorium smithi* on Christmas Island.

Tetramorium walshi Forel, 1890

Identification

TL ca. 1.5 mm; the very dense pilosity of bifid and trifid setae distinguishes this species from all other *Tetramorium* on Christmas Island.

Distribution

Christmas Island: *Tetramorium walshi* was encountered at only five sites during the IWS 2005,

Figure 66 Records of *Tetramorium walshi* on Christmas Island.

all of which are near roads or at mine sites (Figure 66).

Worldwide: Known from India and Thailand (Bolton 1976).

Subfamily Ponerinae Lepeletier, 1835

Genus *Anochetus* Mayr, 1861

Anochetus sp. (*graeffei* group)

Nominal species

Anochetus graeffei Mayr, 1870

Identification

TL ca. 3.0 mm; distinct shape of head and mandibles that insert medially on head (Figure 6B); *Odontomachus simillimum* (Figure 6A) has a similar head and mandible shape, but is nearly three time as large. The taxonomy of *Anochetus* sp. (*graeffei* group) is not resolved and this species must therefore be regarded as representing a species group. Brown (1978; p. 587) provided a detailed discussion on *A. graeffei* systematics: 'The bounds of *graeffei* variation, and whether or not the species divides into sibling species, are ripe subjects for future gamma-taxonomic studies. These studies are certainly warranted, considering the outstanding success the species has had as a colonist through the Indo-Australian area'.

Distribution

Christmas Island: *Anochetus* sp. (*graeffei* group) was found all over the island but only at a limited number of sites (Figure 67). However, these are cryptic ants that hunt for prey in the leaf litter and can be hard to detect unless litter is sifted.

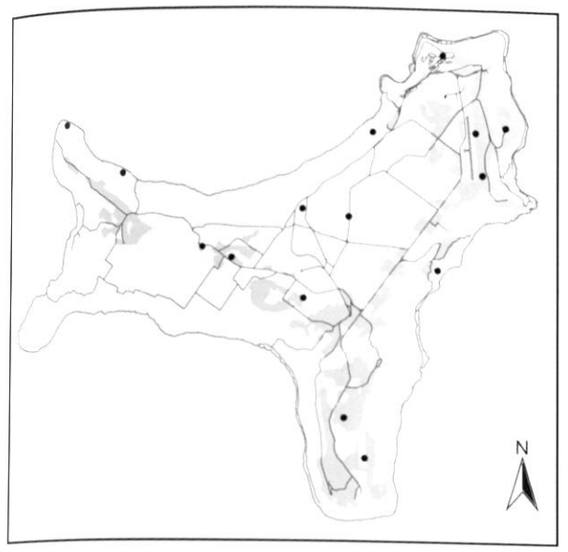


Figure 67 Records of *Anochetus* sp. (*graeffei* group) on Christmas Island.

Worldwide: The nominal species, *A. graeffei*, is reported to range from Southeast Asia to Queensland (Australia), and eastward into Micronesia and the Cook Islands (Wilson and Taylor 1967). It is continuously distributed throughout Melanesia, including New Caledonia. Taxonomic problems, however, make an interpretation of the distribution of species in this group difficult.

Genus *Hypoponera* Santschi, 1938

Hypoponera confinis (Roger, 1860)

Identification

TL ca. 2.2 mm; differs from *H. punctatissima* in the relatively longer antennal scapes, and from *H. opaciceps* by its shiny pronotum and the petiolar node that narrows dorsally (Figure 68).

Distribution

Christmas Island: *Hypoponera confinis* has been found over nearly the whole island albeit at only a few sites (Figure 69).

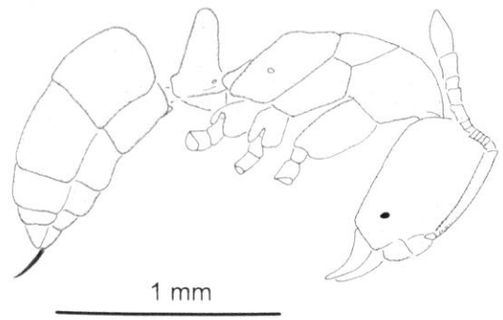


Figure 68 Worker of *Hypoponera confinis*.

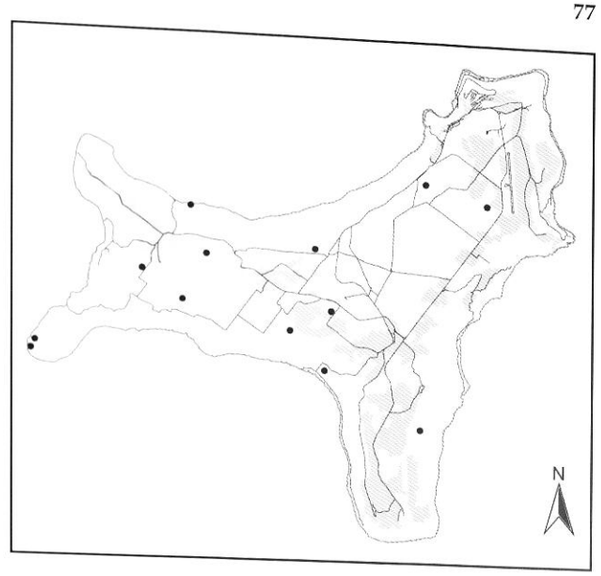


Figure 69 Records of *Hypoponera confinis* on Christmas Island.

