The preferred habitat of the jack jumper ant (*Myrmecia pilosula*)

A study in Hobart, Tasmania

Maldwyn John Evans BSc (Hons), Grad. Dip. Environmental Studies
University of Tasmania

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Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Signed

Maldwyn John Evans

Wednesday, July 02, 2008

Dedication

This thesis is dedicated to my grandparents, Maldwyn and Megan Evans.

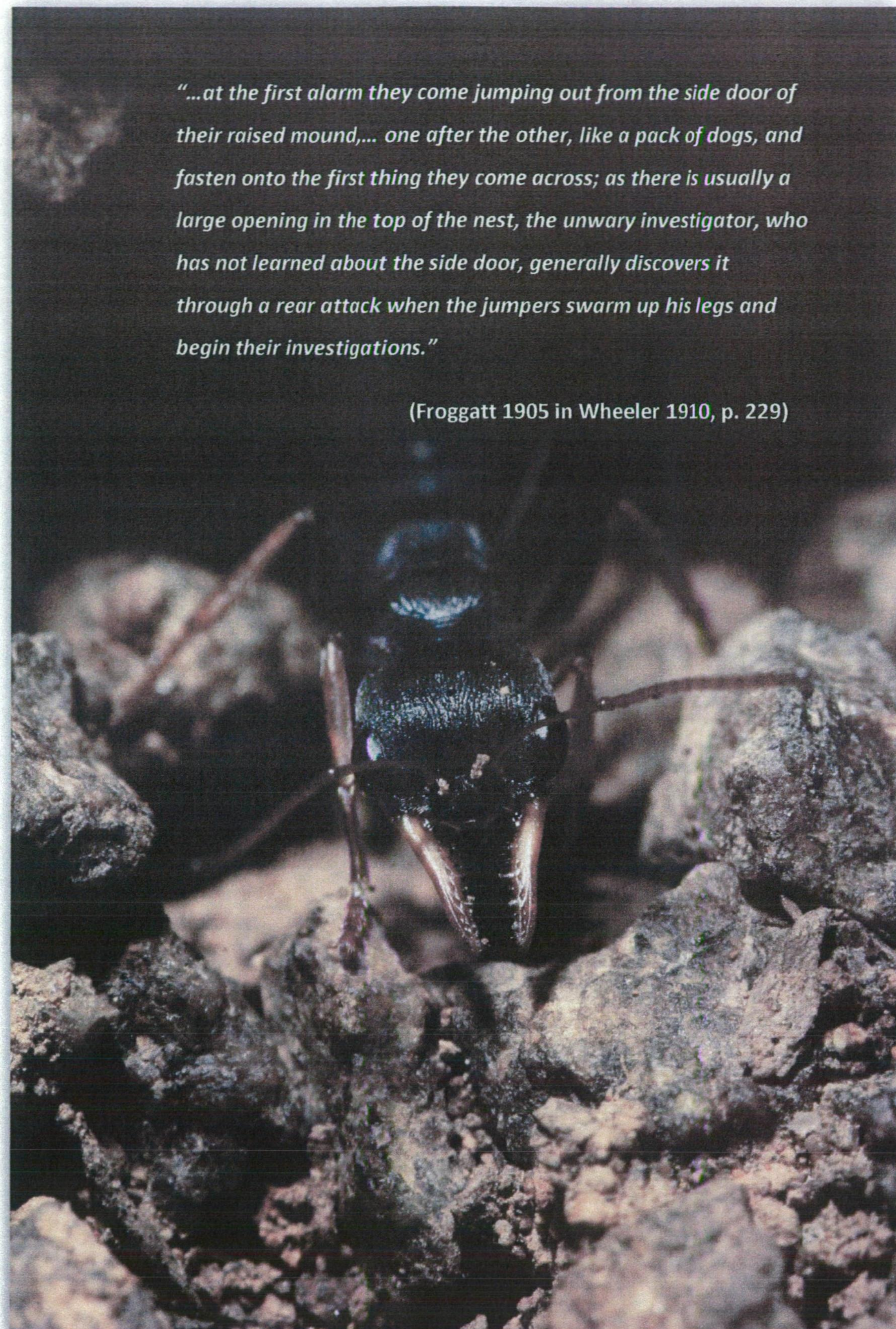
Abstract

The jack jumper ant (*Myrmecia pilosula*), a member of the primitive Myrmecia genus of ants, is well known for its aggressive behaviour and painful, sometimes dangerous sting. However, although the ant is well known to Tasmanians, there are few published studies of its biology or ecology. This project is an attempt to address this lack of research and seeks to explore the interaction between humans and jack jumpers by understanding better the preferred habitat of the ant.

Two studies were undertaken within the boundaries of the study area: Hobart City Council, Tasmania, Australia. In the first study, jack jumper nests were searched for ten times in transects, in each of the natural vegetation types. Data were collected on the presence or absence of jack jumper nests, vegetation type, vegetation structure, moss cover, bare ground cover, coarse woody debris cover, rock cover, litter cover, litter depth, and distance to nearest tree as well as observations made about each nest that was found. In the second study, residents of Hobart were surveyed using a questionnaire regarding the features of their property and whether they had ever seen a jack jumper nest or ant on their property. They were also asked to outline the circumstances in which they were stung. To analyse the data, thematic analyses, correlation analyses, analysis of variance, Wilcoxon tests, chi-square testing, logistic regression and ordination were used.

The results of the study showed that, within the Hobart City Council boundary, jack jumpers are co-extensive with dry eucalypt open woodlands. These warm, dry and relatively open environments provide the ant with a combination of insolation for warmth and vegetation for food resources such as nectar and invertebrate prey. They also utilise the radiative warmth of rocks and dry soil and often enhance their nest's thermal capacity with decorations of seeds, soil, charcoal, stones, sticks and sometimes small vertebrate bones. In a suburban context the ants are associated with native vegetation whilst utilising cracks in concrete, walls, rockeries, dry dirt and dry grassy areas to construct nests. The suburbs with a significant matrix of native vegetation such as Mt. Nelson, Fern Tree and West Hobart all contain the ants, whereas the heavily built up areas of Battery point and North Hobart do not.

Humans are most likely to be stung by a jack jumper ant in their property when carrying out outdoor duties such as gardening or collecting firewood. They may also be stung whilst walking bare foot. A common sense approach should be employed in order to avoid a sting from a jack jumper. For those wishing to live in areas that do not contain the ant, the built up suburbs of Hobart are recommended.



(Above and cover photographs: Felix Wilson)

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1 Introduction

1.1 Venomous animals

Venomous animals pose a threat to humans throughout the world. Animal venom can cause pain, irritation and sometimes death in humans. Australia is well known for its venomous animals. These include marine dwellers such as octopi and jellyfish, many snakes, spiders, wasps and ants and even a mammal species, the platypus (AVRU 2007; Fry *et al.* 2006).

1.2 Hymenoptera stings

Many species of the order Hymenoptera of insects, which includes bees, wasps and ants, are capable of stinging humans (Gauld & Bolton 1996). The stinging apparatus of bees, wasps and ants is a modified ovipositor capable of injecting venom into the flesh of the victim (Gauld & Bolton 1996; Steen *et al.* 2005). If stung, most people experience a mild reaction and only minor discomfort; however, stings can cause death in the small number of people who suffer an allergic reaction to the sting, known as anaphylaxis (Hodgson 1997).

Anaphylaxis is a systemic reaction caused by the release of active mediators from mast cells and basophils (Moneret-Vautrin *et al.* 2005). It can result in urticaria, diaphoresis, angioedema, bronchoconstriction, gastrointestinal disturbance and vascular collapse (Steen *et al.* 2005). Onset of a severe allergic reaction can manifest itself very quickly with the individual exhibiting systemic reactions within a few minutes of receiving the sting (Steen *et al.* 2005). It is very difficult to predict who might be allergic; however, the risk factors include multiple prior stings and older age (Steen *et al.* 2005).

Although death from a sting is very rare, Hymenoptera are considered among the most dangerous venomous animals, especially in temperate latitudes such as Tasmania (Gauld & Bolton 1996). In a survey of envenomation fatalities in the United States, Parrish (1963, in Gauld & Bolton 1996, p. 42) revealed that more than half of the fatalities were as a result of a hymenoptera sting, whereas around 30% were from snake bites (Gauld & Bolton 1996). In Australia, snake bites constitute the largest proportion of the venom deaths (Figure 1.1), but Hymenoptera sting fatalities represent almost as many fatalities as that of snakes (AVRU 2007).

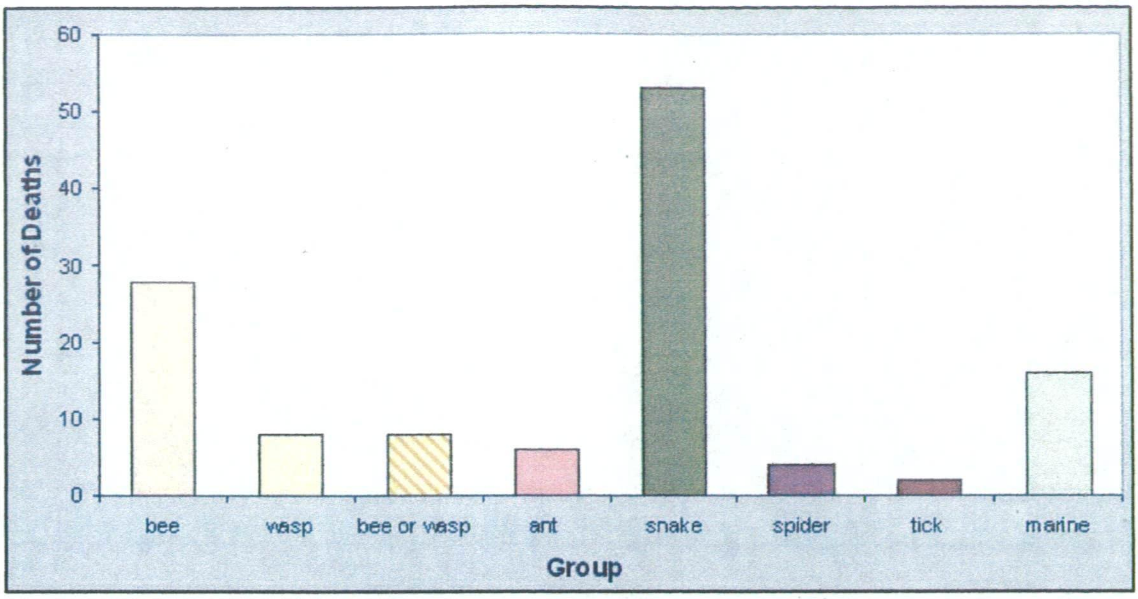


Figure 1.1: Venomous bite and sting fatalities by taxonomic group (1979 – 1998) (AVRU 2007).

1.3 Jack jumper ant (*Myrmecia pilosula*) stings

Stings from the jack jumper ant (*Myrmecia pilosula*) pose a significant risk to people who are allergic to the ants' venom. The ant causes over 90% of ant venom anaphylaxis in Australia (Street et. al. 1994 in Brown *et al.* 2003a, p. 187). In Tasmania, Brown *et al.* (2001) noted that 21% - 25% of the 324 cases of anaphylaxis treated with adrenaline at the Royal Hobart Hospital between 1990 and 1998 were caused by *M. pilosula* compared to the 13% caused by honey bee stings. Brown *et al.* (2001) also recorded four deaths from anaphylaxis due to jack jumper stings between 1980 and 1999. McGain and Winkel (2002) recorded six ant-sting related deaths in the whole of Australia for the same period. All of the fatalities occurred as a result of a sting from a species of *Myrmecia*. Five out of these six fatalities occurred in Tasmania (Brown *et al.* 2001; McGain & Winkel 2002). Few studies offer any insight into where and in what circumstances people are stung by the jack jumper. An exception was a study in Victoria that sent questionnaires to 600 residents of four federal electorates. Of the 417 respondents, 112 had reported being stung by ants, with the most being stung by jack jumper ants (66) and bull ants (19). The most common reported circumstances of people receiving a sting were in gardens (34%) and uncleared bush (32%) with most stings were in the leg (61%) and arms (31%) (Douglas *et al.* 1998).

Many Tasmanians live in fear of a jack jumper sting. In 2006, Antallergy.org, a support group aimed at providing ongoing advocacy, support and raising community awareness about the dangers of anaphylaxis from jack jumper stings, ran a petition to be tabled at the Tasmanian parliament to fund more research into a jack jumper vaccine. The petition received an estimated 3000 signatures which constitutes a significant response from a total

Tasmanian population of just over 400,000 (antallergy.org 2007). Clarke (1986) notes a similarly enthusiastic response and high level of concern among the Tasmanian community. In response to a letter published in Tasmanian newspapers, requesting feedback on people's experiences of jack jumper stings, he reported receiving over 200 replies. Clarke (1986) found that generalised reactions to jack jumper stings are widespread in the Tasmanian community and that victims are terrified of receiving further jack jumper stings.

Despite the dearth of published material on the biology or ecology of *M. pilosula*, there have been a number of research papers regarding the allergenic properties of the species' venom (Davies 2004; Gilhotra & Brown 2006; Inagaki *et al.* 2004; King 1998; Wiese 2006; Wiese *et al.* 2007; Wu 1998; Zelezetsky *et al.* 2005). Like stings from other species of the order Hymenoptera, a *M. pilosula* sting results in burning, swelling and a severe itch that usually subsides within six hours (Hodgson 1997; Steen *et al.* 2005). In sensitised victims, the reaction can be a lot worse. *M. pilosula* venom contains a much larger amount of histamine than bee venom, increasing the risk of severe swelling (Hodgson 1997; Matuszek *et al.* 1992).

Clearly, jack jumper stings present a real threat to the Tasmanian population as well causing real anxiety amongst many in the community. There is therefore a need for research into ways to reduce that threat.

1.4 Treatment and prevention – a brief review

1.4.1 Adrenaline and other medications

At present, a dose of epinephrine (adrenaline) immediately following a sting is the safest, most effective and most accessible treatment for severe allergic reactions to jack jumper venom. People known to be at risk of developing a severe allergic reaction to a Hymenoptera sting should carry epinephrine with them at all times and in circumstances where there is a risk of being stung (Bonifazi *et al.* 2005; Pumphrey 2000). There are risks associated with epinephrine use. Overdosing with epinephrine is potentially fatal and some patients, such as those with cardiovascular or cerebrovascular disease, are at increased risk of adverse reactions. In recently reviewed data from 164 cases in the UK from 1992 to 1998, epinephrine overdose was considered the most likely cause of death in 3 of the 164 cases (Bonifazi *et al.* 2005; Pumphrey 2000). Despite these risks, the benefits are thought to considerably outweigh the risks (Bonifazi *et al.* 2005). Other drugs such as sympathomimetics, antihistamines and corticosteroids can be used as emergency treatments following a hymenoptera sting; however, the efficacy of these drugs is unknown (Bonifazi *et al.* 2005).

1.4.2 Venom immunotherapy (VIT)

One avenue for reducing the risk of an allergic reaction from a hymenoptera sting is a technique called venom immunotherapy. This treatment is thought to be an effective way of treating specific bee, wasp or ant stings (Brown *et al.* 2004). The technique involves administering increasing amounts of the specific Hymenoptera (in this case *M. pilosula*) venom so that the patient builds a tolerance to the venom (Steen *et al.* 2004; Warrell 2003). The time required to reach the adequate maintenance dose is typically several weeks or months. More intensive treatment can also produce immunity, though at a less effective level. Once an adequate level of immunity is reached, the treatment needs to be maintained (Bonifazi *et al.* 2005). The efficacy of venom immunotherapy in the case of jack jumper stings has been established in robust clinical trials by Brown *et al.* at the Royal Hobart Hospital in 2003 (Brown *et al.* 2003b). In those known to experience severe allergic reactions, immunotherapy has shown to reduce the likelihood of systemic reaction from 72% to 3% (Brown & Heddle 2003).

Despite the clinical efficacy of venom immunotherapy, this treatment has practical weaknesses that may make it unviable. The therapy needs large amounts of jack jumper venom which requires large populations of *M. pilosula* to be accessible, most likely as captive populations. The cost and logistics of maintaining such a captive population of jack jumpers and large stores of venom, coupled with the small market of people requiring the treatment, means that venom immunotherapy will probably remain an expensive and impractical method of treatment and is unlikely to become widely available (Brown & Heddle 2003).

1.4.3 Prevention

There are no recommended preventative measures specific to jack-jumper ants; however, Bonifazi *et al.* (2005) have recommended techniques for avoiding Hymenoptera stings in general. These include being careful when eating and drinking outdoors, not walking barefoot, wearing protective garments when gardening and picking fruit, not staying close to beehives while honey is being collected, and not removing vespid (wasp) nests (Bonifazi *et al.* 2005). It is important to remember that stinging is a self-defence mechanism for Hymenoptera – i.e., they will only sting something that they perceive to be a threat - and understanding this principle will help humans avoid being stung (Gauld & Bolton 1996). As discussed above, this principle of avoidance has not been investigated with regard to jack jumper ants. Hence, there is a great need for research into where the ant and its nests are likely to occur in order to help allergy sufferers avoid being stung.

1.5 Research aims

The aims of this study are 1) to test whether there are consistent differences in the attributes of occupied habitat compared to unoccupied habitat of the jack jumper ant; 2) to understand the environments in which humans might encounter jack jumper ants and 3) to use the results to develop recommendations for people wishing to minimise their exposure to these ants.

1.6 Overview of the study

Chapter 1 has given an introduction to the problem of jack jumper sting allergy in Australia, particularly in Hobart. Chapter 2 summarises the body of knowledge of the biology and ecology of *Myrmecia pilosula* and then goes on to discuss some relevant habitat studies on other ant species. Chapter 3, the research design chapter, introduces the study area and outlines the two main methods used to address the questions in chapter 2: a nest survey and a properties survey. Chapter 4 presents the results of the two studies in the form of graphs, tables, maps and a simple narrative. Chapter 5 discusses the results in relation to the questions set out in chapter 2. It then goes on to provide recommendations for those wishing to avoid a confrontation with a *M. pilosula* ant, possibilities for future research and finally draws conclusions in response to the key research questions.

2 Background

The following will outline the existing knowledge of *Myrmecia pilosula* to investigate where gaps in this knowledge occur in order to address the research aims of this thesis. This will be followed by a summary of the biology and ecology of the ant as background, providing context for the study through an understanding of the species. This chapter will then investigate existing research into the habitat preference of ants in general, in order to offer directions and clues to help address the research aims of the project. At the end of the chapter, a number of questions and hypotheses will be stated that will direct the research project.