Worldwide: *Hypoponera confinis* is a widespread species that is probably native throughout India, Ceylon, Indo-China, Indonesia and Melanesia, at least as far east as New Guinea (Wilson and Taylor 1967). Christmas Island may therefore constitute part of its native range.

Hypoponera opaciceps (Mayr, 1887)

Identification

Differs from *H. confinis*, the most common *Hypoponera* on Christmas Island, by a rectangular shape of the petiolar node in lateral view (narrowing dorsally in *H. confinis*), and from *H. punctatissima* by the longer scape.

Distribution

Christmas Island: On Christmas Island, this species was only reported once without precise locality data (Taylor 1990). It was not found during any of the recent surveys.

Worldwide: *Hypoponera opaciceps* is considered of Brazilian origin and in the New World it reaches more or less continuously from the southern United States as far south as Montevideo in Uruguay (Wilson and Taylor 1967). It appears to have been introduced into the Old World more or less irregularly by human commerce and was reported in a number of Polynesian localities, but also the Philippines and New Caledonia (Wilson and Taylor 1967).

Hypoponera punctatissima (Roger, 1859)

Identification

Differs from the other two members of

Figure 70 Records of *Hypoponera punctatissima* on Christmas Island.

Figure 71 Records of *Leptogenys falcigera* on Christmas Island.

Hypoponera on Christmas Island by the shorter antennal scape.

Distribution

Christmas Island: One worker was collected by pitfall trap during the recent cave survey from Daniel Roux Cave Upper (CI-56) (Figure 70). Prior to this, a single specimen of *H. punctatissima* has been reported from Christmas Island without precise locality data (Taylor 1990).

Worldwide: *Hypoponera punctatissima* is probably of African origin and has been carried extensively by man to the warmer parts of the globe (Wilson and Taylor 1967).

Remarks

Males of this species are peculiar in that they have highly worker-like ergatoids, and normal winged males have not been found (Wilson and Taylor 1967). This behavioural adaptation may have contributed to this species' success at establishment when introduced into new areas (Taylor 1967).

Genus *Leptogenys* Roger, 1861

Leptogenys falcigera Roger, 1861

Identification

TL ca. 6.0 mm; the shape of the mandibles (Figure 11A) unmistakably identify this species on Christmas Island. Species identification is based on the record of Taylor (1990).

Distribution

Christmas Island: *Leptogenys falcigera* was only found near the main settlement Flying Fish Cove in the northeastern part of the island and in the far south (Figure 71). It appears to prefer disturbed habitats.

Worldwide: *Leptogenys falcigera* is probably of African origin (Wilson and Taylor 1967).

Leptogenys harmsi Donisthorpe, 1935

Identification

TL ca 5.5 mm; *L. harmsi* forms part of the *conigera*-group of *Leptogenys* (Andersen 2000a); the petiole of this species has a distinct shape, with its rear face distinctly higher than the frontal face (Figures 12B *vs.* 12A, 72). We attributed *L. peuqueti* as reported by Collingwood and Hedlund (1980) to this species, as it also forms part of the *conigera*-group. Pending further revisionary work, we must also consider the earlier report of the similar *L. diminuta* (Smith, 1857) as misidentification of the common *L. harmsi*, as we can assume that Donisthorpe (1935) was aware of the earlier identification of this species as *L. diminuta* by Kirby (1888, 1900) (see Table 1).

Distribution

Christmas Island: *Leptogenys harmsi* is predominantly found on the eastern parts of the

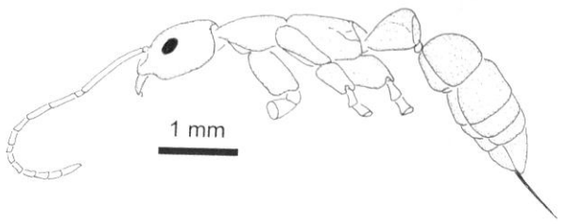


Figure 72 Worker of *Leptogenys harmsi*.

Figure 73 Records of *Leptogenys harmsi* on Christmas Island.

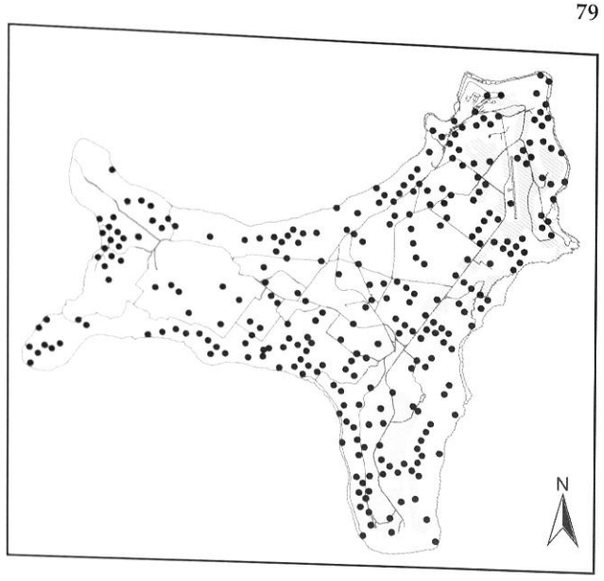


Figure 75 Records of *Odontomachus simillimus* on Christmas Island.

island and is common near disturbed areas and roads (Figure 73).

Worldwide: Originally described from Christmas Island. Based on the ANIC collection it is widespread in the Indonesian area and possibly a junior synonym (Taylor 1990).

Genus *Odontomachus* Latreille, 1804

Odontomachus simillimus F. Smith, 1858

Identification

Similar head and mandibles as *Anochetus* sp. (*graeffei* group), but much larger (TL ca. 8.0 mm) and with a petiolar node that ends in a dorsal thorn (Figure 74).

Distribution

Christmas Island: *Odontomachus simillimus* was recorded from Christmas Island as early as 1915 (Table 1). This is a large and conspicuous species that is easily collected. It is widespread and common on the island (Figure 75), but generally absent in mine sites.

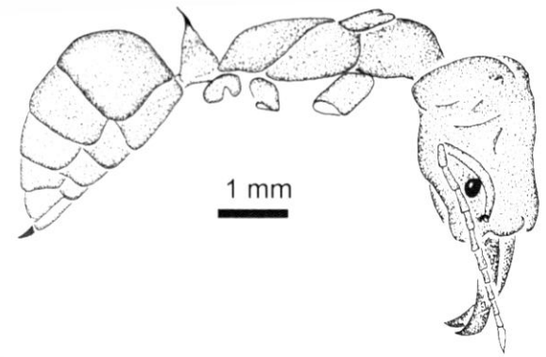


Figure 74 Worker of *Odontomachus simillimus*.

Worldwide: *Odontomachus simillimus* ranges continuously from Ceylon to Micronesia and inner Polynesia. Within this range it is one of the dominant ants, maintaining dense populations in a wide variety of habitats (Wilson and Taylor 1967).

Remarks

There is no doubt that the early records of *O. haematodes* from Christmas Island represent misidentified *O. simillimus* (see Table 1). The similarity of these species is indicated by the description of a new subspecies of *O. haematodes* from Christmas Island, *O. haematodes* var. *breviceps*, which was subsequently synonymised with *O. simillimus* (Table 1).

Genus *Pachycondyla* Smith, 1858

Subgenus *Brachyponera* Emery, 1900

Pachycondyla (*Brachyponera*) *christmasi* (Donisthorpe, 1935)

Identification

TL ca. 3.0 mm; two spines on the tibia of the third leg, well-developed eyes (Figure 76) (in contrast to *Pachycondyla* (*Trachymesopus*) *darwinii*; Figure 78) and no teeth on the inner margin of the claws of the third leg (in contrast to *Leptogenys*).

Distribution

Christmas Island: *Pachycondyla* (*Brachyponera*) *christmasi* is widespread on the plateau with the exclusion of mine sites. It is less common on the terraces of Christmas Island (Figure 77).

Worldwide: Appears to be a common species in the Indo-Australian region based on collections of the ANIC (Taylor 1990).

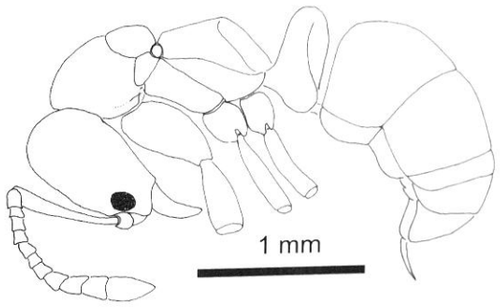


Figure 76 Worker of *Pachycondyla* (*Brachyponera*) *christmasi*.

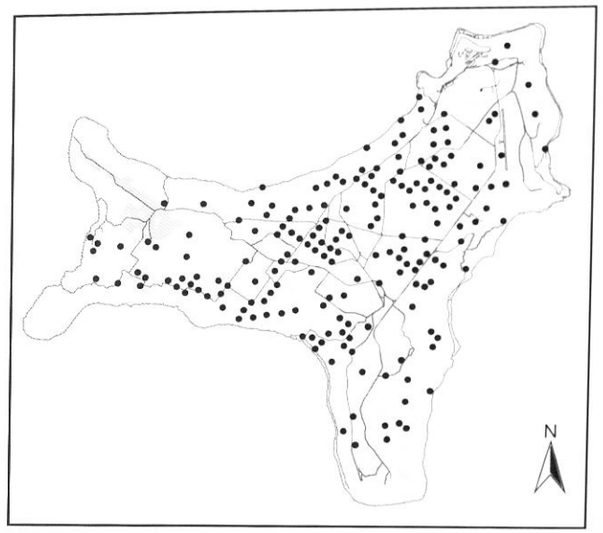


Figure 77 Records of *Pachycondyla* (*Brachyponera*) *christmasi* on Christmas Island.

Remarks

Pachycondyla (*Brachyponera*) *christmasi* was originally described from Christmas Island, but it appears to be widespread in the Indonesian area based on the ANIC ant collection; a senior synonym may exist (Taylor 1990). Collingwood and Hedlund (1980) suggested it to be a junior synonym of *Pachycondyla solitaria*. We could not confirm this synonymy, as we did not have access to material of *P. solitaria*. Hence, we list this abundant species from Christmas Island as *P.* (*B.*) *christmasi* pending a revision of the genus.