2.1 Previous work on *Myrmecia pilosula*

Despite the infamy of the jack jumper ant, little work has been published regarding the biology or ecology of the species. *M. pilosula* was first described in 1858 by F. Smith of the British Museum from specimens collected near Hobart (Smith 1858). Noting the ant to be 'covered with a fine, short, silky, ashy pile' (Smith 1858, p. 146), he named the species *M. pilosula* utilising the word 'pilose' meaning 'covered with hair, especially soft hair' (Atkinson & Moore 2006, p. 914). A century later, Haskins and Haskins (1950) published the results of three years of observational study of all the known *Myrmecia* species and offered the first detailed study of the genus, including observational studies of *M. pilosula*. Later papers extended understanding of the biology of the genus (Haskins & Haskins 1955, 1980). Around the same time, Clark (1951), published volume 1 of 'The Formicidae of Australia' which addressed the phylogeny and descriptions of all the known species of the subfamily Myrmeciinae, including *M. pilosula*. A number of papers were then published regarding the biology of various *Myrmecia* species. In the work, Gray (1971b, 1971a, 1974b, 1974a) published a number of papers outlining *M.pilosula* nest structure as well as general observations about the *Myrmecia* species.

In 1986, it was discovered that, what was previously thought a single taxon called *M. pilosula,* was in fact a number of karyotypically distinct sibling species (Crosland & Crozier 1986; Crosland *et al.* 1988b). In 1986, Crosland and Crozier found a colony of chromosome number $n = 1$ *M. pilosula*, which they claimed was a new species. This new species, subsequently described as *M. croslandi* (Taylor 1991), is the only known species in the animal phyla above a nematode with $n = 1$ (Crosland & Crozier 1986; Taylor 1991). Since then, a number of *M. pilosula* sibling species have been discovered with different chromosome numbers ($2n = 2$ to $2n = 84$). This range of chromosome numbers spans almost that of the whole Hymenoptera order (apart from *Nothomyrmecia macrops* $2n = 94$)

(Ogata & Taylor 1991). For the purposes of this thesis, I will refer to the *M. pilosula* species group, as discovered by Crosland and Crozier, as a single species; *M. pilosula.*

Following this discovery, Crosland and Crozier (Crosland *et al.* 1988b; Crosland *et al.* 1988a) expanded their genetic studies on *M. pilosula,* by publishing details of *M. pilosula* nest rearing in a laboratory context (Crosland *et al.* 1988a).

Much of the understanding of *Myrmecia* species, including *M.pilosula,* and indeed of all ant species, was comprehensively summarised by Holldobler & Wilson (1990). Ogata & Taylor (1991) reviewed the genus *Myrmecia* including the *M. pilosula* group which they found to contain at least 15 species. *M. pilosula* is mentioned in guidebooks by both Andersen (1991) and Shattuck (1999, 2007) but they offer little in the way of new insights about the biology or ecology of the ant.

For those who wish to find general information and photographs of *M. pilosula*, there are a number of websites dedicated to ants. Australian Ants Online (Shattuck 2007) is a useful source that compliments and mirrors Shattuck's *Australian Ants: their biology and identification* (Shattuck 1999). Antallergy.org (2007) and the South Australian Museum (McArthur 1999) offer general information regarding the ant and the potential dangers of a sting. A key resource for photographs of all ant species, including some high quality images of *M. pilosula* is provided on Myrmecos.net (Wild 2005).

Although the information on *M. pilosula* is sparse, more work has been completed on other species of the genus *Myrmecia*. Morphologically and behaviourally, species in the genus *Myrmecia* are considered relatively similar (Andersen 1991). Therefore, studies of other species of the genus have contributed a large part of the biological and ecological understanding of *M. pilosula.* Much of the following background information about *M. pilosula* is developed from that understanding.

2.2 Biology and Ecology of *Myrmecia pilosula*

2.2.1 Phylogeny of *Myrmecia pilosula*

M. pilosula is a member of the formicid sub-family Myrmeciinae that contains two tribes, Myrmeciini and Prionomyrmecini. The tribe Myrmeciini contains the two most primitive ant genera: *Myrmecia* and *Nothomyrmecia* (Ward & Brady 2003). Species of *Myrmecia* are commonly known as bulldog and jack jumper ants. All 89 species in the genus, excluding one in found New Caledonia, *M. apicalis,* are native to Australia. They are widespread in Australia especially in the east and south (Figure 2.1) (Ogata & Taylor 1991; Shattuck 1999).

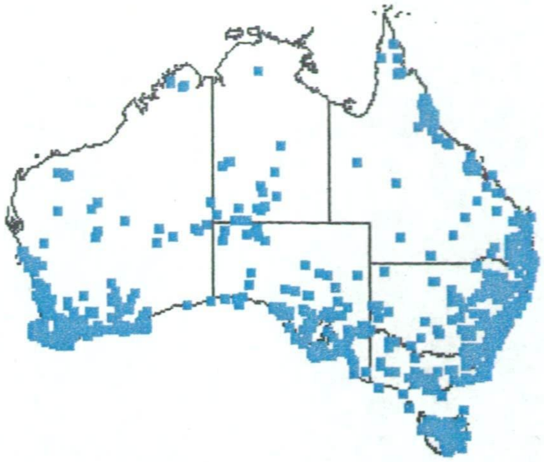


Figure 2.1: Collection sites for *Myrmecia* species (Shattuck 2007).

2.2.2 Evolutionary history of *Myrmecia pilosula*

By the Oligocene (25 to 40 million years ago), ants had proliferated worldwide to become one of the most abundant insect groups. Ants are closely related to bees, wasps, solitary wasps and a few lesser known groups and these groups make up the sub-division of Hymenoptera known as 'Aculeata' (the stinging Hymenoptera) (Gauld & Bolton 1996). *Myrmecia* are among the most primitive of ants and are believed to have once had a much wider global distribution than today (Andersen 1991). Using a combination of morphological and molecular data, Ward & Brady (2003) concluded that Myrmeciine ants were previously more widespread than their current distribution, existing in Europe, South America and Africa. They hypothesised that Myrmeciinae arose in Gondwana in the late Mesozoic, becoming isolated on different southern continents by plate tectonics and that the most recent common ancestor of the group existed between 51 and 101 million years ago. They also hypothesised, in the absence of fossil specimens, that Myrmeciinae had a foothold in Africa in the late Cretaceous or early Tertiary (Ward & Brady 2003).

The retained primitive behaviours of the genus, such as solitary foraging, a lack of recruitment of nest -mates to food sources, and primitive suite of chemical communications have led some to believe that the *Myrmecia* genus is competitively disadvantaged in comparison to other more advanced ant genera, resulting in its current limited distribution (Holldobler & Wilson 1990; Ward & Brady 2003). *Myrmecia,* including *M. pilosula,* are most abundant in the southern parts of Australia. This may be due to a preference for a colder climate or an intolerance of tropical climates; however, it may also be due to the presence of competitively aggressive ants, such as *Oecophylla*, in tropical climes that have entered Australia in the last 20 million years (Ward & Brady 2003).

2.2.3 Morphology of *Myrmecia pilosula*

Morphologically, *M. pilosula* is very similar to other *Myrmecia* species which are easily recognised by their large eyes and elongated mandibles with inner margins bearing saw-like teeth (Figure 2.2) (Andersen 1991; Shattuck 1999). They are some of the largest ants in Australia (Shattuck 1999). *M. pilosula* is black in colour apart from its orange mandibles, legs and antennae (Figure 2.3). It is by far the most common 'jumper ant' and can be distinguished from larger bull-ants by its smaller size and its characteristic jerky leaps (Andersen 1991).

Figure 2.2: *M. pilosula* head showcasing large eyes and mandibles (Photograph: Felix Wilson)

Figure 2.3: *M. pilosula* workers (Photograph: Felix Wilson)

2.2.4 The colony life cycle

The life-cycle of *Myrmecia* is typical of most ants (Figure 2.4). The cycle starts when winged queens and males (known as alates) leave the colony to search for a mate in a nuptial flight. A common meeting point such as a tall tree or hilltop is chosen, and most of the alate ants in the area meet to mate (Shattuck 1999). Once mated, the queen searches for a suitable nest site (Shattuck 1999). Nuptial flight events for *M. pilosula* are not well documented; however, Crosland *et al.* (1988a) observed an unspecified *Myrmecia* species nuptial flight in 1986. The meeting occurred at the top of a 50 m high hillock, the highest peak for 7 km around. This account is consistent with Froggatt (Froggatt 1916 in Crosland *et al.* 1988a, p. 307) who described a flight taking place on a hillock 100m above the surrounding country. Whilst undertaking my research, I witnessed a *M. pilosula* nuptial flight at the pinnacle of Mt. Field West, around 100 kilometres from Hobart, at 1434 metres in altitude. The event was observed at around 1500 hrs in mid February and the temperature was around 20°C with a mild breeze. Male and queen Jack jumper ants were observed at the very pinnacle of the mountain and did not wander far. Queens were observed to be pursued by several males at a time (Figure 2.5).

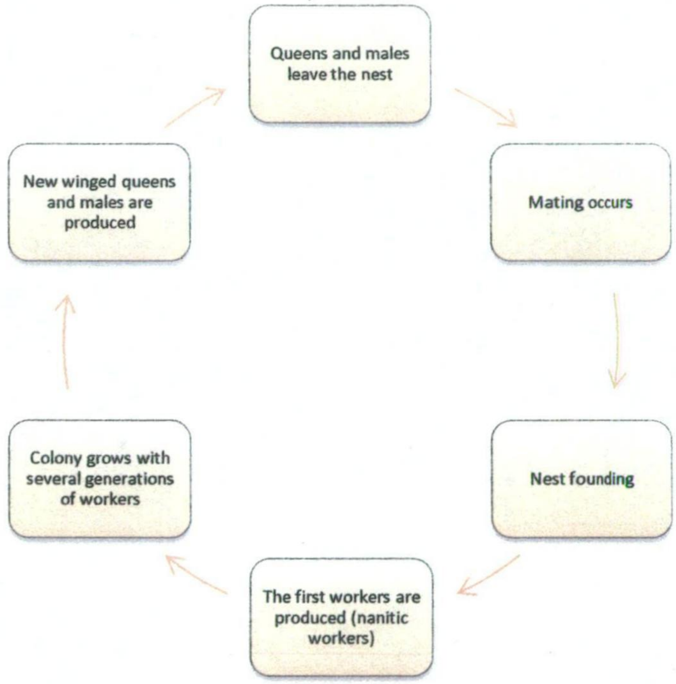


Figure 2.4: The typical life-cycle of ant colony (Shattuck 2007)

Figure 2.5: A nuptial flight event at the top of Mt. Field West, Tasmania (Photograph: Iain Mackay)

Once the queen chooses a nest site, usually in the ground, she constructs a cell (Haskins & Haskins 1950). Following her establishment in the cell, the queen sheds her wings and lays a number of eggs which hatch into her first young. Unlike many of the less primitive ant species, queens of *Myrmecia* do not permanently close the cell. In contrast, in a condition known as *partially claustral colony founding*, the queen forages from her cell for food (Haskins & Haskins 1950; Holldobler & Wilson 1990; Wheeler 1932). She fetches food such as insect prey for the young until they are old enough to fetch it for themselves (Haskins & Haskins 1955; Shattuck 1999; Wheeler 1932). Once the initial young, called nanitic workers (Shattuck 1999), have grown enough to leave the nest, they forage outside to help feed the young (Haskins & Haskins 1955). In some ant species, usually the more primitive ant genera where workers have retained functional ovaries, worker- laid eggs (trophic eggs) are used to feed larvae, the queen and less commonly, other workers. Freeland (1958) observed this in both *M.gulosa* and *M.forceps,* but it is uncertain whether this occurs for *M.pilosula*. As the colony matures and there are enough workers to take over foraging duties from the queen completely, she ceases to forage altogether, receiving her food by the workers via regurgitation or insect prey transported into the nest for her (Haskins & Haskins 1955; Shattuck 1999). As the colony matures, it begins to produce fertile winged females and males (alates) at certain times of the year (Shattuck 1999). These winged females and males then leave the nest for their nuptial flight.

A laboratory study of 6 individual ants by suggests that *M. pilosula* can live for up to 1 year and 7 months, but on average live 1 year and 4 months (Haskins & Haskins 1980; Holldobler & Wilson 1990).

2.2.5 Life in the colony

Ant colonies are almost exclusively female societies with the few males remaining in the nest until they leave on the nuptial flight to find mates (Holldobler & Wilson 1990). A typical ant colony consists of an egg-laying queen, many adult workers and the brood (eggs, larvae and pupae) (Shattuck 1999). The most numerous ants by far are the workers, which are sterile females. These tend to the brood and the queen, and maintain, construct and defend the nest (Shattuck 1999). This arrangement is typical of *M. pilosula*; however, Haskins & Haskins (1950) discovered that *M. pilosula* frequently had up to seven fertile females in each colony. Myrmeciinae show typical age polyethism, meaning that the younger workers attend to the brood and queen, the older workers to nest work and the oldest workers to foraging (Freeland 1958; Holldobler & Wilson 1990).

The colony size of ant species can range from 20 to 700,000 individuals. *Myrmecia* species are considered to have small colonies of up to 1000 and many colonies do not exceed 200 (Gray 1974a; Haskins & Haskins 1950; Higashi & Peeters 1990; Holldobler & Wilson 1990). Gray (1974a) excavated four *M.pilosula* nests with ant populations ranging from 34 to 344 ants.

2.2.6 Recruitment

Myrmecia workers are not known to use pheromones to recruit nest-mates to a food source. However, *Myrmecia* workers are known to transport aged and ailing individuals, callow workers, nest queens, and males to a food source. In this energy intensive recruitment behaviour, the worker faces the nest-mate, seizes her by the mandibles or antennae and drags her over the ground. The transported worker appears not to cooperate in any way (Holldobler & Wilson 1990).

No observations are published regarding the alarm pheromones of *M.pilosula;* however, *M.gulosa* is known to induce territorial alarm by using pheromones from three sources: an alerting substance from the rectal sack, an activating pheromone from the Dufour's gland, and an attack pheromone from the mandibular glands (Robertson, 1971 in Holldobler & Wilson 1990, p. 249). This may be similar in the case of *M.pilosula* and, if so, would account for the species' ability to attack *en masse* to defend the nest. Frehland *et al.* (1985) discovered a visual alarm behaviour in *Myrmecia* ants. He found that a small number of 'sentinel' workers distribute themselves within a few square metres around the undisturbed nest. If one of these ants was disturbed it began a frantic, erratic run. Once another of these 'sentinals' was sighted the original worker feigned an attack. The second worker, meanwhile, began its own erratic run. This pattern was observed to go on until one of the 'sentinals' reached the nest and was then able to recruit more nest-mates who subsequently attacked in numbers.

2.2.7 Foraging

Myrmecia species are classed by Andersen (1995, p. 17) as 'specialist predators'. They have acute predatory skills and rely on visual and tactile cues to prey on a wide variety of insects and spiders (Gray 1971b, 1971a; Holldobler & Wilson 1990). Gray (1971a) discovered that *Myrmecia* forage on different species of prey, appearing to have evolved distinct food preferences to reduce competition. This may be the case with *M. pilosula;* however, no studies exist to test this conclusion. As well as predating on insects, *Myrmecia* species visit extrafloral nectaries to retrieve sugary secretions including the leaves of *Acacia mearnsii* (Holldobler & Wilson 1990). Gray (1971a) watched one *M.desertorum* worker forage for nectar and prey for 80 minutes, meticulously searching every leaf. He noted that the workers of *M.desertorum* and *M.dispar*, when leaving the nest, headed straight for a tree to forage (Gray 1971a). He also noted that *Myrmecia* workers can travel up to 70 m in one hour and some travel up 150 m from the nest. Every ant species has its own distinctive daily schedule for foraging (Holldobler & Wilson 1990). The exact time of day (or night) at which *M. pilosula* forage is unknown although it is suspected that like other *Myrmecia* species, *M. pilosula* are known to forage until dusk (Holldobler & Wilson 1990).

2.2.8 Pollination

Ants play only a minor role in pollination of plants despite their ubiquity (Holldobler & Wilson 1990). It is not known whether *M. pilosula* contributes to plant pollination; however, Peakall *et al.* (1987) discovered occasional pollination of the orchid *Leporella fimbriata* by male *M. urens,* which mistake the flower for virgin queens, thereby picking up and transporting pollenia in the process.

2.3 The preferred habitat of *Myrmecia pilosula*

The only published material available regarding the preferred habitat of *M. pilosula* is notes and diagrams of the structure of the nest of the ant. Gray (1974a) found that the nest structure for most *Myrmecia* species including *M. pilosula* usually takes one of two common forms: a simple nest structure and a complex nest structure (Figure 2.6). Of the 56 *Myrmecia* nests documented, 4 were *M. pilosula* nests. He concluded that all *Myrmecia,* except *M. mjobergi* which nest in trees, nest in the ground and the nests of the smaller species, including *M. pilosula,* typically have smaller mounds camouflaged by leaf litter, debris and grass but sometimes do not have mounds. He noted that two of the nests reached 15cm below ground and one 33cm. The 'diffuse' structure described for species including *M.pilosula* consisted of two or more main shafts with linking chambers interconnected with galleries. He commented that *M. pilosula* nests can vary considerably from one region to another. Clark (1925 in Gray 1974a, p. 110) described *Myrmecia* nests as usually going down two feet vertically with pockets towards the top and down the shaft, terminating in a large chamber. In *M. frogatti,* the nest has a vertical unbranched shaft that connects 6 to 12 chambers down to 80-145cm (Ito *et al.* 1994).