Subgenus *Trachymesopus* Emery, 1911

Pachycondyla (*Trachymesopus*) *darwinii* (Forel, 1893)

Identification

TL ca. 2.0 mm; the presence of two spines on the third tibia (one pectinate spine in the similar *Hypoponera*) in combination with the very small eyes (Figure 78) identifies this species within the

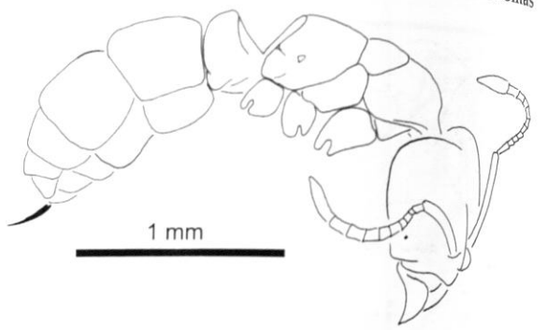


Figure 78 Worker of *Pachycondyla* (*Trachymesopus*) *darwinii*.

Ponerinae of Christmas Island. The identification of this species remains tentative since the workers reported here are unusually larger than queens in collections (A. Andersen personal communication).

Distribution

Christmas Island: This species was reported by Taylor (1990) based on a single queen without detailed locality data. The only recent record is from 19th Hole Cave collected during a cave survey in April 2004 (WAM, registration no. BES13582) (Figure 79).

Worldwide: This species is widespread in the Indo-Australian region (Taylor 1990).

Remarks

The record of two workers of this species from caves on Christmas Island suggests troglobitic behaviour. This may also explain why this species is mainly known from females collected at lights (A. Andersen personal communication).

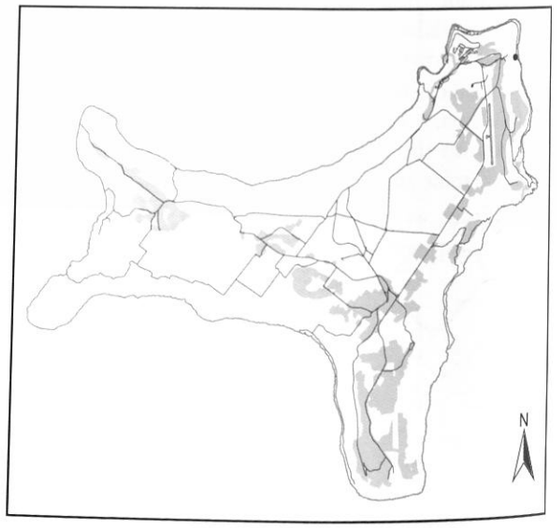


Figure 79 Records of *Pachycondyla* (*Trachymesopus*) *darwinii* on Christmas Island.

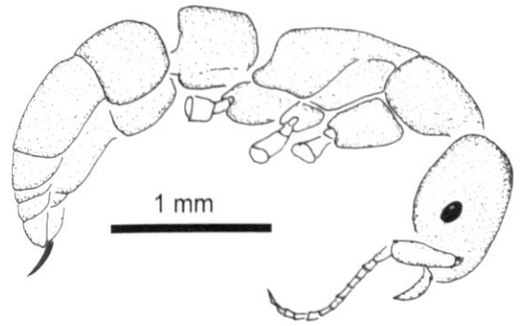


Figure 80 Worker of *Platythyrea* sp. (*parallela* group).

Genus *Platythyrea* Roger, 1863

Platythyrea sp. (*parallela* group)

Nominal species

Platythyrea parallela (Smith, 1859)

Identification

TL ca. 2.5 – 3.0 mm; uniformly brown; the long, almost cylindrical shape of the petiole identifies this species in comparison to all other Ponerinae from Christmas Island (Figure 80). The taxonomy of the species in this group is not resolved and therefore it is listed here as a species group (A. Andersen personal communication).

Distribution

Christmas Island: Although workers of *Platythyrea* sp. (*parallela* group) are conspicuous, some species of this group are known to forage arboreally (A. Andersen personal communication), rendering them potentially difficult to collect by hand. As such, the current distribution of *Platythyrea* sp. (*parallela* group) as illustrated in Figure 81 may not fully represent the distribution of this species across the island.

Worldwide: The nominal species, *Platythyrea parallela*, is considered native to Australia (Shattuck and Bennett 2001). It is also found from tropical Asia to Samoa (Wilson and Taylor 1967) and Fiji (Ward and Wetterer 2006).

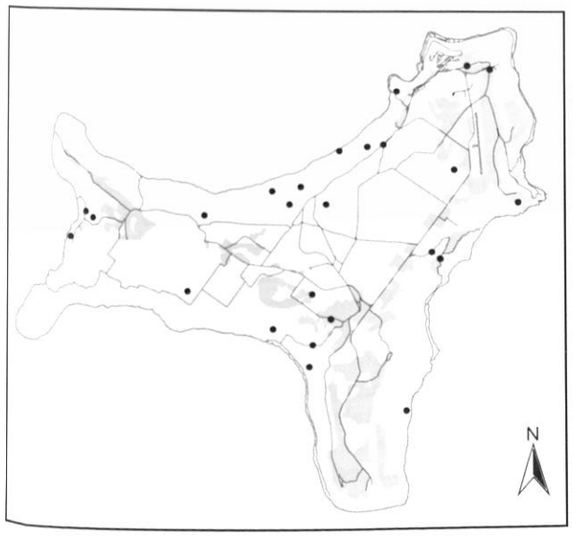


Figure 81 Records of *Platythyrea* sp. (*parallela* group) on Christmas Island.

Genus *Ponera* Latreille, 1804

Ponera swezeyi (Wheeler, 1933)

Identification

The smallest ponerine ant on Christmas Island (TL ca. 1.7 mm, HW 0.30 – 0.32 mm); the presence of a translucent spot on the underside of the petiole (fenestra) undoubtedly identifies this species. Accurate species identification is possible with a key in a detailed revision of *Ponera* (Taylor 1967).

Distribution

Christmas Island: This species was collected at only four sites; two waypoints in the IWS 2005, at Grants Well Cave (CS) and at the BMP survey site (Figure 82)

Worldwide: This species was thought to be endemic to Hawaii until it was discovered on Samoa (Wilson and Taylor 1967). The native range of *P. swezeyi* is thought to be South-East Asia (Taylor 1990).

Remarks

This species' predilection to soil nesting rather than rotting logs (as is usual in *Ponera*) may have increased the likelihood of its dispersal by man (Wilson and Taylor 1967).

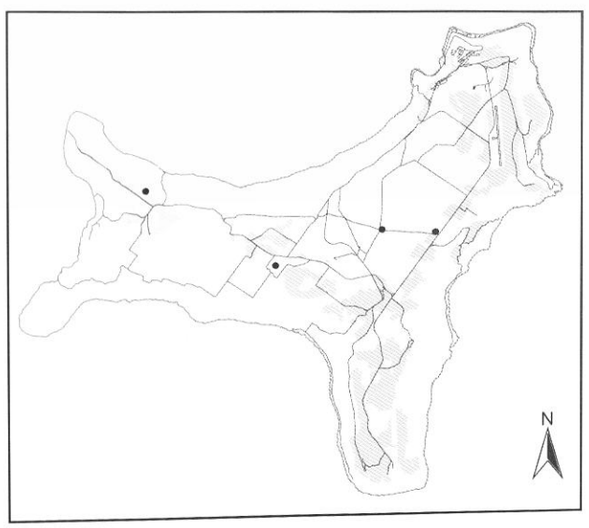


Figure 82 Records of *Ponera swezeyi* on Christmas Island.

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Any new key to ants, in particular on subfamily and generic level, will unavoidably contain elements of previously published keys. Of great help to establish useful diagnostic characters at the subfamily and generic level were Shattuck (1999), Wilson and Taylor (1967), Bolton (1999), Andersen (2000a), Reimer (unpublished) and Ward (2005).

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REFERENCES

Abbott, K.L. (2005). Supercolonies of the invasive yellow crazy ant, *Anoplolepis gracilipes*, on an oceanic island: forager activity patterns, density and biomass. *Insectes Sociaux* **52**: 266–273.

Abbott, K.L. (2006). Spatial dynamics of supercolonies of the invasive yellow crazy ant, *Anoplolepis gracilipes*, on Christmas Island, Indian Ocean. *Diversity and Distributions* **12**: 101–110.

ABRS (2006). *Australian Faunal Directory. Checklist for Vespoidea: Formicidae*. Australian Biological Resources Study, Canberra. Available at: http://www.environment.gov.au/ biodiversity/abrs/online-resources/fauna/afd/search.html#morenbs (verified 10 October 2007).

Agosti, D. and Johnson, N.F. (2005). Antbase (version 05/2005). Available at: http://www.antbase.org (verified 10 October 2007).

Andersen, A.N. (2000a). *The Ants of Northern Australia. A Guide to the Monsoonal Fauna*. CSIRO Publishing, Collingwood (Australia). 106 pp.

Andersen, A.N. (2000b). A global ecology of rain forest ants: functional groups in relation to stress and disturbance. In: Agosti, D., Majer, J.D., and Tennant, L. (eds) *Measuring and Monitoring Ant Biodiversity* Smithsonian Institution Press, Washington, US, pp. 25–34.

Bach, C.E. (1991). Direct and indirect interactions between ants (*Pheidole megacephala*), scales (*Coccus viridis*) and plants (*Pluchea indica*). *Oecologia* **87**: 233–239.

Bolton, B. (1976). The ant tribe Tetramoriini (Hymenoptera: Formicidae). Constituent genera, review of smaller genera and revision of *Triglyphothrix* Forel. *Bulletin of the British Museum (Natural History) Entomology*. **34**: 281–379.

Bolton, B. (1977). The genus *Tetramorium* Mayr in the Oriental and Indo-Australian regions, and in Australia. *Bulletin of the British Museum (Natural History) Entomology* **36**: 67–151.

Bolton, B. (1979). The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Malagasy region and in the New World. *Bulletin of the British Museum (Natural History) Entomology* **38**: 129–181.

Bolton, B. (1980). The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Ethiopian zoogeographic region. *Bulletin of the British Museum (Natural History) Entomology* **40**: 193–384.

Bolton, B. (1983). The Afrotropical dacetine ants (Formicidae). *Bulletin of the British Museum (Natural History) Entomology* **46**: 267–416.

Bolton, B. (1987). A review of the *Solenopsis* genus-group and revision of Afrotropical *Monomorium* Mayr (Hymenoptera: Formicidae). *Bulletin of the British Museum (Natural History) Entomology* **54**: 263–452.

Bolton, B. (1994). *Identification Guide to the Ant Genera of the World*. Harvard University Press, Cambridge (MA) 222 pp.

Bolton, B. (1995). *A New General Catalogue of the Ants of the World*. Harvard University Press, Cambridge (MA). 504 pp.