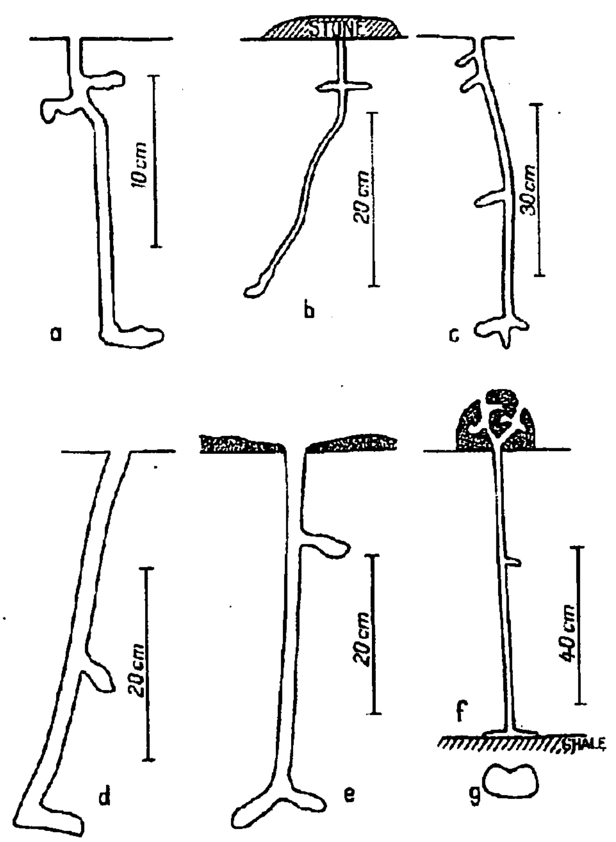


Fig. 1. — *Young nest of: a)* Myrmecia varians; *b)* Myrmecia dixoni; *c)* Myrmecia froggatti; *d)* Myrmecia nigriceps; *e)* Myrmecia desertorum *with mound; f)* Myrmecia gulosa *with mound; g) dorsal view of chamber at bottom of nest of* Myrmecia gulosa.

Figure 2.6: *Myrmecia* nest hand drawings by Gray (Gray 1974a, p. 111)

Myrmecia species often share their nest with other ant species. In Gray's (1974b) study of the fauna associated with nests of *Myrmecia,* he discovered that other ant species, usually of smaller species had set up colonies in the nest. For example, *Iridomyrmex anceps* are thought to prey on *Myrmecia* eggs, larvae and pupae in the nest.

As discussed earlier, the jack jumper ant is infamous around Hobart. When conducting the research, I was involved in many conversations with people around Hobart, most, if not all, with an opinion about the jack jumper ant. There are many opinions about the habitat and distribution of the ant too. It is worth noting some of these observations, particularly when they come from sources who might be considered 'experts' on jack jumpers. A/Prof. Simon Brown, the head researcher of the jack jumper immunotherapy program, asserts that wherever there is native bush around Hobart, the jack jumper resides, and also that it can inhabit non-native vegetation in certain circumstances. He also believes they exist in all suburbs around Hobart (Brown 2008, pers. comm.). Maria Fletcher, of Antallergy.org, also believes they are widespread, but notes that she experiences them much less living in Fern Tree, a suburb at the foot of Mt. Wellington, than she has done in other suburbs around Hobart. Maria also emphasises the need to know where the ant resides in Hobart (Fletcher 2007, pers. comm.). Entomologist and ecologist Dr. Peter McQuillan disputes the claim that they can be found in all suburbs but does concur with that the ant can inhabit areas with non-native bush (McQuillan 2008a, pers. comm.). He also notes that the ants can nest under paving stones and in cracks of concrete (McQuillan 2007a, pers. comm.). In preliminary observations, I have observed that nests are frequently found on the edge of paths, an observation confirmed by many of my colleagues. However, ecologist and botanist Prof. Jamie Kirkpatrick states that he has observed nests in native bush as much as on the sides of paths (Kirkpatrick 2007, pers. comm.). There is clearly a need for evidence-based answers as to whether the jack jumper ant is as widespread as some believe and whether it is attracted to the edges of paths.

2.4 Habitat preference of other ant species

Since no comprehensive study of the habitat of *M. pilosula* is available, other than the simple nest observations described above, a review of other species of ants' habitat preference might shed light on the relationship between habitat features and occupation by *M. pilosula*. There have been a number of studies looking into ant diversity along various gradients including elevation, precipitation and vegetation type. Although these studies emphasise a conservation of biodiversity viewpoint, they do offer insights into general habitat –ant relationships.

2.4.1 Ants, vegetation and moisture

Changes in vegetation can affect ant assemblages. Indeed, vegetation can be an indication of a change of altitude, water availability and soil fertility (Reid *et al.* 1999). Certain ant species prefer certain vegetation types. Vegetation structure is often a factor that affects ant populations (Vasconcelos *et al.* 2008). It is a major regulator of microclimatic conditions which influences ant activity. It also affects the availability of food and nesting sites for ants as well as the competitive interactions between species. It follows that changes in the abundance of dominant ant species, mediated by changes in vegetation structure, can have major impacts on ant assemblages (Vasconcelos *et al.* 2008).

Ants are not only affected by the vegetation type, but they also affect the vegetation and environment that they inhabit. They participate in many ecosystem processes and can have an enormous impact on soil characteristics, vegetation and other organisms in the community (Holldobler & Wilson 1990; Osorio-Perez *et al.* 2007). They can improve conditions for plant growth by exposing nutrients and minerals, mixing soil, improving soil aeration as well as increasing water drainage. Ants can also have a significant detrimental effect to the plants around the nest influencing the spatial distribution of nutrients (Holldobler & Wilson 1990; Osorio-Perez *et al.* 2007; Torres *et al.* 1999).

There are several studies that showcase the relationship between vegetation and ants. In their study in the Spring Mountains, Nevada, USA, Sanders, Moss and Wagner (2003) found that major changes in identity of ant species present along elevation gradients coincided with changes in the dominant vegetation. Morrison (1998) found in a study of island populations of ant in the Bahamas that certain species of ants were positively related to different variables. For example, *Dorymyrmex pyramicus* was positively related to vegetation and elevation, whereas *Pheidole punctatissima* was positively related to plant species number (Morrison 1998). Lassau and Hochuli (2004) investigated the responses of habitat complexity in undisturbed habitats on Sydney sandstone ridge-top woodland. They found that habitat complexity affected ant species richness. Ant species richness was negatively associated with herb cover, tree canopy cover, soil moisture and leaf litter (Lassau & Hochuli 2004).

Vegetation structure, in particular has been shown to influence ant assemblages. Retana and Xim (2000), in a study of an ant community in the Spanish Mediterranean area, found that vegetation cover resulted in an increase in the abundance of the most common species. In more open habitats, dominant and subordinate species were abundant during different periods of the day. In areas with high vegetation cover, dominants benefited from lower temperatures and their period of activity was lengthened. Botes *et al.*(2006), in a study in the Western Cape, South Africa, used pitfall trapping to sample ants at altitudinal bands stretching over three vegetation types. Some species of ant were shown to vary according to vegetation variables and others according to temperature variables. In their study of the ant species of a Brazilian savanna, Vasconcelos *et al.* (2008) found that variations in tree cover and cover by tall grasses significantly affected ant species composition.

In a study of ant abundance along a moisture gradient in a Panamanian rainforest, Kaspari and Weiser (2000) found that ant activity increased during the wet season than the dry season. Although this does not indicate that jack jumpers will prefer moister environments, it does indicate that wetness (or dryness) could be a key feature of preferred habitats for the ant.

2.4.2 Ants and altitude

There are a number of studies that trace ant diversity patterns along elevational gradients. In a study of the abundance of foraging ants with a change in forest characteristics in Connecticut, Weseloh (1995) found that ant abundance was less at high altitudes and in moister sites. In a study of ant abundance along an elevational gradient in a tropical rainforest in the Philippines, Samson, Rickart and Gonzales (1997) found that ants were extremely rare above 1500 metres and greater in diversity at lower altitudes. Fisher (1999), in a survey of ant species along an elevational gradient in a protected area in Madagascar found that species richness peaked at mid-elevation. Sanders, Moss and Wagner (2003) in their study along elevation gradients in an arid ecosystem also found that species richness peaked at mid-elevation. Closer to home, Majer *et al.* (2001) described ant assemblages sampled from rain forest canopies ranging from southern Victoria through to Cape York Peninsula, Australia, and also in Brunei. They found that species richness was negatively correlated with latitude and elevation. Altitude is related to temperature and ants are considered to be poor thermoregulators, that is, they are strongly thermophilic (Holldobler & Wilson 1990). Apart from a very few cold-temperate species such as *Nothmyrmecia macrops* and *Prenolepis imparis,* they function poorly below 20°C and not at all below 10°C (Holldobler & Wilson 1990). These demonstrations of the response of ants to elevation indicate that *M. pilosula* might have a preferred elevational range.

2.4.3 Ants, disturbance and urbanisation

The effect of certain types of disturbance, such as grazing, burning, mining, plantations, and farming, on ant communities is well known (Andersen *et al.* 2004; Andrew *et al.* 2000; Armbrecht *et al.* 2005; Hoffmann & Andersen 2003; Schnell *et al.* 2003; York 2000). Ant monitoring has been used in a variety of land use situations to monitor ecosystem health, including mining impacts (Hoffmann *et al.* 2000; Read 1996; Read & Pickering 1999), conservation assessment (Clay & Schneider 2000), grazing impacts (Woinarski *et al.* 2002) and forest management (Neumann 1992; Vanderwoude *et al.* 2000). Ants have been split into functional groups to provide a framework to analyse disturbance by ant community responses (Andersen 1995; Andersen *et al.* 2004; Andersen *et al.* 2002). Responses of individual species varies with disturbance type and intensity, but groups of species can be identified as 'increasers' or 'decreasers' in relation to disturbance (Andersen *et al.* 2004). Also, ant species richness has been found to increase with increased time from disturbance (Majer 1983; Majer & Brown 1986). *Myrmecia* have been found to be 'decreasers' with increasing disturbance (Hoffmann & Andersen 2003). They are known to decrease with increased agriculture (Hoffmann & Andersen 2003) and are typically the last ants to colonise mine sites undergoing rehabilitation. However, in all of these studies, *M. pilosula* occurrence is low, resulting in insufficient numbers collected for any meaningful statistical analyses (Hoffmann & Andersen 2003).

In human dominated environments, invertebrate diversity and abundance is thought to be aided by patches of habitat and proximity to natural habitat (Blair & Launer 1997; Bolger *et al.* 2000; Dickman 1987; Eversham *et al.* 1996; Hardy & Dennis 1999). In a study of the ant fauna of urbanised areas in Perth, Australia, Majer and Brown (1986) found that ant species richness was significantly lower in gardens than in native vegetation. However, some species were more common in gardens than in the native bush and species richness increased with the age of the garden, litter cover and garden area. Gardens where pesticides were used, tall shrubs were dense and management including intense watering had a low number of ant species. Their findings for *Myrmecia* species were that they decreased with urbanisation, with the reasons discussed being the ants' poor ability to recolonise coupled with the attempts of the householders to eradicate these larger and more conspicuous species.

2.5 Nest architecture studies

The nests of ants do not receive the same amount of attention in comparison to the nests of other social insects (Tschinkel 2004). The methods and materials that worker wasps, termites and bees use to build their nests has been reviewed a number of times (Downing & Jeanne 1988; Seeley 1995; Theraulaz *et al.* 1999; Tschinkel 2004). However, this is not the case for subterranean ants' nests. Reasons for this are more than likely related to their hidden (underground) nature as well as the fact that they are made from excavation of materials rather than construction using materials brought in as is the case for other social insects (Tschinkel 2004). In general, ants nests are thought to be relatively simple in structure with variation in volume, complexity and form being apparent between different species (Diehl-Fleig & Diehl 2007).

Recently, Tschinkel (2004, 2005) has sought to remedy the lack of detailed research into nest architecture by completing some detailed studies. He made casts of a number of *Pogonomyrmex badius* and *Camponotus socius* nests using orthodontal plaster or, at great risk to his socks, molten zinc and aluminium. He found that the nests comprised of two basic units: descending shafts and horizontal chambers. These basic elements combined to produce some spectacular nests. The *C. socius* nests were much smaller in structure than that of *P.badius.*

There have been a number of more recent studies of nest architecture (Diehl-Fleig & Diehl 2007; Forti *et al.* 2007; Verza *et al.* 2007). All studies showed that the ant nests comprised of chambers and shafts. Unfortunately, no nest architecture studies have been completed on any of the species in the Myrmeciinae genus apart from the simple studies by Clark and Gray mentioned earlier (Gray 1971b, 1971a, 1974b, 1974a). More extensive studies would give an insight into what materials *M. pilosula* prefers to nest in.

2.6 Research questions

This chapter established that there is a lack of any habitat preference studies for *M. pilosula*. Yet, the review of habitat studies of ant diversity raised a number of questions which will be investigated in order to address the aims of the project:

Question 1: What environmental conditions do *Myrmecia pilosula* prefer to nest in?

Question 2: What are the characteristics of a typical *Myrmecia pilosula* nest?

Question 3: How does *Myrmecia pilosula* respond to urbanisation?

Question 4: What habitats increase the risk of humans receiving a sting from *Myrmecia pilosula* and how could this risk be reduced?

3 Research Design

This chapter is a summary of the research design and methods used to address the questions in chapter 2. Initially, the study area will be introduced and details relevant to the study, such as vegetation type and geology, will be outlined. Following on from this, the methods used for the project will be summarised. The chapter will end with an outline of the analyses used on the data collected during the study.

3.1 The study area

The problem of the interaction between the jack jumper ant and humans is significant in and around Hobart, the capital city of Tasmania; the island state of Australia. Because of this, and the limited time available for the study, the municipality of Hobart (Figure 3.1) was chosen as the study site.

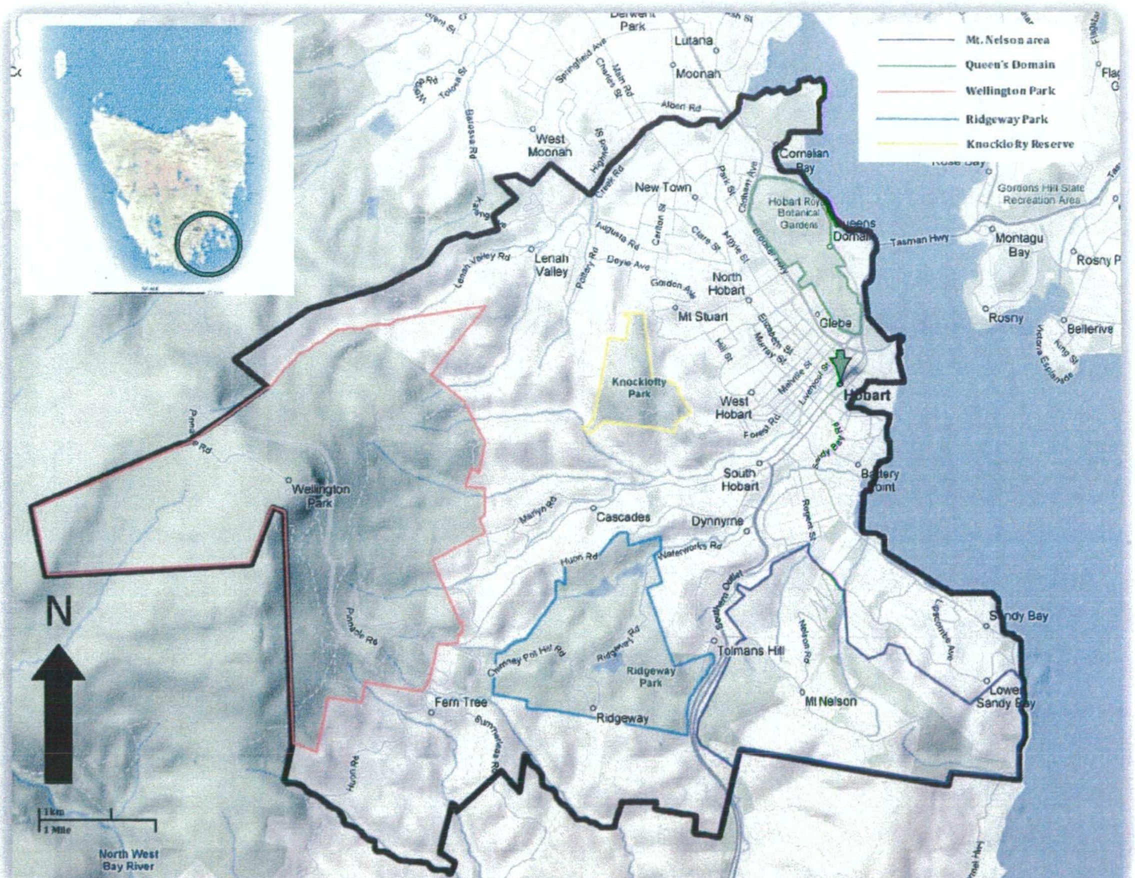


Figure 3.1: Map of Hobart City Council showing habitat survey study areas (black line denotes municipality boundary). Inset - Map of Tasmania with Hobart circled (DPIW Tasmania 2008; Google Maps 2008).

3.1.1 Overview

The Municipality of Hobart (Figure 3.1) extends from the shoreline of the river to the 1271 metre high pinnacle of Mt Wellington (DPIW Tasmania 2005; Hobart City Council 2007). Hobart is located on the western side of the River Derwent and lies within the territory traditionally inhabited by the Nuenonne and Paredarerme indigenous peoples (Atkinson & Moore 2006). The municipality, covering 7790ha, contains a large amount of natural vegetation with 62% of the area (4806ha) considered to be natural bushland (Hobart City Council 2008d), in both private and public ownership (Hobart City Council 2007). Its vegetation is diverse, a result of the range of altitudes and environments within the municipality. The bush extends from the alpine heathlands of Mt Wellington, down the forested foothills, through the suburbs, and into the city itself (Hobart City Council 2007). Many of its suburbs, such as West Hobart and Mt. Nelson often contain patches of remnant natural vegetation between buildings, roads and footpaths.

3.1.2 Climate

Hobart has a maritime climate being located in the mid-latitude westerly wind belt, dominated by southern maritime air masses. The heat absorption and storage by the ocean circling the island provides for mild winters and cool summers (Jackson 1999). Hobart's mean winter minimum and maximum temperatures are 4.6 °C and 11.6 °C, and its mean summer minimum and maximum temperature are 12°C and 21.6°C (Australian Government 2007). As Tasmania sits in the Southern Ocean, Hobart's climate can vary greatly from day to day. Hobart also experiences a lot of local microclimatic changes due to the changes in altitude and the terrain of Mt. Wellington and its foothills. Figure 3.2 indicates how temperatures within Hobart vary by showing the difference in maximum temperatures at two extremes of altitude within the Hobart City Council municipality.