Bolton, B. (1999). Ant genera of the tribe Dacetonini (Hymenoptera: Formicidae). *Journal of Natural History* **33**: 1639–1689.

Bolton, B. (2000). The ant tribe Dacetini, with a revision of the *Strumigenys* species of the Malagasy Region by Brian L. Fisher, and a revision of the Austral epopostrumiform genera by Steven O. Shattuck. *Memoirs of the American Entomological Institute* **65**: 1–1028.

Bolton, B. and Collingwood, C.A. (1975). Hymenoptera, Formicidae. In: *Handbooks for the Identification of British Insects* 6: part 3c. London, Royal Entomological Society of London.

Brady, S.G. and Ward, P.S. (2005). Morphological phylogeny of army ants and other dorylomorphs (Hymenoptera: Formicidae). *Systematic Entomology* **30**: 593–618.

Brooks, D. unpublished. Cave Fauna Survey, Christmas Island, 18/6/04 – 23/6/04.

Brooks, M.L. (1999). Habitat invasibility and dominance by alien annual plants in the western Mojave Desert. *Biological Invasions* **1**: 325–337.

Brown, W.L. (1958). A review of the ants of New Zealand. *Acta Hymenopterologica* **1**: 1–50.

Brown, W.L. (1960). Contributions towards a reclassification of the Formicidae. III. Tribe Amblyoponini (Hymenoptera). *Bulletin of the Museum of Comparative Zoology Harvard* **122**: 145–230.

Brown, W.L. (1975). Contributions toward a reclassification of the Formicidae. V. Ponerinae, tribes Platythyreini, Cerapachyini, Cylindromyrmecini, Acanthostichini, and Aenictogitini. *Search, Agriculture* **5**: 1–116 (Ithaca, New York).

Brown, W.L. (1978). Contributions toward a reclassification of the Formicidae. VI. Ponerinae, tribe Ponerini, subtribe Odontomachitis. Section B. Genus *Anochetus* and bibliography. *Studies in Entomology (N.S.)* **20**: 549–652.

Brown, W.L. and Wilson, E.O. (1959). The evolution of the dacetine ants. *Quarterly Reviews of Biology* **34**: 278–294.

Byers, J.E. (2002). Impact of non-indigenous species on natives enhanced by anthropogenic alteration of selection regimes. *Oikos* **97**: 449–458.

Campbell, T.G. (1964). Entomological Survey of Christmas Island (Indian Ocean), with special reference to the insects of medical, veterinary, agricultural and forestry significance. *CSIRO Research Report*.

Clark, D., Guayasamin B., Pazamino C., Donoso C. and Paez De Villacis, Y. (1982). The tramp ant *Wasmannia auropunctata*: Autecology and effects on ant diversity and distribution on Santa Cruz Island, Galapagos. *Biotropica* **14**: 196–207.

Claussen, J. (2005). Native plants of Christmas Island. *Flora of Australia Supplementary Series* **22**: 1–146.

Collingwood, C.A. (2001). The ants (Hymenoptera: Formicidae) of Niue, South West Pacific. *Entomologist's Monthly Magazine* **137**: 139–143.

Collingwood, C.A. and Hedlund, K. (1980). Ants collected by Hal Heatwole from Cocos Keeling and Christmas Islands. *CSIRO Report*, 5 pp.

Collingwood, C.A., Tigar, B.J. and Agosti, D. (1997). Introduced ants in the United Arab Emirates. *Journal of Arid Environments* **37**: 505–512.

Crawley, W.C. (1915). Ants from North and South-West Australia (G. F. Hill, Rowland Turner) and Christmas Island, Straits Settlements – Part II. *Annals and Magazine of Natural History* **15**: 232–239.

Creighton, W.S. (1950). The Ants of North America. *Bulletin of the Museum of Comparative Zoology* **104**: 1–585.

Davis, N. (2002). *The invasive yellow crazy ant (Anoplolepis gracilipes) on Christmas Island, Indian Ocean: impacts on the frugivorous bird fauna*. BSc (Hons.) Thesis, School of Biological Sciences. Monash University, Melbourne.

Davis, P.R. and van Schagen, J. (1993). Effective control of pest ants. *Journal of Agriculture, Western Australia* **34**: 92–95.

Davis, P.R., van Schagen, J.J., Widmer, M.A. and Craven, T.J. (1993). *A review of Argentine ant research in Western Australia*. Perth, Agricultural Protection Board of Western Australia. 95 pp.

Deyrup, M. and Deyrup, S. (1999). Notes on the introduced ant *Quadristruma emmae* (Hymenoptera: Formicidae) in Florida. *Entomological News* **110**: 13–21.

Deyrup, M., Davis, L. and Cover, S. (2000). Exotic ants in Florida. *Transactions of the American Entomological Society* **126**: 293–326.

Donisthorpe, H.J. (1935). The ants of Christmas Island. *Annals and Magazine of Natural History* **15**: 629–636.

Edwards, J.S. and Thornton, I.W.B. (2001). Colonization of an island volcano, Long Island, Papua New Guinea, and an emergent island, Motmot, in its caldera lake. VI. The pioneer arthropod community of Motmot. *Journal of Biogeography* **28**: 1379–1388.

Greenslade, P. (1972). Comparative ecology of four tropical ant species. *Insectes Sociaux* **19**: 195–212.

Gunawardana, D. (2005). *Monomorium fieldi* Forel (Hymenoptera: Formicidae) is the current name to use for ants previously known as *Monomorium antipodum* Forel and *Monomorium orientale* Mayr in New Zealand. *The Weta* **30**: 14–15.

Haskins, C.P. and Haskins, E.F. (1965). *Pheidole megacephala* and *Iridomyrmex humilis* in Bermuda – equilibrium or slow replacement? *Ecology* **46**: 736–740.

Heterick, B. 1997. The interaction between the coastal brown ant, *Pheidole megacephala* (Fabricius), and other invertebrate fauna of Mt Coot-tha (Brisbane, Australia). *Australian Journal of Ecology* **22**: 218–221.

Heterick, B. 2001. Revision of the Australian ants of the genus *Monomorium* (Hymenoptera: Formicidae). *Invertebrate Taxonomy* **15**: 353–459.

Hoffman, D.R. 1997. Reactions to less common species of fire ants. *Journal of Allergy and Clinical Immunology* **100**: 679–683.

Hoffmann, B.D., Andersen, A.N. and Hill, G.J.E. (1999). Impact of an introduced ant on native rain forest invertebrates: *Pheidole megacephala* in monsoonal Australia. *Oecologia* **120**: 595–604.

Holway, D., Suarez, A.V. and Case, T.J. (2002). Role of abiotic factors in governing susceptibility to invasion: a test with Argentine ants. *Ecology* **83**: 1610–1619.

Hölldobler, B. and Wilson, E.O. 1990. *The Ants*. Belknap Press, Cambridge, Massachusetts.

Ingram, K.K., Bernardello, G., Cover, S. and Wilson, E.O. (2006). The ants of the Juan Fernández Islands: genesis of an invasive fauna. *Biological Invasions* **8**: 383–387.

ISSG (2004). Global Invasive Species Database. Invasive Species Specialist Group of the IUCN Species Survival Commision. Available at: http://www.issg.org/database/welcome/ (verified 10 October 2007).

Jahn, G.C. and Beardsley, J.W. (1994). Big-headed ants, *Pheidole megacephala*: interference with the biological control of gray pineapple mealybugs. In:

Williams DF (ed.) *Exotic Ants: Biology, Impact, and Control of Introduced Species*. Westview Press, Boulder, pp. 199–205.

Kirby, W.F. (1888). On the insects (exclusive of Coleoptera and Lepidoptera) of Christmas Island. *Proceedings of the Zoological Society London* **1888**: 546–555.

Kirby, W.W. (1900). *A monograph of Christmas Island (Indian Ocean). Physical features and geology. With descriptions of the fauna and flora by numerous contributors*. (Andrews, C.W., ed.). British Museum of Natural History, London, pp. 81–88, plate 14.

Lieberburg, I., Kranz, P.M. and Seip, A. (1975). Bermudian ants revisited: the status and interaction of *Pheidole megacephala* and *Iridomyrmex humilis*. *Ecology* **56**: 473.

Lit, I.L. and Caasi-Lit, M.T. (2004). Taxonomic survey and biological observations of insects associated with bamboo shoots in the Philippines. *Philippine Agricultural Scientist* **87**: 335–348.

Majer, J.D. (1985). Recolonization by ants of rehabilitated mineral sand mines on North Stradbroke Island, Queensland, with particular reference to seed removal. *Australian Journal of Ecology* **10**: 31–48.

Majer, J.D. (1994). Spread of Argentine ants (*Linepithema humile*), with special reference to Western Australia. In: Williams DF (ed.) *Exotic Ants: Biology, Impact and Control of Introduced Species*. Westview Press, Boulder, pp. 163–173.

Manaki Whenua Landcare Research (2006). Invasive Ant Threat. Information Sheets. Available at: http://www.landcareresearch.co.nz/research/biosecurity/stowaways/Ants/invasive_ants (verified 10 October 2007).

Masuko, K. (1990). Behavior and ecology of the enigmatic ant *Leptanilla japonica* Baroni Urbani (Hymenoptera: Formicidae: Leptanillinae). *Insectes Sociaux* **37**: 31–57.

McArthur, A.J. and Shattuck, S.O. (2001). A taxonomic revision of the *Camponotus macrocephalus* group (Hymenoptera: Formicidae) in Australia. *Transactions of the Royal Society of South Australia* **125**: 25–43.

McGlynn, T.P. (1999). The worldwide transfer of ants: geographical distribution and ecological invasions. *Journal of Biogeography* **26**: 535–548.

Morrison, L.W. (1996). The ants (Hymenoptera: Formicidae) of Polynesia revisited: species numbers and the importance of sampling intensity. *Ecography* **19**: 73–84.

Ness, J.H. and Bronstein J.L. (2004). The effects of invasive ants on prospective ant mutualists. *Biological Invasions* **6**: 445–461.

O'Dowd, D.J., Green, P.T. and Lake, P.S. (1999). *Status, impact, and recommendations for research and management of exotic invasive ants in Christmas Island National Park*. Environment Australia, Darwin, Northern Territory.

O'Dowd, D.J., Green, P.T. and Lake, P.S. (2003). Invasional 'meltdown' on an oceanic island. *Ecology Letters* **6**: 812–817.

Prins, A.J. (1985). *Formicoidea*. In: Scholtz C.H. and Holm, E. (eds) *Insects of Southern Africa*. Durban, Butterworths. Pg. 443–451.