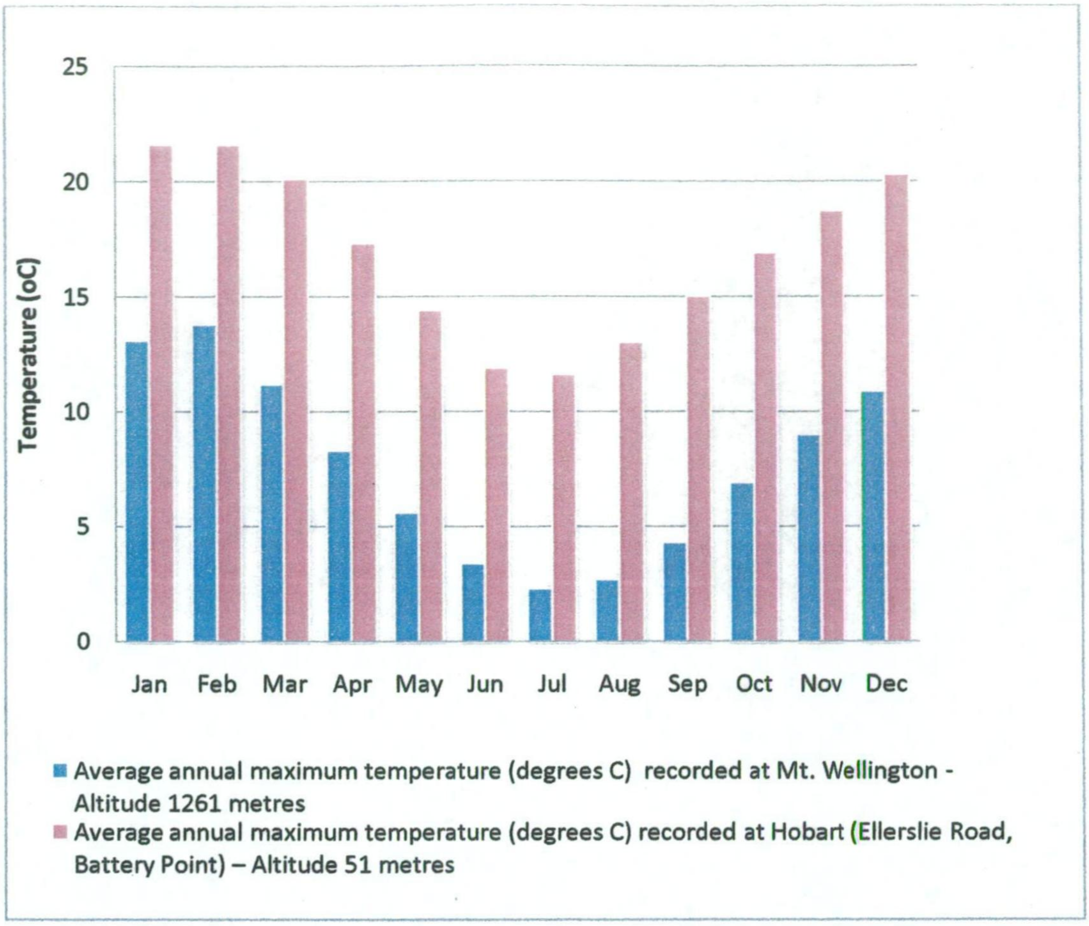


Figure 3.2: Bar chart showing the average maximum temperatures (°C) for Hobart and Mt. Wellington (Australian Bureau of Meteorology 2008a).

Since records began in 1882, Hobart's mean rainfall has been 616.7mm a year with around 86 days a year with over 1mm of rain (Australian Bureau of Meteorology 2008a). As with temperature, rain within Hobart can vary according to location (see Figure 3.3). Snowfalls at sea level are rare, however, falls on the summit of Mt. Wellington are common with snow often settling in winter for long periods of time (Colls 2001; Johnson 1994).

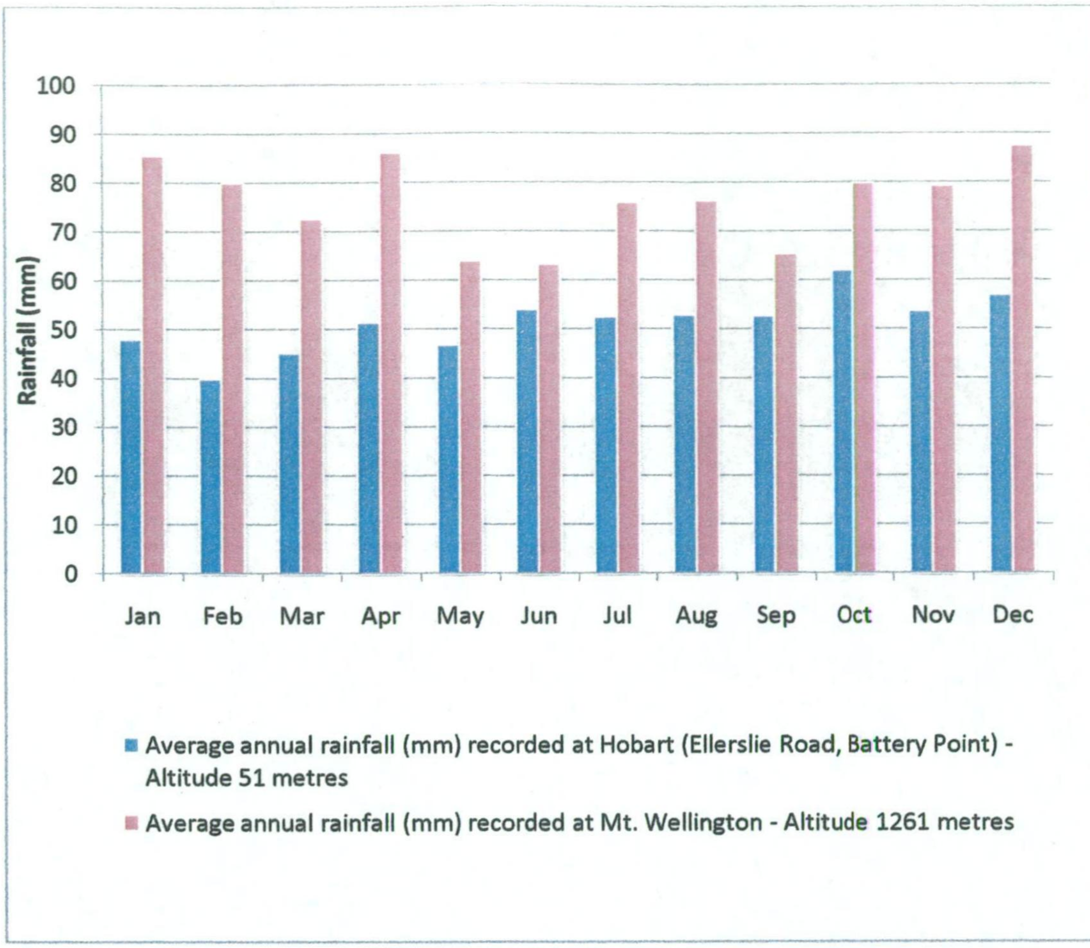


Figure 3.3: Bar chart showing the mean rainfall (mm) for Hobart and Mt. Wellington (Australian Bureau of Meteorology 2008b)

Hobart, at latitude 43° lies near the upper margin of the zonal wind system known as the Roaring Forties (Jackson 1999). Hobart experiences predominantly north-western winds (Australian Bureau of Meteorology 2008b). Because of this, coupled with the effects of solar radiation, north to north-west aspects are the warmest and driest in Hobart (Johnson 1994).

Jurassic dolerite is the most widespread rock around Hobart and indeed Tasmania (Leaman 2002; Spanswick & Kidd 2000). The Hobart area also contains Quarternary sediments and dolerite; Tertiary basalts and sediments; Triassic quartzite sandstones and Permian glaciomarine sediments (Calver *et al.* 2004).

3.2 Study design

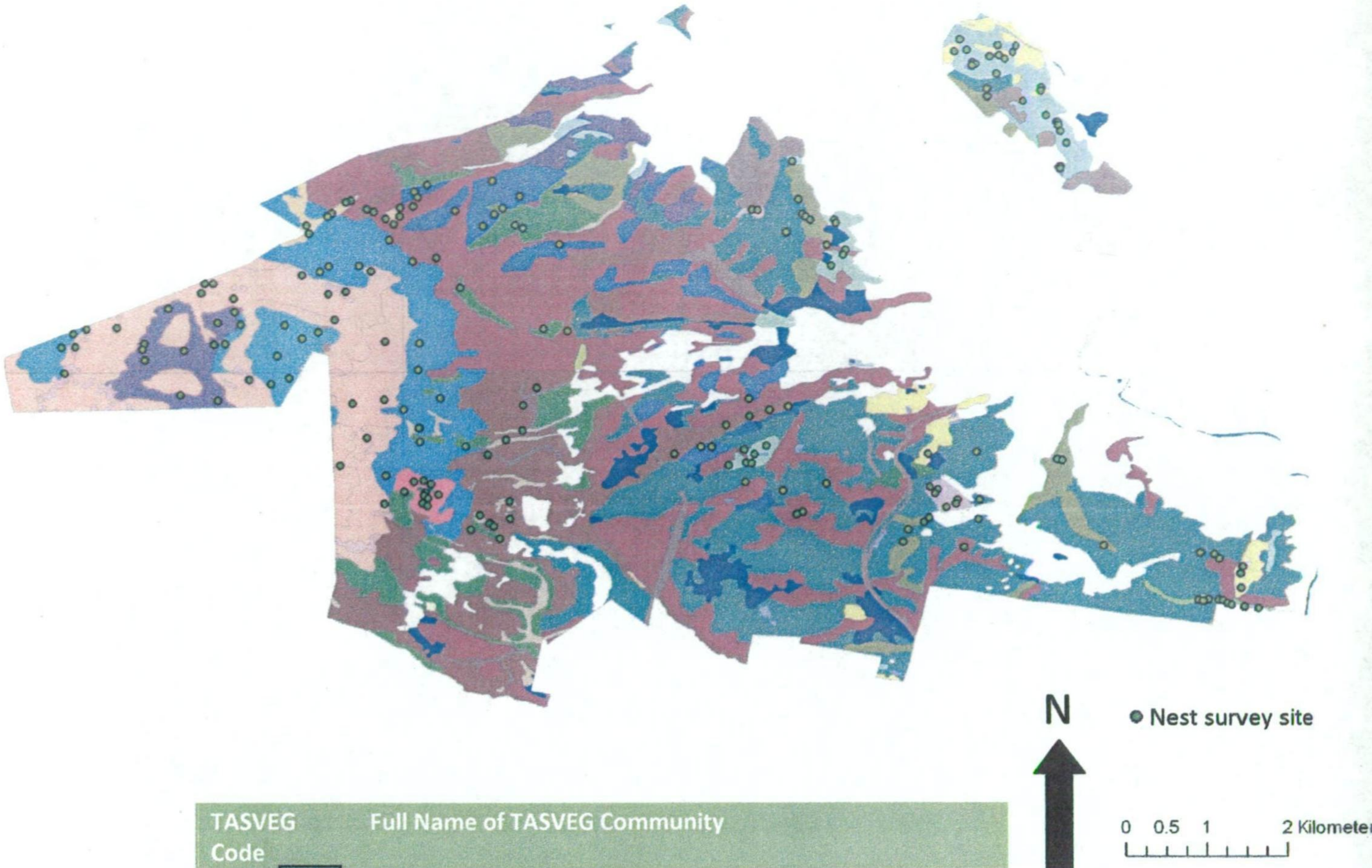
Two tests were designed to answer the research questions posed in chapter 2: a nest survey and a questionnaire based survey of the people of Hobart with special reference to their properties.

3.3 Nest survey

The geology, hydrology, soil, aspect, terrain, altitude and climate all have an effect on plants and each different environment is most favourable to a specific set of vegetation types (Doing 1981; Kruckeberg 2002; Read 1994; Specht 1970). Hobart's diversity of vegetation types range from alpine heathlands to wet sclerophyll forests to native grasslands. This range of vegetation types was chosen, therefore, as a template to select a range of habitat types for this study.

3.3.1 Hobart's bushland

In order to gain access to most of the vegetation types within the Hobart City Council municipality, the public reserves within the area were chosen (Figure 3.1). This negated the need for permission to access private reserves. Within the municipality of Hobart City Council, there are extensive areas of natural bushland. Around 62% of this natural bush is in reserves. Most of these reserves are managed by Hobart City Council (62%, almost 3000 hectares), but there are also state reserves, national reserves and private reserves (Hobart City Council 2007). The following is a summary of the reserves that were used in the habitat survey, including a brief description of the vegetation types, according to TASVEG (Figure 3.4) that fall within the reserves and their significance to the study.



TASVEG Code	Full Name of TASVEG Community
DAS	*Eucalyptus amygdalina* forest and woodland on sandstone
DCO	*Eucalyptus coccifera* forest and woodland
DDE	*Eucalyptus delegatensis* dry forest and woodland
DGL	*Eucalyptus globulus* dry forest and woodland
DOB	*Eucalyptus obliqua* dry forest
DOV	*Eucalyptus ovata* forest and woodland
DPU	*Eucalyptus pulchella* forest and woodland
DTO	*Eucalyptus tenuiramis* forest and woodland on sediments
DVG	*Eucalyptus viminalis* grassy forest and woodland
GTL	Lowland *Themeda triandra* grassland
HUE	Eastern alpine vegetation (undifferentiated)
NAD	*Acacia dealbata* forest
NAV	*Allocasuarina verticillata* forest
NNP	*Notelaea-Pomaderris-Beyeria* forest
ORO	Lichen lithosere
SBR	Broad-leaf scrub
SHS	Subalpine heathland
WOU	*Eucalyptus obliqua* wet forest (undifferentiated)
WRE	*Eucalyptus regnans* forest
WSU	*Eucalyptus subcrenulata* forest and woodland

Figure 3.4: TASVEG map of Hobart City Council Municipality with nest survey sites (green dots)

Base data from theLIST, © State of Tasmania. Projection: UTM, Zone 55. Datum: GDA 94

3.3.1.1 Knocklofty Reserve

Knocklofty reserve, located above West Hobart, is about 126ha in area and is owned and managed by Hobart City Council (North 2001). There is no knowledge of pre-European activities in the park, however, it is more than likely that the site experienced periodic aboriginal burning (North 2001). European settlers used the site as a source of firewood, quarry stone and for rough grazing land (Hobart City Council 2008a). Knocklofty connects the bushland at the foothills of Wellington Park to the centre of Hobart (North 2001). The park is used by dog walkers, joggers, bush walkers, cyclists, and picnickers (Hobart City Council 2008a). Topographically, the reserve is a hill ranging from 120 to 372 metres in elevation, with much of the slopes between 6 and 20 degrees (Brown 1983). A large part of the geology of the reserve is formed by a Jurassic dolerite knoll, with the eastern face of the hill formed from Triassic sandstone. Much of the sandstone has experienced quarrying evidenced by the numerous small and moderately sized borrow pits and larger more recent quarries, although most of these occur just outside the boundaries of the reserve (North 2001). Soils at Knocklofty include podzolic soils on sandstone and dolerite (Spanswick & Kidd 2000).

Knocklofty is dominated by dry sclerophyll and grassy forest, a number of which are considered critical to conservation (Figure 3.5). Most of the reserve is covered in *Eucalyptus pulchella* forest and woodland (TASVEG code - DPU), but there is a small extent of *E. ovata* forest and woodland (DOV) and *E. globulus* forest and woodland (DGL). There is also a small patch of *E. viminalis* grassy forest and woodland (DVG) at the very north of the reserve, as well as *E. amygdalina* forest and woodland on sandstone (DAS) that is interspersed with the quarried Triassic sandstone to the east of the hill (DPIW Tasmania 2008). Jack jumpers are known to occur in the reserve (personal observation), however, there are no studies of the invertebrates that use the area and the various habitats within.

Figure 3.5 (a, b and c): Photographs of the vegetation communities of Knocklofty. From left to right: *E. ovata* woodland, *E. viminalis* woodland and *E. globulus* woodland (photographs: author).

3.3.1.2 Queen's Domain

The Queen's Domain was given to the public in 1860 and is managed by the Hobart City Council. The 170ha site contains the last remnant of Hobart's endemic grassland. It also contains Aboriginal middens, indicating indigenous habitation before the arrival of Europeans. It also contains the Governor's house, the Royal Botanic Gardens (both still crown land), sporting fields and an aquatic centre (Hobart City Council 2008c). The site is used by dog walkers, bush walkers, cyclists, picnickers, for sporting events and also affords good views over the Derwent for those who make the trip to the top of the hill.

The Queen's Domain is a Jurassic dolerite hill with fertile, black, sandy clay-loam gradational soils (Kirkpatrick 2004; Spanswick & Kidd 2000). The hill extends from sea- level to 90 metres (Kirkpatrick 2004).The grasslands, grassy woodland and grassy forest on the Queen's Domain is of very high conservation significance (Kirkpatrick & Blake 1995)(Figure 3.6). The patches of Lowland *Themeda triandra* grassland (GTL) are of significance to conservation as well as being the only site within this study to be grassland. The Queen's Domain also contains the majority of the *E. viminalis* grassy forest and woodland (DVG) and *Allocasuarina verticillata* forest (NAV) within this study. There are no invertebrate studies for the Queen's Domain and it is not known whether the jack jumper ant exists within its boundaries.

Figure 3.6 (a, b and c): Photographs of the vegetation communities of the Queen's Domain. From left to right: Lowland *Themeda triandra* grassland, *Allocasuarina verticillata* forest and *Eucalyptus viminalis* grassy forest and woodland (photographs: author).

3.3.1.3 Mount Nelson

Mount Nelson, one of the foothills of Mt. Wellington and a suburb of Hobart, reaches an altitude of around 270 metres (Calver *et al.* 2004). The suburb contains significant amounts of native bush in both reserves and private land. The area is used by dog walkers, bush walkers, cyclists and picnickers. The area contains a number of separate reserves; the University of Tasmania reserve, the Commonwealth Government run Trugannini Reserve, the Lambert Park Skyline Reserve, and the reserve on the Hobart College grounds (Hobart City Council 2007). There are also a number of private plots of land as well as Porter's Hill that has been recently acquired by Hobart City Council. The Lambert Rivulet is one of the few rivulet systems within Hobart that maintains its native vegetation (Hobart City Council 1998).

Mt Nelson is dominated by *E. pulchella* forest and woodland (DPU), along with *E. globulus* dry forest and woodland (DGL) and *E. obliqua* dry forest (DOB). Vegetation types of significance to this study are the *E. ovata* forest and woodland (DOV) and the only extent of *Notelaea-Pomaderris-Beyeria* forest (NNP), a dry rainforest community, to exist within Hobart City Council (DPIW Tasmania 2008)(Figure 3.7). Mt Nelson is almost entirely underlain by Jurassic dolerite, apart from some patches of contact metamorphosed Permian glaciomarine siltstone and limestone in the Hobart College grounds and Porter Hill and some Quarternary dolerite boulders on Porter Hill (Calver *et al.* 2004; Hobart City Council 1998). As a result of the geology, the soils are fertile black clay soils (Spanswick & Kidd 2000). The area is home to many native invertebrate species including the jack jumper ant and the Mt. Nelson Stag Beetle (*Lissotes basilaris*), which is found only in the Mt Nelson area (Calver *et al.* 2004).

Figure 3.7 (a, b and c): Photographs of the vegetation communities of Mt. Nelson. From left to right: *Notelaea-Pomaderris-Beyeria* forest, Lowland *Themeda triandra* grassland and *E. ovata* forest and woodland (photographs: author).

3.3.1.4 Ridgeway Park

Ridgeway Park is a reserve of natural bushland that protects the source of a major part of Hobart's drinking water. It also contains the Waterworks reservoirs, first constructed in the 1860s to capture the flow of creeks and rivers originating on the higher slopes of Mt Wellington. The park forms another unbroken stretch of natural bush, from the suburbs to Wellington Park (Hobart City Council 2008b). The area is used by bush walkers, mountain cyclists and picnickers. The Waterworks also provides barbecue spots for hire (Hobart City Council 2008b).

Ridgeway park is dominated by *E. pulchella* forest and woodland (DPU) and *E. obliqua* dry forest (DOB) (Figure 3.8). There is, indicating a change in geology, a patch of *E. amygdalina* forest and woodland on sandstone (DAS) as well as, indicating a change in moisture levels, an extent of *E. obliqua* wet forest (WOU) to the north of the reservoirs. The bedrock of

Ridgeway reserve consists mostly of Jurassic dolerite; however, there are significant stretches of Triassic and Permian sediments towards the North West of the park (Calver *et al.* 2004). Soils at Ridgeway are podzolic soils on dolerite and sandstone (Spanswick & Kidd 2000). Although no published material was available describing the invertebrate fauna of Ridgeway, jack jumper ants are known to occur in the park (personal observation).

Figure 3.8 (a, b and c): Photographs of the vegetation communities of Ridgeway Park. From left to right: *E. tenuiramis* forest and woodland on sediments, *E. obliqua* dry forest and *E. pulchella* forest and woodland (photographs: author).

3.3.1.5 Wellington Park

Wellington Park, the biggest of the reserves within the Hobart City Council municipality, contains Mt Wellington (1271metres), which forms the backdrop to Hobart. The park is managed by the Wellington Park Trust, a cooperative body consisting of various land owning and management agencies, including Hobart City Council. The Hobart City Council manages the most eastern part of this large park, where the park falls into the Hobart City Council municipality, whereas the other parts are managed by various other councils (Wellington Park Management Trust 1997, 2005). The park is used for a variety of activities including bushwalking, cycling, picnicking and dog walking.

Wellington Park offers this study the majority of the wet and rainforest vegetation communities and all of the sub-alpine vegetation communities (Figure 3.9). In the gullies of the park there are *Acacia dealbata* forest (NAD) and Broad-leaf shrub (SBR). The south east of the park is dominated by wet vegetation types including *E. regnans* forest (WRE) and the only extent of *E. subcrenulata* forest and woodland (WSU) in the Hobart City Council municipality. Up the slopes of Mt. Wellington there is *E. delegatensis* dry forest and woodland (DDE) and *E. coccifera* forest and woodland (DCO) communities. At the top, the communities include Eastern alpine vegetation (undifferentiated) (HUE) and subalpine heathland (SHS). The park also contains an array of boulder fields classed in TASVEG as lichen lithosere (ORO) (DPIW Tasmania 2008; Leaman 2001). Again, like many of the other reserves, there is no information describing the invertebrate fauna of Wellington Park, however, jack jumper ants are known to occur within its boundaries (personal observation).

Figure 3.9 (a, b and c): Photographs of the vegetation communities of Wellington Park. From left to right: Eastern alpine vegetation (undifferentiated), *E. coccifera* forest and woodland and Lichen lithosere (photographs: author).

3.3.2 Vegetation types

Vegetation types are well mapped in Tasmania by TASVEG, the state-wide map of vegetation communities (Harris & Kitchener 2005). The system was therefore a natural choice as a tool to identify the various vegetation types surveyed in this study of the habitat of the jack jumper ant.

According to the TASVEG classification there are over twenty vegetation types within the Hobart City Council municipality. Figure 3.4 shows the TASVEG map for Hobart City Council and the accompanying legend indicates the vegetation types classified in this system. Appendix I gives a brief description of each of the TASVEG communities in this study. Communities that fall within the Hobart City Council municipality but not within the study areas of Wellington Park, Knocklofty, Mt Nelson, Ridgeway and the Queen's Domain have been omitted from the legend. These communities are 'agricultural land' (FAG), 'permanent easement'(FPE), 'plantations for silviculture' (FPL), 'regenerated cleared land' (FRG), 'extra-urban miscellaneous' (FUM), 'urban areas' (FUR), and 'water, sea' (OAQ). These communities fall beyond the scope of the nest survey as they are not natural vegetation types. The community *E. amygdalina* (DAI) was also omitted because the locations were not within the reserves and therefore not easily accessible.

A haphazard method was used to pick the sites (Figure 3.4), as a truly random sampling method was not possible as particular vegetation types were targeted (Gotelli & Ellison 2004). Spatial biases regarding sites were difficult to avoid when the extent of the vegetation type was restricted to one or two localities. Examples of this are the sites in NNP, WSU, NAD, SBT, and GTL.

3.3.3 Sampling the jack jumper ant

To model the preferred habitat of the jack jumper ant, a simple presence or absence test for ant presence in each vegetation type was chosen. Presence or absence data is preferable to abundance data when modeling habitat preference. Binary information is sufficient to model habitat preference and is less misleading than abundance information which is influenced by many factors other than habitat quality (Matern *et al.* 2007). Searches were made at a total of ten sites per vegetation type which was considered adequate replication (Kirkpatrick 2007, pers. comm.). Ten searches conducted in each of the twenty vegetation types thus yielded sufficient data to test the preferred habitat profiles of the ant at two hundred sites.

There are a number of techniques for surveying terrestrial invertebrates. Baits can be used to assess the presence or absence of a species of invertebrate (New 1998). The principle of baits is that animals are attracted to a specific or sometimes more general chemical stimulus (New 1998). *Myrmecia pilosula* are thought to forage on extrafloral nectaries to retrieve sugary secretions (Holldobler & Wilson 1990), which might indicate that they would be attracted to baits of sugar. However, Greenslade and Greenslade (1971) have commented that some species of invertebrate lack the behavioural flexibility to be attracted to baits. For example, foraging workers of *M. pyriformis,* closely related to *M. pilosula,* ignored baits of sugar in the field, yet laboratory reared *M. pyriformis* did not (Greenslade & Greenslade 1971). Therefore baits were not considered reliable enough to be used in the nest survey.

An alternative to baits and the most commonly used method for collecting ground dwelling arthropods is pitfall trapping (Ward *et al.* 2001). Pitfall traps using preservatives such as alcohol have been used extensively in studies of key groups such as ants, spiders and beetles. They are cheap, easy to carry and to maintain. However, many factors make accurate interpretation of the data from pitfall traps difficult. Catch size and trapping efficiency can vary according to topography, exposure, temperature, moisture and vegetation structure (Melbourne 1999; New 1998). Also, in pitfall trap surveys, *Myrmecia* species rarely occur in large enough numbers for meaningful statistical analysis (Hoffmann & Andersen 2003). In addition, *M. pilosula* are thought to spend a large amount of time foraging in vegetation above ground (Holldobler & Wilson 1990), and could be missed in pitfall catches. Since this survey looked for ants in habitats that vary according to all of the above variables, with an ant that returns unreliable catches using this technique, pit-fall trapping was considered unsuitable.

Direct searching is considered valuable when information is needed on the biology or distribution of invertebrates within a habitat (New 1998). Some ant species inhabit large distinct nests and can be sampled easily (Greenslade & Greenslade 1971). This is the case with jack jumper ants. Their nests are easy to find, consisting of a conspicuous pebbly mound or a hole surrounded by a number of jack jumper ants. Considering that nests are an indication of their preferred habitat, direct searching for nests was chosen for this study. A direct search, although labour intensive, was also considered the quickest and most efficient way of looking for ants nests.

The two main sampling techniques at site points are either temporal (duration of searching) or spatial (using a quadrat or transect) (New 1998). Since the structure of vegetation would affect the efficacy of a timed search (e.g. a 5 minute search in rainforest would result in a much less effective search than a 5 minute search in grassland), the latter, a spatial search, was chosen. An area of $100m^2$ was considered appropriate to search for the ants nests. This ensured that the area would be large enough so that nests would be found if present and small enough as not to homogenise the environmental variables of the site (McQuillan 2007b, pers. comm.). A transect of 25 m x 4 m was chosen as it was considered a more time efficient method of searching for a nest in an area of $100m^2$ than by using a quadrat of 10 m by 10 m (Kirkpatrick 2007, pers. comm.).

3.3.4 Season, Time and Weather

The two hundred transect surveys were completed during November and December in the summer of 2007. Summer is considered the optimal time to study ants in Tasmania because ants are strongly thermophilic, functioning poorly below 20°C and not at all below 10°C (Holldobler & Wilson 1990). Jack jumpers are thought to be no exception to this, being largely inactive during the winter months and active during the summer months (McQuillan 2007a, pers. comm.). Also, during the winter months, much of the sub-alpine area of Mt. Wellington can be blanketed in snow and ice, making a nest search more difficult. The surveys were conducted in fine weather during daylight hours between 9 am and 7 pm. The temperature varied during the research, although this variation was considered not enough to affect the behaviour of jack jumper ants, or more importantly, the identifiability of their nests.

3.3.5 Transect sites

In the field, transect sites were located with a combination of a road map and a Garmin GPS 12 Personal Navigator global positioning system (GPS). Once the sites were located, various measurements were taken (Appendix II). Firstly, the GPS coordinates were noted, along with the altitude. Aspect and slope were measured using a compass clinometer. Following this, a transect was measured out using two tape measures. The first tape measure was used to measure out a transect width of 4 m. The second was placed, starting at the 2 m mark on the first tape measure, perpendicularly to it (Figure 3.10). Following this, the search for jack jumper nests commenced. This involved walking along the second tape measure continually scanning for jack jumper ants and their nests within 2 m each side of the tape until the 25 m mark was reached. The search was thorough ensuring that the more cryptic nests were recorded, by overturning rocks and comprehensively searching bush, scrub and any other debris.

Figure 3.10: Transect measurement using tape measure (photograph: author).

3.3.6 Vegetation

Though each site had a prescribed vegetation community as mapped on TASVEG, on the ground vegetation type is not necessarily the same as TASVEG indicates. Patterns can change according to the scale of mapping and the boundaries between vegetation types are often blurred, with the transition between vegetation types being gradual rather than sudden as is indicated in the vegetation map (Harris & Kitchener 2005). The vegetation communities are also dynamic, that is, they change in time and space. Therefore, to ensure accurate representation of the vegetation types present at each site, it was felt necessary to record vegetation communities.

In the field, vegetation was classified using a system derived from Walker and Hopkins (1990) and Specht (1970). For non-rainforest vegetation, the dominant species, growth form, height and crown cover/foliage cover class was estimated using the classes in Table 3.1. The recorded vegetation attributes were later classed according to Walker and Hopkins (1990) and Specht (1970). The example on Table 3.1 would be classed as *E. globulus, Acacia dealbata, Poa* grassy open forest.

Table 3.1: Example of classification of non-rainforest vegetation in the field

Non- rainforest Vegetation				
Statum	Dom. Species	Growth form	Height (m)	Crown/ Foliage cover class (%)
1	e.g. *Eucalyptus globulus*	Tree	<2, 2-8, 8-30, >30	<10, 10-30, 30-70, >70
2	e.g. *Acacia dealbata*	Shrub	<2, 2-8, 8-30, >30	<10, 10-30, 30-70, >70
3	e.g. *Poa spp.*	Grass	<2, 2-8, 8-30, >30	<10, 10-30, 30-70, >70
4			<2, 2-8, 8-30, >30	<10, 10-30, 30-70, >70
5			<2, 2-8, 8-30, >30	<10, 10-30, 30-70, >70

For rainforest vegetation, the complexity (simple, simple-complex, or complex), leaf size (nanophyll, microphyll, notophyll, mesophyll or macrophyll), floristic complexity of tallest stratum (mixed, one or two species or mixed plus one species), indicator growth forms (moss, fern, fan palm, feather palm, vine or none), height, crown/foliage cover class, and the species of emergent were all recorded in a table similar to Table 3.2. The example in Table 3.2 would be classed as simple notophyll closed forest with *E.obliqua* emergents. For codes and criteria for each classification see Walker and Hopkins (1990)and Specht (1970).

Table 3.2: Example of classification of rainforest vegetation in the field

Rainforest Vegetation						
Complexity	Leaf size	Floristic compositio n of tallest stratum	Indicator growth forms	Height (m)	Crown/ Foliage cover class	Emergents
S, X, C	notophyll	M, S, X	6	<2, 2-8, 8-30, >30	<10, 10-30, 30-70, >70	*E.obliqua*

3.3.7 Plant identification

The dominant species of each strata were identified to the species level using a number of plant identification books and guides (Cameron 2000; Collier 1989; Collier & Howells 2006, 2007; Howells & Gulline 2003; Kirkpatrick 1997; Kirkpatrick & Backhouse 2007; Lane *et al.* 1999; Whiting *et al.* 2004; Wiltshire 2007). Prof. Jamie Kirkpatrick of the University of Tasmania helped to identify any difficult species. Some species could only be identified to genus level, for example some *Poa* grass species, in which case they were recorded as spp. (e.g. *Poa* spp.).

3.3.8 Soil

To test whether jack jumpers prefer to nest using certain soil types, a simple test of soil texture and drainage was completed at each nest survey site. Field texture was measured by collecting a small handful of soil using a hand trowel, moistening the soil and kneading it into a ball of soil, or bolus, that was formed so that it just failed to stick to the fingers. The bolus was then sheared between the thumb and finger in a technique to estimate for mineral and organic soils. For more information see McDonald and Isbell (1990).

Soil drainage was estimated by pouring water into a hole dug with the hand trowel (usually the space remaining from the soil texture test) and estimating the drainage according to the criteria in Table 3.3. Detailed explanations of the criteria used to assess the drainage can be found in McDonald and Isbell (1990).

Table 3.3: Example of soil texture and drainage test recordings in the field

Soil	
Field texture grade (mineral soils)	Field texture grade (organic)
S, LS, CS, SL,L, ZL, SCL, CL, CLS, ZCL, LC, LMC, MC, MHC, HC	IP, HP, AP, SP, LP, CP, GP
Soil drainage: Very poor, poor, imperfectly, moderately well, well, rapidly	

3.3.9 Other environmental variables

Soil moisture, canopy cover, litter, rock cover, coarse woody debris (CWD) and habitat complexity are known to affect invertebrate assemblages (Harmon *et al.* 1986; Lassau & Hochuli 2004). To test their effect on *M. pilosula*, a number of environmental variables were estimated for the area of transect. Rock cover, bare ground cover, CWD cover, litter cover and moss cover were all estimated using the percentage classes in Table 3.4. Litter depth was estimated by pointing a pencil into the litter until the tip touched the surface below. Using this method, three measurements were taken and the average of those measurements was recorded.

Table 3.4: Example of other environmental variables recorded in the field

Other conditions (average)	
Rock cover: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	Average litter depth (cm)
Bare ground: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
CWD cover: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	1.5
Litter cover: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
Moss cover: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	

3.3.10 Canopy cover photographs

To accurately test the canopy cover of each habitat, a canopy cover photograph was taken in each transect. The camera, a Pentax Optio E30 7.1 megapixel digital camera, was held roughly 10 centimetres from the ground with the lens pointed vertically up into the canopy and a picture taken. These photographs (Figure 3.11) were later converted into percentage of canopy cover by Darren Turner of the School of Geography and Environmental Studies, University of Tasmania using a program he wrote and named 'Canopy Cover'.

Figure 3.11 (a, b, and c): Examples of canopy cover photographs taken during the nest survey (Photographs: Author)

3.3.11 Finding a nest

To avoid bias, only the first nest found in each transect was picked to make measurements and observations of individual jack jumper nests. To test variation in size of nest to habitat, measurements of the largest dimension and its perpendicular dimension were recorded as well as an estimate of the height above ground of the nest mound. The outline shape of the nest was noted as well as the contents of the decoration material. The environmental variables in Table 3.4 were replicated for an area of roughly 2 m radius around the nest. As *M. pilosula* are thought to forage on extrafloral nectaries, the nearest tree or bush was identified as well as its distance to the nest. Canopy cover photographs were taken above the nest as in 3.3.10 as well as photographs of the nests themselves.

A corresponding nest control point was selected by throwing a stone whilst spinning; an attempt to randomise its selection. All non-nest observations were repeated for the control.

3.3.12 Risk Assessment

All field work undertaken through the University of Tasmania requires a comprehensive risk assessment and control analysis. The generic 'Project/Task Risk Assessment & Control Procedure' form was completed for the nest survey and pair trial study combined. The potential for a snake bite and a jack jumper ant sting was considered great enough to take measures and a 'Safe Work Practices (SWP) Form' was completed and procedures implemented. These measures included carrying an epipen©, a snakebite bandage and a mobile phone at all times during the field research. Familiarity with the emergency procedures in dealing with an anaphylactic shock from a jack jumper ant or a snake-bite was also required. During field research, I saw a number of snakes but was not bitten. Also, I was not stung by any jack jumper ants until the last 5 minutes of the field work, at the end of over 150 hours in the field. I did not experience adverse reactions to the stings.