Ravary, F. and Jaisson, P. (2004). Absence of individual sterility in thelytokous colonies of the ant Cerapachys *biroi* Forel (Formicidae, Cerapachyinae). *Insectes Sociaux* **51**: 67–73.

Reimer, N.J. (1994). Distribution and impact of alien ants in vulnerable Hawaiian ecosystems. In: *Exotic Ants. Biology, Impact, and Control of Introduced Species* (D.F. Williams, ed.), Westview Press, Boulder, San Francisco, Oxford. pp. 11–22.

Reimer, N.J. unpublished. Key to the Ants of Hawaii.

Schagen, van J.J., Davis, P.R. and Widmer, M.A. (1994). Ant pests of Western Australia, with particular reference to the Argentine ant (*Linepithema humile*). In: *Exotic ants: Biology Impact, and Control of Introduced Species*. Williams DF (ed.). Westview Press, Boulder, pp. 174–180.

Schmidt, M. and Hoffman, D.R. (1999). Venom allergens of the tropical fire ant, *Solenopsis geminata*. *Journal of Allergy and Clinical Immunology* **103**: S163–S163.

Seifert, B. (2003). The ant genus *Cardiocondyla* – a taxonomic revision of the *C. elegans, C. bulgarica, C. batesii, C. nuda, C. shuckardi, C. stambulfii, C. wroughtonii, C. emeryi*, and *C. minutior* species groups. *Annalen des Naturhistorischen Museums in Wien* **104B**: 203–338.

Shattuck, S.O. (1999). *Australian ants: Their biology and identification*. Collingwood, Melbourne, CSIRO Publishing.

Shattuck, S.O and Bennett, N.J. (2001). Australian Ants Online. CSIRO, Australia. Available at: http://www.ento.csiro.au/science/ants/default.htm (verified 10 October 2007).

Simberloff, D. (1995). Why do introduced species appear to devastate islands more than mainland areas? *Pacific Science* **49**: 87–97.

Smith, M.R. (1965). House-infesting ants of the eastern United States. *Technical Bulletin, Agricultural Research Service, U.S. Department of Agriculture*, 1326.

Smith, D.R. (1979). Superfamily Formicoidea. Pp. 1323–1467 in Krombein, K.V. Hurd, P.D., Smith, D.R. and Burks, B.D. (eds). *Catalog of Hymenoptera in America north of Mexico*. Smithsonian Institution Press, Washington D.C. 2735pp.

Taylor, R.W. (1967). A monographic revision of the ant genus *Ponera* Latreille (Hymenoptera: Formicidae). *Pacific Insects Monograph* **13**: 1–112.

Taylor, R.W. (1990). *Ants*. In: Report: A.N.P.W.S. Consultancy Agreement: C.S.I.R.O. Entomological Survey of Christmas Island. Phase 2 and Final Report. Report of Project No. 8889/13.

Trager, J.C. (1984). A revision of the genus *Paratrechina* (Hymenoptera: Formicidae) of the continental United States. *Sociobiology* **9**: 51–162.

Tweedie, M.W.F. (1933). Some insects from Christmas Island, Indian Ocean. *Bulletin of the Raffles Museum* **8**: 98–101.

Vanderwoude, C., Lobry De Bruyn, L.A. and House, A.P.N. (2000). Response of an open-forest ant community to invasion by the introduced ant, *Pheidole megacephala*. *Austral Ecology* **25**: 253–259.

Ward, P.S. (2005). A synoptic review of the ants of

California (Hymenoptera: Formicidae). *Zootaxa* **936**: 1–68.

Ward, D.F. and Wetterer, J.K. (2006). Checklist of the Ants of Fiji (Hymenoptera: Formicidae). *Bishop Museum Occasional Papers* **85**: 23–47.

Wetterer, J.K. and Wetterer, A.L. (2004). Ants (Hymenoptera: Formicidae) of Bermuda. *Florida Entomologist* **87**: 212–221.

Wetterer, J.K. (2005). Worldwide distribution and potential spread of the long-legged ant *Anoplolepis gracilipes*. *Sociobiology* **45**: 77–96.

Wheeler, W.M. (1910). *Ants, their structure, development and behavior*. Columbia University Press. New York and London. 663 p.

Wheeler, W.M. (1922). On the distribution of the ants of the Ethiopian and Malagasy regions. *Bulletin of the American Museum of Natural History* **45**: 13–37.

Whitcomb, W.H., Gowan, T.D. and Buren, W.F. (1982). Predators of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) larvae. *Florida Entomologist* **65**: 150–158.

Wilson, E.O. and Taylor, R.W. (1967). The ants of Polynesia (Hymenoptera: Formicidae). *Pacific Insects Monograph* **14**: 1–109.

With, K.A. (2002). The landscape ecology of invasive spread. *Conservation Biology* **16**: 1192–1203.

Williams, D.F. and Whelan, P. (1991). Polygynous colonies of *Solenopsis geminata* (Hymenoptera, Formicidae) in the Galapagos-Islands. *Florida Entomologist* **74**: 368–371.

Yamauchi, K., Furukawa, T., Kinomura, K., Takamine, H. and Tsuji, K. (1991). Secondary polygyny by inbred wingless sexuals in the dolichoderine ant *Technomyrmex albipes*. *Behavioral Ecology and Sociobiology* **29**: 313–319.

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