3.4 Nest survey data analyses

To analyse the data, a number of tests were completed using a variety of statistical techniques. These included chi-square tests, analysis of variance (ANOVA), linear regression, logistic regression and ordination. Throughout the analyses, if $p < 0.05$, the data was considered to be significant (Gotelli & Ellison 2004). The analyses were done using Microsoft Excel (Microsoft 2006), PC Ord 4 (McCune & Mefford 1999), Minitab 15 (Minitab Inc 2007) and JMP 7.0.1 (SAS 2007).

3.4.1 Correlation

To test whether any of the environmental variables were collinear, pair-wise comparisons were calculated between all the environmental variables in the nest survey. Non-parametric tests (Spearman ρ) were also performed. The same tests were done for the first nest and control data. When a relationship was above 0.5 or below -0.5, it was considered to be large enough to consider the variables as covariates.

3.4.2 Chi-square testing

As both the predictor and response variables were categorical, chi-square testing was chosen for the vegetation type and structure, geology, aspect categories, soil drainage categories. Chi-square tests measure the extent to which the observed frequencies differ from the expected frequencies. The test, referred to as the Pearson chi-square statistic is calculated as:

Equation 1 (Gotelli & Ellison 2004):

$$X^2_{\text{Pearson}} = \sum_{all\ cells} \frac{(Observed - Expected)^2}{Expected}$$

To analyse the associations between jack jumper nest occurrence and vegetation types, the transects were categorised into broad vegetation types by referring to the first dominant strata (e.g. *Eucalyptus pulchella* forest and woodland). The broad groups were classed into two categories; dry eucalypt vegetation types and other vegetation types. A chi-square test was done to determine the significance of the relationship between nest presence and these two categories. To test whether the vegetation structure was related to presence or absence of nests, chi-square tests were completed for each stratum's height and cover against nest presence.

The geology of each habitat site was determined by reference to the geological map of Hobart (Calver *et al.* 2004)using the GIS coordinates of each site. The 15 geological types were then categorised into three broader geological types: dolerite, sandstone/siltstone and scree/talus and a chi-square test was undertaken to test the significance of any relationship to nest presence or absence.

To determine the effect of aspect on the location of the nests, the aspect data were divided into five classes, on the basis of deduced relative soil moisture availability and solar radiation (Bowkett & Kirkpatrick 2003; Kirkpatrick & Nunez 1980). These were 1, north-west; 2, north and west; 3, north-east and south-west; 4, east and south; and 5, south-east. Class 1 is the warmest and driest and class 5, the coolest and moistest. A chi-square test was completed on these classes to determine the significance of their relationship with nest presence.

3.4.3 Analysis of variance (ANOVA) and Wilcoxon test on ranks

Analysis of variance (ANOVA) was used to compare the mean values of the environmental variables of altitude, slope, soil clay content, rock cover, bare ground cover, coarse woody debris (CWD) cover, moss cover, litter cover, litter depth and canopy cover (photographed). ANOVA was suitable as the independent variable was categorical (in this case nest presence or absence) and the dependent variable was continuous (Gotelli & Ellison 2004). For the purpose of these analyses the ranges (e.g. cover 1-5%) were converted into mid-point values (e.g. 3). ANOVA is built on the concept of partitioning of the sum of squares and assumes that random samples of measured values fit a bell-shaped distribution (Gotelli & Ellison 2004). This assumption was tested by producing histograms of residuals, often revealing uneven distributions of the data (Appendix XV, Appendix XXI). Therefore, a non-parametric test (Wilcoxon) was also employed to test the data further for significant differences (Gotelli & Ellison 2004). The same tests were applied to the environmental data obtained from the first nest and control observations which included rock cover, bare ground cover, CWD cover, moss cover, litter cover, litter depth, canopy cover and distance to the nearest tree. Data from only fifteen of the nests found was recorded.

To test whether the size of nests changes with elevation, two measures of the nest size, the largest width and corresponding perpendicular width, were multiplied together to give an index of nest area. This was regressed against elevation to determine whether a linear relation existed between nest size and elevation.

3.4.4 Logistic regression

Logistic regression models have been shown to be useful in the analysis of relationships between a binary response variable and one or more explanatory variables (Hosmer & Lemeshow 2000). Advantages are that the probability of occurrence of an event can be predicted as a function of one or more independent variables (Hosmer & Lemeshow 2000; Peeters & Gardeniers 1998). In this case, the event, the presence of a nest, was predicted as a function of one or more of the environmental variables. Only the significant data, as revealed in the ANOVA and Wilcoxon tests, were regressed using this technique.

The 'presence/absence response curve' of a species (Ter Braak & Looman 1986) describes the probability of that species being present, $\pi(x)$, as a function of a measured environmental variable x (Peeters & Gardeniers 1998). The general expression for this probability is:

Equation 2 (Hosmer & Lemeshow 2000; Peeters & Gardeniers 1998):

$$\pi(x) = \frac{\exp^{\beta_0 + \beta_1 x + \beta_2 x^2}}{1 + \exp^{\beta_0 + \beta_1 x + \beta_2 x^2}}$$

The parameters β_0, β_1 and β_2 of Equation 2 are regression coefficients with β_0 as intercept or constant term (Peeters & Gardeniers 1998). It can be transformed to the logit function in Equation 3:

Equation 3 (Hosmer & Lemeshow 2000; Peeters & Gardeniers 1998):

$$g(x) = \log\left[\frac{\pi(x)}{1 - \pi(x)}\right] = \beta_0 + \beta_1 x + \beta_2 x^2$$

The importance of this transformation is that $g(x)$ has many of the desirable properties of a linear regression model, with the transformation of $\pi(x)$ to $g(x)$resulting in a linear regression model in which the logit, $g(x)$, is linear in its parameters, may be continuous and may range from $-\infty$ to $+\infty$, depending on the range of x (Hosmer & Lemeshow 2000; Peeters & Gardeniers 1998).

For each curve generated, the ROC area was calculated to indicate the model's ability to discriminate between sites with ant nests versus those without. Values of ROC > 0.7 indicated acceptable discrimination (Hosmer & Lemeshow 2000).

3.4.5 Ordination

Ordination was used to visualise the relationship of nest sites in multivariate space, on the basis of the environmental variables. Ordination is a technique to order complex data, by creating new simpler axes along which samples are scored or ordered. The technique of ordination used was non-metric multidimensional scaling (NMDS) which results in a plot in which distance reflects relationship so that the different objects are placed far apart in ordination space, while similar objects are placed closer together (Gotelli & Ellison 2004). It is important to note that ordination is a representation of the raw data, and not an analysis of its significance. Therefore, the plots were used to supplement the other data analyses.

3.5 Hobart properties survey

The limited time allocated for this research project restricted the time available to undertake a study of the effects of urbanisation on *M. pilosula*. Surveys of people can be undertaken to obtain information not available from other sources (Hay 2000). Thus, to investigate the effects of urbanisation on *M. pilosula*, a questionnaire of property owners/occupiers was designed in an attempt to harness the interest around Hobart in the ant.

By asking the people of Hobart to voluntarily fill out questionnaires regarding the presence or absence of the ant, it was possible to get data for the built up areas of the Hobart City Council Municipality that were outside of the scope of the habitat survey. The questionnaire contained quantitative and qualitative questions. The answers provided from the qualitative questions were intended to supplement the main findings of the quantitative studies. A simple questionnaire was designed, split into 3 sections; Section A, Section B and Section C, with a total of nine questions (Appendix III).

3.5.1 The questionnaire

Section A led the participant into the questionnaire with questions about their property. The answers provided in this section, it was thought, would give comparative quantitative data that could be categorised for later analysis.

In Question 2, a table was used for the estimation of the structure of the garden. The table was designed to help engage the participant in the survey as well as give the easiest way to compare data between properties on various aspects of the garden. The answers provided in this question would be used to compare environmental attributes, and although not as accuráte as the habitat survey, it was thought that the answers might offer some valuable insights into where the'ant likes to reside in properties, for example whether that ant prefers native vegetation more than exotic vegetation.

The second section of the questionnaire, Section B, contained questions regarding the presence or absence of the jack jumper ant on the participant's property. These questions were important in gathering information about the interaction between humans and jack jumpers by asking the participants to write their own experiences with the ant or nests.

The last section asked the participant for their address. Answers to this question allow the presence or absence of the ant to be spatially located in different suburbs. It also revealed the location of each property and its proximity to native bush, and helped address the question of whether the ant can exist in areas of varying urbanisation. This question was left until last, so that the participant would be, by the end of the survey, more familiar with the aim of the research and perhaps more willing to offer their address.

The ability to pin-point the location of the address where an ant or nest was present or absent was important for this study. The locations of the sites spatially were located using a combination of Google Earth and Google Maps (2008)(Figure 3.12). Google Earth is accurate to 10 to 20 metres, whereas Google Maps allowed exact location of the property, showing cadastral data. To test further questions of urbanisation and proximity to native bush and the ants' presence or absence, a technique of estimating the percentage of cover in a constant area around the property was employed. The area, a circle with a 100 metres radius, was generated above the participants property on Google Earth using a free utility provided by the Google Earth Community (Polaroid_Ink 2008). Estimates were made within the circle of the covers of native vegetation, grass, hard surfaces such as concrete or bitumen, soft surfaces such as dirt or sand, non-native vegetation and buildings (hereafter referred to as circle environmental variables). A select number of localities were ground-truthed for confirmation that the estimates derived from the satellite images were correctly identified. Another variable, distance to suitable patch of native bush, was measured using the ruler tool. The minimum area defined as a suitable patch of native bush was 100 metres^2, an area thought big enough to sustain a population of jack jumpers (McQuillan 2008b, pers. comm.).

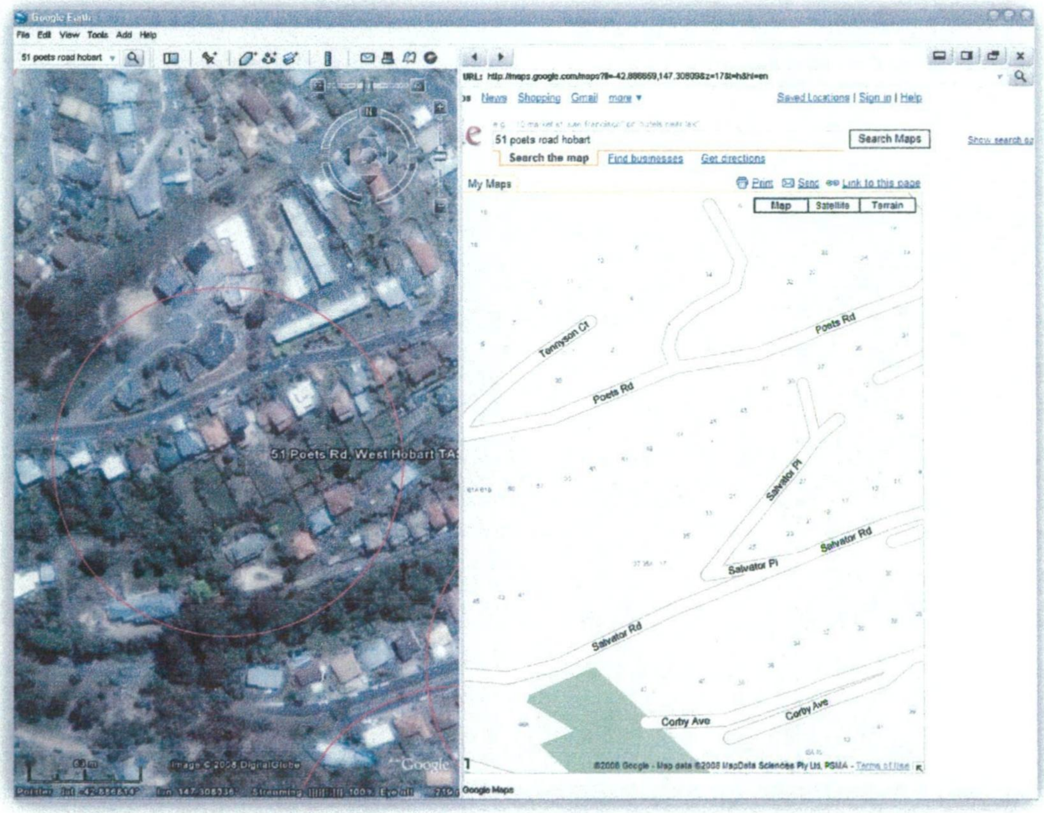


Figure 3.12: Technique for estimating cover of circle environmental variables at a given address. Note: Google Earth on left, Google Maps on Right. Also note: inaccuracy of address location in Google Earth in comparison to exact location ascertained from Google Maps (Google Earth 2008; Google Maps 2008).

3.5.2 Selection and recruitment of participants

Two main methods of recruitment were utilised for the Hobart properties participants. The first method was to email the staff and students of the School of Geography and Environmental Studies and ask them to participate. To ensure that data was received from properties that did not contain jack jumpers or their nests as well as properties that did contain them, this point was emphasised.

The second method took advantage of the infamy of the jack jumper ant around Hobart. As mentioned in chapter 1, there have been a number of enthusiastic responses with regard to the jack jumper ant from the Hobart public. Therefore to reach potential participants, the Hobart media were engaged. Initially, the survey and information sheet were made available on the antallergy.org website for participants to download and either email or post their completed questionnaire (antallergy.org 2008). I then did a radio interview with Mike Lockerby of the Australian Broadcasting Corporation (ABC) on the 31st of March 2008, followed by a series of small segments and a live radio interview on Local ABC Radio. The next day, the University of Tasmania sent a release (Appendix VI) to Tasmanian media outlets about the research. As a result, contact was made by Ultra 106.5 local Radio resulting in another radio interview. The *Hobart Mercury* Newspaper also made contact, and an article was published the next day. In all the interviews and the newspaper article, details of the study were given, and calls for people to participate in the survey were made (Appendix VII). The need for completed questionnaires from people with properties without the ant as much as those with the ant was emphasised.

3.5.3 Ethical clearance

As the Hobart properties survey involved interaction with humans, ethics approval was required. A minimal risk ethics application was submitted to the Human Research Ethics Committee (HREC) Network with the application receiving approved on the 1st of February 2008 (Appendix V). A condition of ethical clearance was that a coversheet outlining the purpose and significance of the study and the contact details of the investigators should be provided to participants along with the questionnaire (Appendix IV).

3.6 Hobart properties survey data analysis

To help understand the effect of property size and percentage of environmental variables on property, ordination using PC Ord 4 (McCune & Mefford 1999) was undertaken. Extra variables provided by the participants were either categorised into one of the pre-determined variables (e.g. paddock was categorised into grass/lawn) or omitted because there were no consistent and similar variables that participants recorded more than five times. For the purposes of the ordination, the environmental variables (building cover, concrete cover, bitumen cover, paving cover, grass/lawn cover, non-native trees cover, flower garden, native bush cover and building size) were classed as quantitative and the nest or ant presence/absence as categorical. The above variables were checked for collinearity using pair-wise association and a non-parametric test (Spearman ρ). A chi-square test was used to analyse the size category of property against nest presence. Logistic regression was used to model significant variables as predictors of ant presence.

To analyse the qualitative data from Section B, a form of content analysis called thematic analysis was utilised. Content analysis is a research technique for making replicable and valid inferences from data according to their context (Krippendorff 1980). Thematic analysis is the process of encoding qualitative information and allows the translation of qualitative information into quantitative data (Boyatzis 1998; Gerbner *et al.* 1969). A theme may be indentified at the manifest level (directly observable) or at the latent level (underlying the phenomenon) (Boyatzis 1998). In this case, the themes (an example theme would be that jack jumper nests were found in native bush) were deduced from the comments and the analysis was mostly at the manifest level. The themes were kept to a minimum to increase the likelihood of occurrence, however, they were not categorised too broadly so as to not homogenise the data. Thematic analysis is subjective (Boyatzis 1998) and ideally an alternative analyst apart from myself could have been employed to interpret the data into themes. However, the limited time of the study did not allow this; therefore, I made every attempt to be objective when carrying out the thematic analysis. As well as analysing the quotes given by the participants using thematic analysis, some of the more notable quotes were given in the results.

Ordination was used to analyse the circle environmental variables obtained from the property localities against the presence/absence of ants and nests. The circle variables and distance to native vegetation were analysed for collinearity using pair-wise association and a non-parametric test (Spearman ρ). ANOVA and Wilcoxon tests were used to analyse the distance from native bush variable against the presence/absence categorical data. For the circle variables, ANOVA and Wilcoxon tests were used with logistic regression plots modeled for those variables that were found to be significant.

4 Results

The following showcases the results of the data collected and analyses completed in the form of tables, figures, maps, graphs and a simple narrative. Firstly, the results of the nest survey will be given, followed by those of the Hobart properties survey. Any data, tables or figures that were not necessary in order to showcase these results can be found in the appendices. This includes complete datasheets of all of the studies in the project (Appendix VIII, Appendix IX, Appendix X, Appendix XI, Appendix XII and Appendix XIII), boxplots of the ANOVA (Appendix XX, Appendix XXII, Appendix XXIV and Appendix XXVI) and histograms of residuals of the ANOVA (Appendix XIX, Appendix XXI, Appendix XXIII and Appendix XXV).

4.1 Nest survey

Of the 200 transect sites searched, 24 contained jack jumper nests (12%). Nests were found in all of the bush reserves used in the study (Figure 4.1).

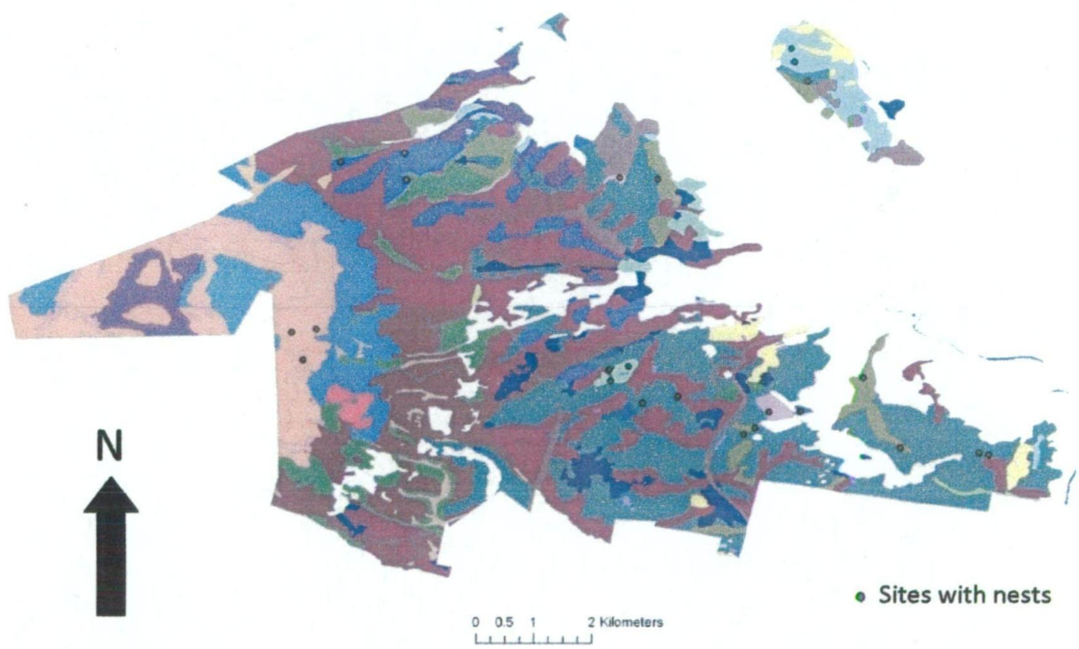


Figure 4.1: Sites that contained jack jumper nests (Base data from theLIST, © State of Tasmania. Projection: UTM, Zone 55. Datum: GDA 94)

4.1.1 Vegetation type and structure

Nests were found to be associated with dry eucalypt sites and not associated with wet eucalypt, alpine heathland, rainforest, and *Poa* grassland vegetation types (Figure 4.2 and Table 4.1). Nests were found in nearly half of the transect sites classified as *Eucalyptus pulchella* forest and woodland and *E. ovata* forest and woodland. Nests were less common in other dry sclerophyll sites.

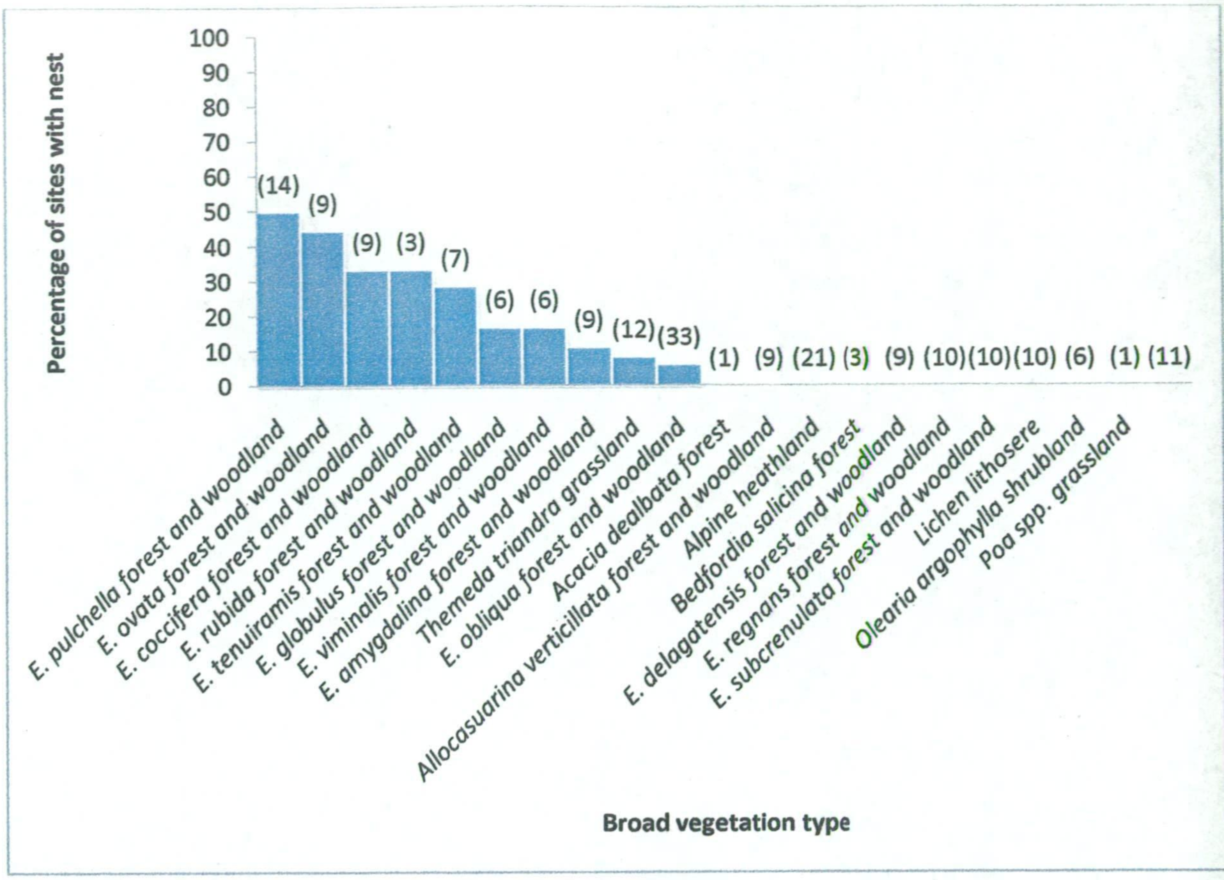


Figure 4.2: Percentage of sites that contained nests by broad vegetation type (total number of sites sampled in brackets).

Table 4.1: Chi^2 test of percentage of dry eucalypt and other sites that contain nests.

Vegetation group	n	Nest presence (%)	Nest Absence (%)	Chi^2	P-value
Dry Eucalypt	76	28.95	71.05	33.340	<0.001
Other	124	1.61	98.39	33.340	<0.001

Nests were more likely to be found in vegetation types where stratum 1 was between 8 and 30 metres in height and with 10-30% cover, i.e. open woodland (Table 4.2 and Table 4.3). Nests were also found in vegetation types where the stratum 2 cover was between 10 and 30%. Nests were found in roughly 6% of stratum 1 and 2 if the cover was 30-70%.

Table 4.2: Chi^2 tests of nests against vegetation cover. Strata with insufficient values to calculate a chi^2 were omitted from the table (Bold p-values indicate significant results).

Stratum	Cover (%)	Number of sites (n)	Nest presence (%)	Nest Absence (%)	Chi^2	p-value
1	10-30	86	18.60	81.40	4.966	**0.026**
	30-70	77	6.49	93.51	4.513	**0.034**
	>70	22	4.55	95.45	1.493	0.222
2	10-30	94	18.09	81.91	4.098	**0.043**
	30-70	64	6.25	93.75	4.373	**0.037**
	>70	10	10.00	90.00	0.100	0.752
3	10-30	77	15.58	84.42	0.256	0.613
	30-70	21	9.52	90.48	0.538	0.463
4	10-30	30	16.67	83.33	0.000	1.000
	30-70	8	0.00	100.00	1.976	0.160

Table 4.3: Chi^2 tests of nests against vegetation height. Strata with insufficient values to calculate a chi^2 were omitted from the table (Bold p-values indicate significant results).

Stratum	Height (m)	Number of sites (n)	Nest presence (%)	Nest Absence (%)	Chi^2	p-value
1	<2	35	2.86	97.14	3.753	0.053
	2-8	12	8.33	91.67	0.220	0.639
	8-30	124	17.74	82.26	8.273	**0.004**
	>30	18	0.00	100.00	2.894	0.089
2	<2	92	15.22	84.78	0.943	0.330
	2-8	77	10.39	89.61	0.743	0.393
	8-30	8	12.50	87.50	0.001	0.976
3	<2	80	17.50	82.50	2.659	0.103
	2-8	24	4.17	95.83	2.659	0.103
4	<2	36	19.44	80.33	1.400	0.237

4.1.2 Environmental variables

Most of the correlations were expected (Table 4.4, Table 4.5, Appendix XIV and Appendix XV). For example, easting was shown to be positively correlated with dolerite and negatively correlated with altitude, which would be explained by the fact that the majority of dolerite within the boundaries of the study is found in the east at lower altitudes. Also, dolerite was negatively correlated with canopy cover, which could be explained by the fact that the vegetation types with denser cover are to be found on the foothills of Mt. Wellington where the geology is less likely to be dolerite. Most significantly for this study was that litter cover and depth was positively correlated with canopy cover. The only strong correlation for the first nest and control variables was litter depth against litter cover (Table 4.6 and Appendix XVI).

Table 4.4: Correlation of variables (Only pairs with R-value of > 0.5 or < -0.5 are shown).

Variable 1	Variable 2	R- value
Dolerite	Canopy Cover	-0.5735
Litter cover	Canopy Cover	0.6875
Litter depth	Canopy Cover	0.6237
Altitude	Easting	-0.8545
Dolerite	Easting	0.6379
Stratum 3 Cover	Stratum 3 Height	0.5048
Dolerite	Sandstone/Siltstone	-0.8758
Litter depth	Dolerite	-0.5864
Litter depth	CWD	0.5461
Litter depth	Litter cover	0.5851

Table 4.5: Non-parametric correlation test (Spearman ρ) highlighting the collinearity of certain environmental variables (Only significant pairs with R-value of > 0.5 or < -0.5 are shown).

Variable 1	Variable 2	Spearman ρ	Prob>|ρ|
Altitude	Easting	-0.9423	0.0001
Cover_3	Height_3	0.9097	0.0001
Cover_4	Height_3	0.506	0.0001
Cover_4	Height_4	0.9878	0.0001
Cover_5	Cover_4	0.5233	0.0001
Cover_5	Height_4	0.5396	0.0001
Cover_5	Height_5	0.9991	0.0001
CWD	Canopy cover	0.6783	0.0001
CWD	Height_1	0.6805	0.0001
Dolerite	Sandstone/Siltstone	-0.762	0.0001
Height_1	Canopy cover	0.6756	0.0001
Height_2	Canopy cover	0.5689	0.0001
Height_2	Height_1	0.5886	0.0001
Height_4	Height_3	0.5251	0.0001
Height_5	Cover_4	0.5226	0.0001
Height_5	Height_4	0.5394	0.0001
Litter	Canopy cover	0.8116	0.0001
Litter	CWD	0.6414	0.0001
Litter	Height_1	0.6551	0.0001
litter depth	Canopy cover	0.8029	0.0001
litter depth	CWD	0.741	0.0001
litter depth	Height_1	0.7167	0.0001
litter depth	Height_2	0.5236	0.0001
litter depth	Litter	0.801	0.0001
litter depth	Moss	0.5584	0.0001
litter depth	Sandstone/Siltstone	0.506	0.0001
Moss	Canopy cover	0.5868	0.0001

Table 4.6: Correlation of first nest and control variables.

	Canopy cover	Nearest tree	Rock	Bare ground	CWD	Litter cover	Moss
Nearest tree	-0.2746						
Rock	0.0222	0.0573					
Bare ground	-0.2050	0.4022	-0.1035				
CWD	-0.1511	-0.2782	-0.0943	-0.2436			
Litter cover	0.1120	-0.1479	0.0039	-0.1909	-0.0263		
Moss	0.1641	0.0221	-0.0690	-0.0233	0.0299	0.1963	
Litter depth	-0.0704	-0.1953	0.2249	-0.1439	0.2179	0.4465	0.1591

The sites sampled spanned from near sea level to the top of Mt. Wellington. Jack jumper nests occurred at lower elevations within the sampled set. The mean elevation for presence of colonies was 335 m which was lower than the mean elevation for absence at 515 m (Table 4.10). Nests increased in surface area with elevation, although the proportion of variation explained by elevation was relatively low (Figure 4.3).

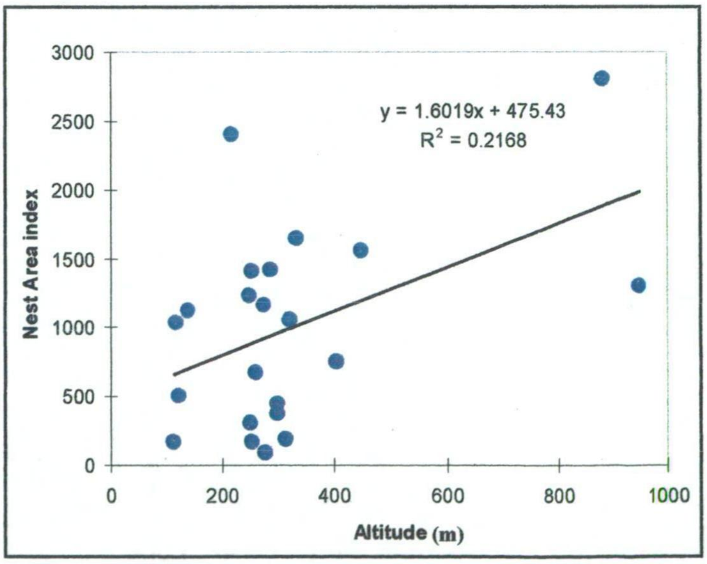


Figure 4.3: Altitude against nest area index (R^2=0.217, P=0.029).

The only significant correlation between geology and nest presence was the absence of nests on scree or talus (Table 4.7).

Table 4.7: Chi² test of percentages of sites with broad geological types that contained nests (Bold p-values indicate significant results).

Geology	n	Nest presence (%)	Nest Absence (%)	Chi²	P
Dolerite	94	14.89	85.11	1.406	0.236
Sandstone	77	12.99	87.01	0.116	0.734
Scree/Talus	29	0.00	100.00	4.625	**0.032**

Nests were found in sites with a slope ranging from 0° to 40° (Figure 4.4). There was no correlation between slope and nest presence (Table 4.10).

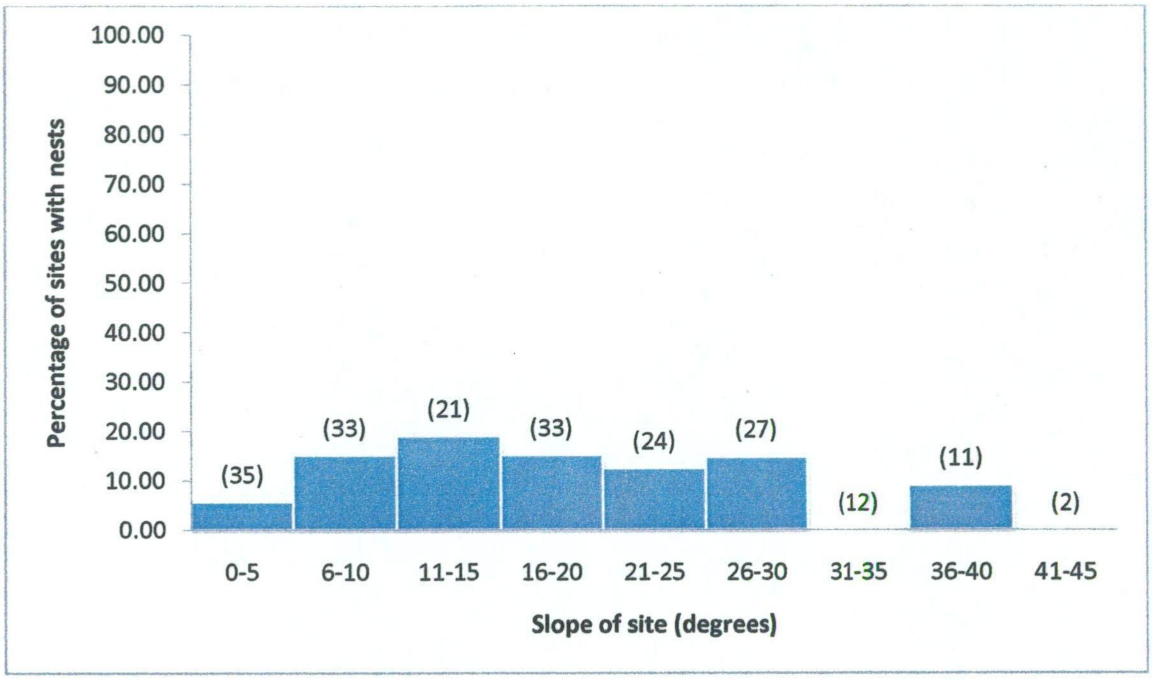


Figure 4.4: Percentage of sites with nests present by slope range (total number of sites sampled in brackets).

Ant nests occurred in all five of the aspect classes with the highest percentage in class 2 and the lowest in category 4 (Table 4.8). However, the chi² test showed that only the category 2 results were significant.

Table 4.8: Chi² test of percentage of sites containing nests according to aspect class (Bold p-values indicate significant results).

Aspect Class	Number of sites	Nest Presence (%)	Nest Absence (%)	Chi²	P
1 (warm and dry)	20	15.00	85.00	0.076	0.783
2	58	20.69	79.31	4.366	**0.037**
3	50	12.00	88.00	0.066	0.797
4	39	5.13	94.87	2.734	0.098
5 (cool and moist	17	5.88	94.12	0.847	0.357

The NMDS ordination of the sites based upon 8 environmental variables (rock cover, bare ground cover, coarse woody debris (CWD) cover, litter cover, litter depth, clay content, drainage and moss cover) highlights a strong relationship between absence of a nest and increased litter cover and depth (Figure 4.5). Moss and CWD cover are also shown to be positively correlated with absence of nests. The ordination shows a band of nest presence ranging from low scores on both axis 1 and axis 2 diagonally to high scores on both axis 1 and axis 2. At intermediate scores, there are nest absences mixed in with presences, hinting that some of the absences might be expected to contain nests (false absences).

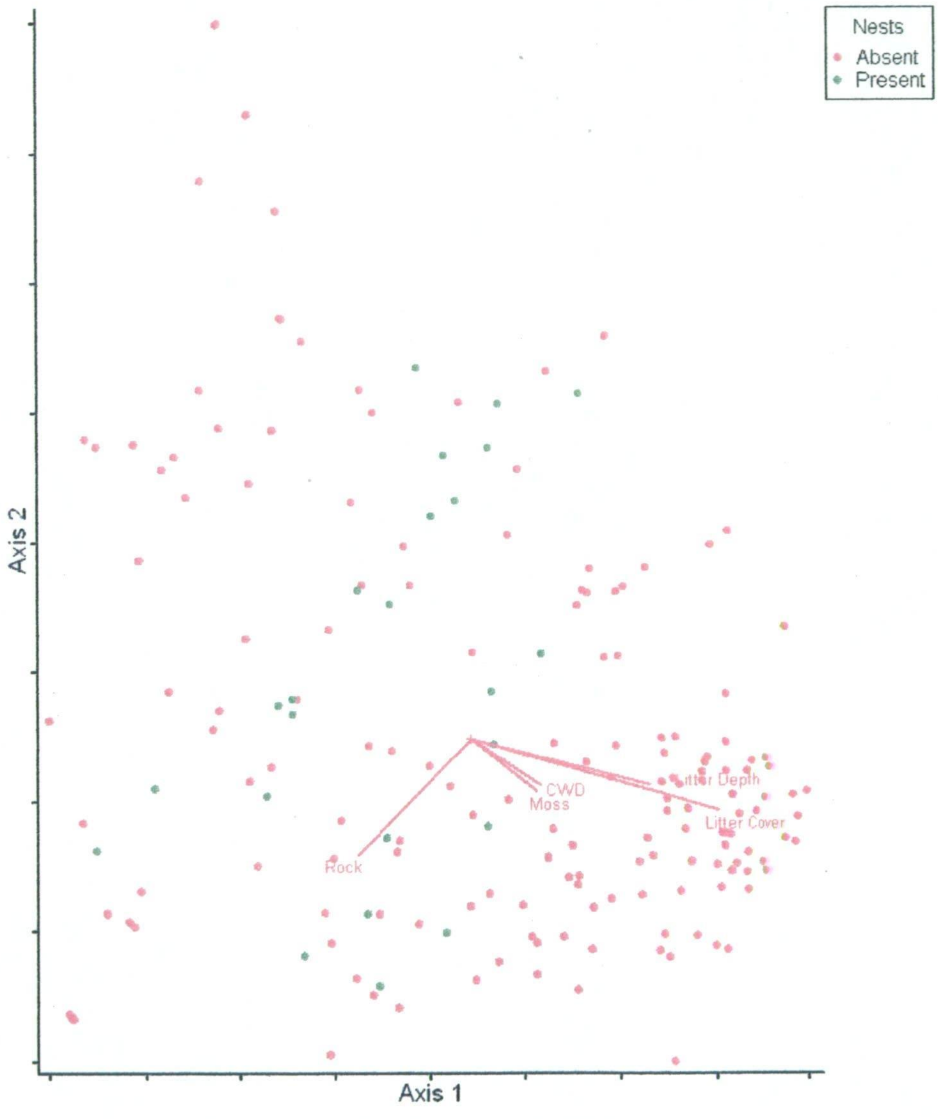


Figure 4.5: NMDS ordination of nest sites based upon environmental variables (Stress in 2D= 16.84, R^2 cut-off= 0.200).

There was no correlation between nest presence and soil clay content or soil drainage (Table 4.9 and Table 4.10).

Table 4.9: Chi^2 test of the percentages of the sites with nests according to soil drainage.

Soil drainage	n	Nest Presence (%)	Nest Absence (%)	Chi^2	P
Very poor	21	4.76	95.24	2.166	0.141
Poor	53	18.87	81.13	0.696	0.404
Imperfectly	32	25.00	75.00	2.783	0.095
Moderately well	16	12.50	87.50	0.126	0.722
Well	20	10.00	90.00	0.541	0.462

There was no correlation between nest presence and rock cover for both the transect and first nest and control sites (Table 4.10 and Table 4.11).

Bare ground cover at the transect sites and first nest and control sites that contained nests were shown to have larger means and standard deviations than those sites without nests, with the ANOVA and Wilcoxon analyses showing that this was highly significant. The logistic plots indicate this same pattern, with the probability of finding a nest increasing more rapidly at around 30% cover (Figure 4.6), although this plot accounts for only a small proportion of the data. The plot for the first nest and control was not significant (Figure 4.7).

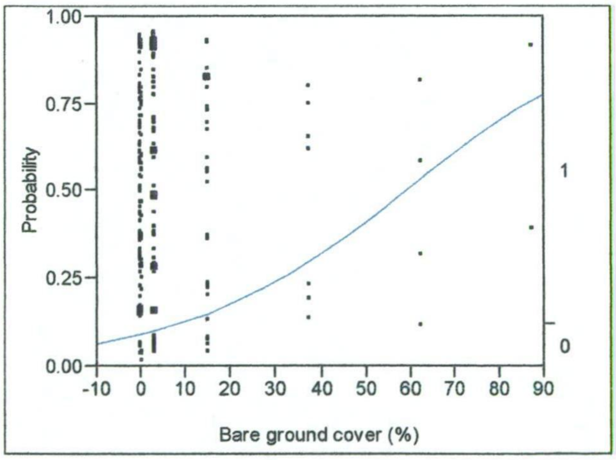


Figure 4.6: Logistic regression showing the probability of a site containing a nest according to percentage of bare ground cover (P=0.0007, R^2=0.0559, ROC=0.71035).

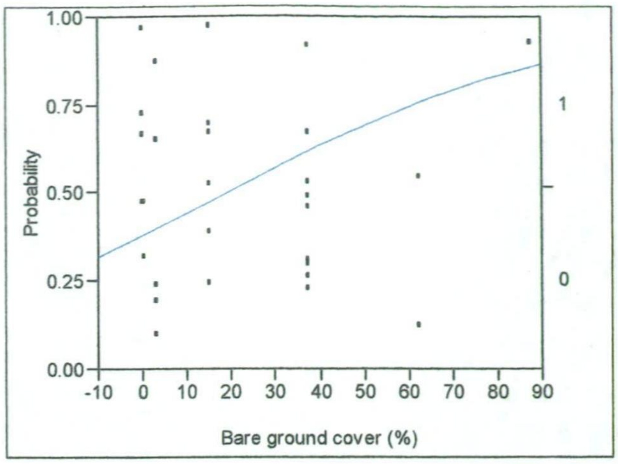


Figure 4.7: Logistic regression showing the probability of a site containing a nest according to percentage of bare ground cover (First nest and control) (P=0.1377, R^2=0.0548, ROC=0.71667).

There was no correlation between ant presence or absence and coarse woody cover or moss cover in either the transect sites or first nest and control (Table 4.10 and Table 4.11). A decrease in litter cover was found to be strongly correlated with nest presence (Table 4.10). Nest presence was associated with a site litter cover of between 0 and 20% whereas sites that did not contain nests were associated with cover ranging from 0 to 60%. The logistic regression plot shows that the probability of finding a nest in a site was highest at 0% litter cover (about 0.3) and decreased to zero at 90% litter cover (Figure 4.8). However, the resulting ROC value (0.645) fell below the acceptable level of the model's ability to discriminate presence from absence of sites with nests (0.7). The analysis of the first nest and its control showed similar results, although the difference was not significant (Table 4.11).

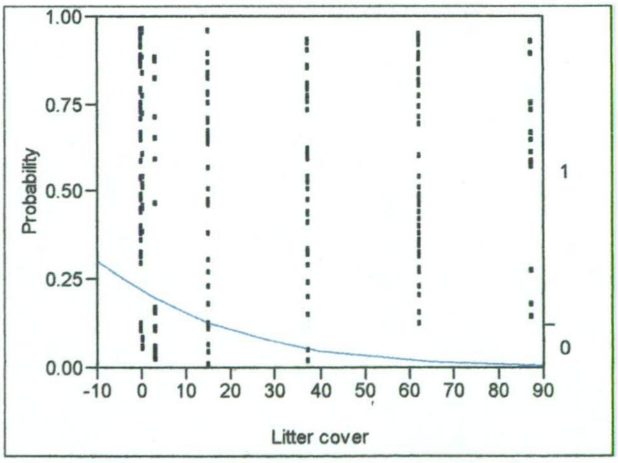


Figure 4.8: Logistic regression showing the probability of a site containing a nest according to percentage of litter cover (P=0.0001, R^2=0.1072, ROC=0.645).

Litter depth was negatively correlated with nest presence (Table 4.10).The mean depth for presence of nests was 0.85cm whereas the mean depth for absence was 1.96cm. The logistic regression plot shows that the probability of nest presence against litter depth

(Figure 4.9). However, the resulting ROC value (0.625) fell below the acceptable level of the model's ability to discriminate presence from absence of sites with nests. The analysis of the first nest and its control yielded data that were not significant (Table 4.11).

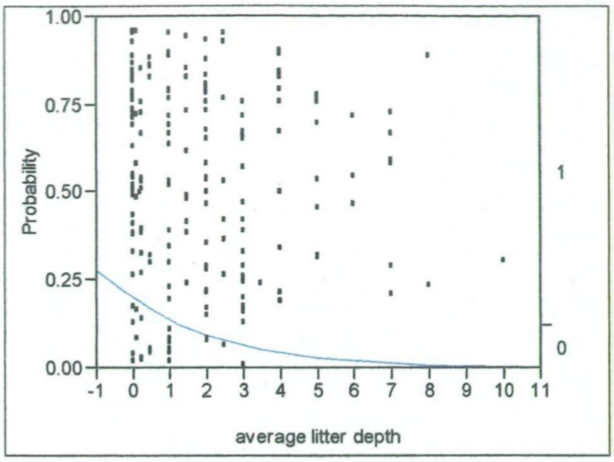


Figure 4.9: Logistic regression showing the probability of a site containing a nest with litter depth (cm) ($P=0.0033$, $R^2=0.0590$, ROC=0.625).

Nests were found in sites with between 10 to 60 % canopy cover, particularly within the range of 10 to 30 % and sites with nests having considerably less canopy cover on average, than sites without nests (Table 4.10). Sites without nests spanned a larger range in canopy cover than those with nests. The logistic plot shows that the probability of finding a nest decreases with a canopy cover. The plot was significant, but its ROC fell below the acceptable level (Figure 4.10). The results of the canopy cover photographs taken above the first nest found and a corresponding control site showed no correlation with nest presence (Table 4.11).

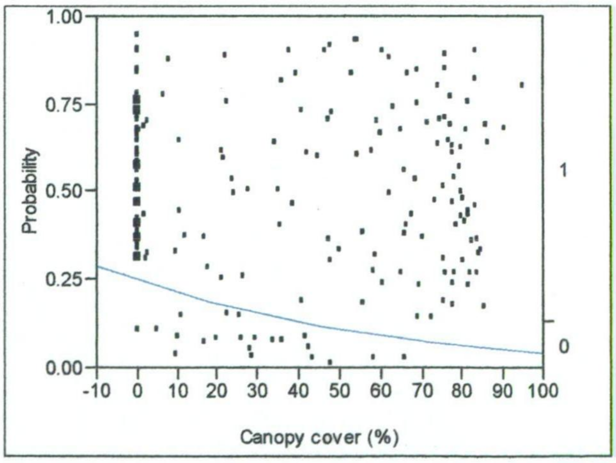


Figure 4.10: Logistic regression showing the probability of a site containing a nest with a percentage of canopy cover ($P=0.0070$, $R^2=0.0559$, ROC=0.67445).

Nests were found to be on average closer to a *Eucalyptus* tree than the control point and deviated less (Table 4.11). The logistic regression plot shows that the probability of a nest being found within 1m to a eucalypt tree was higher than 0.75, whereas the probability of a nest being found 13m from a tree was zero (Figure 4.11).

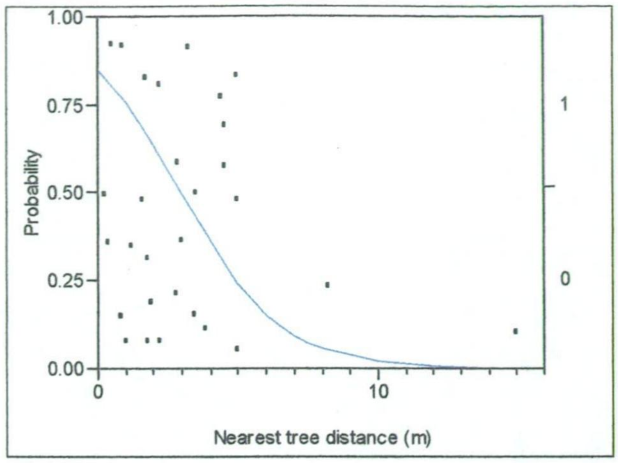


Figure 4.11: Logistic regression showing probability distance from nearest tree (P=0.0088, R^2=0.1711, ROC=0.752).

Table 4.10: Nest survey environmental variables (ANOVA and Wilcoxon) (Bold p-values indicate significant results) (For histograms of residuals and boxplots see Appendix XV and Appendix XX)

Variable	Nest presence				Nest absence				ANOVA		Wilcoxon	
	Mean	SD	Low	High	Mean	SD	Low	High	F ratio	P > F	Z	P > |z|
Altitude (m)	334.96	224.27	109	942	515.67	391.26	38	1260	$F_{1,186}$=4.8862	**0.0282**	-1.65985	0.0969
Slope (°)	17.29	9.26	2	38	17.76	12.08	0	52	$F_{1,199}$=0.0336	0.8548	0.01505	0.9880
Soil clay content (%)	24.35	13.53	2.5	50	22.96	11.47	2.5	50	$F_{1,147}$=0.2687	0.605	0.81615	0.4144
Rock Cover (%)	16.37	27.13	0	87.5	18.98	25.48	0	87.5	$F_{1,199}$=0.1978	0.6570	1.53808	0.1240
Bare ground cover (%)	17.50	24.24	0	87.5	4.84	11.30	0	87.5	$F_{1,199}$=18.6790	**0.0001**	3.46603	**0.0005**
CWD cover (%)	6.58	8.84	0	37.5	8.86	13.15	0	62.5	$F_{1,199}$=0.6732	0.4129	0.59414	0.5524
Moss cover (%)	5.31	9.05	0	37.5	11.32	16.73	0	62.5	$F_{1,199}$=2.9619	0.0868	-0.91611	0.3596
Litter cover (%)	8.08	10.79	0	37.5	29.61	29.03	0	62.5	$F_{1,199}$=12.9021	**0.0004**	-2.33769	**0.0194**
Litter depth (cm)	0.85	0.82	0	3	1.96	2.07	0	10	$F_{1,199}$=6.6892	**0.0104**	-2.01014	**0.0444**
Canopy cover (%)	28.36	16.92	0	65.75	47.36	31.83	0	95.16	$F_{1,166}$=7.4891	**0.0069**	-2.63594	**0.0084**

Table 4.11: Nest survey first nest and control environmental variables (ANOVA and Wilcoxon) (Bold p-values indicate significant results) (For histograms of residuals and boxplots see Appendix XXI and Appendix XXII).

Variable	Nest presence				Nest absence				ANOVA		Wilcoxon	
	Mean	SD	Low	High	Mean	SD	Low	High	F ratio	P > F	Z	P > |z|
Rock Cover (%)	11.40	17.51	0	62.5	8.18	16.37	0	62.5	$F_{1,28}$=0.2610	0.6136	-0.24766	0.8044
Bare ground cover (%)	28.47	20.64	0	62.5	16.36	24.24	0	87.5	$F_{1,28}$=2.1051	0.1583	-2.01082	**0.0443**
CWD cover (%)	8.60	3.48	0	62.5	4.43	3.60	0	15	$F_{1,28}$=0.6927	0.4126	0.45047	0.6524
Moss cover (%)	3.60	5.98	0	15	8.82	18.54	0	62.5	$F_{1,28}$=1.0731	0.3094	0.13649	0.8914
Litter cover (%)	14.87	4.59	0	62.5	20.21	17.52	0	62.5	$F_{1,28}$=0.6544	0.4256	0.95556	0.3393
Litter depth (cm)	0.75	0.70	0	2.5	1.20	1.30	0	4	$F_{1,28}$=1.3851	0.2495	0.64264	0.5205
Canopy cover (%)	39.24	23.46	0	76.97	35.71	25.14	0	88.22	$F_{1,27}$=0.1472	0.7043	0.48245	0.6295
Dist. to nearest tree (m)	2.07	1.33	0.27	5.00	4.40	3.63	0.50	15.00	$F_{1,28}$=5.3830	**0.0281**	2.29270	**0.0219**

4.1.3 Nest characteristics

Most of the nests found in the habitat survey were similar in structure (Table 4.12, Figure 4.12, Figure 4.13, Figure 4.14, Figure 4.15, Figure 4.16, Figure 4.18, Figure 4.19, Figure 4.20 and Figure 4.21). Nests were found built around many 'emergent structures', often built around rocks and clumps of grass. Nests were decorated with stones, soil, seeds, charcoal, small sticks and on one occasion, small vertebrate bones. There were often plants surrounding the nest including *Themeda triandra* and *Poa rodwayi.* An exception to this similar structure, was one nest found in, what appeared to be, a crack in sandstone rock bedding (Figure 4.17).

Table 4.12: Observations made about the first nest found in each transect.

Transect Site	Emergent structure	Decoration material	Plants around nest
H4	*Poa rodwayi*	Stones, soil, seeds	*Themeda triandra*
H12	Clumps of *Themeda triandra* and *Austrostipa spp.*	Soil, seeds, small sticks	*Themeda triandra*
H15	*Poa rodwayi*	Soil, charcoal, small sticks, leaves	
H29	Rock (19x19x19cm)	Stones, charcoal, small sticks	*Lepidosperma concavum*
H31	*Pultenaea juniperina*	Stones, charcoal, small bones	
H44	None	Stones, soil, charcoal, small sticks	*Austrodanthonia caespitosa*
H46	None	Stones, charcoal	none
H48	*Poa rodwayi*	Soil, charcoal	*Lomandra longifolia*
H114	Mound of Grass	Stones, soil, charcoal, seeds, small sticks, small leaves	
H117	Rock (size was not recorded)	Stones, soil, seeds, small sticks, Hakea needles	Built around *Hakea lissosperma*
H127	Rock (size was not recorded)	Stones, soil, small sticks	
H131	None	None	*Poa rodwayi*
H134	*Poa rodwayi*	Charcoal, seeds, small sticks	
H140	Rock (20 x20x20cm)	Stones, soil, seeds	
H142	Burnt CWD of about 5cm diameter	Stones, charcoal, seeds, small sticks, sand, leaves	
H151	Rock (15x10x6cm)	Soil, charcoal, seeds, small sticks	*Themeda triandra, Poa spp.*
H155	None	Stones, soil, charcoal	*Dianella revoluta, Acacia myrtifolia*
H162	*Poa rodwayi*	Soil, charcoal, seeds, small sticks	*Poa rodwayi, Astroloma humifusum*
H168	*Dianella revoluta*	Stones, soil, seeds, small sticks	*Poa spp., Leptospermum scoparium*
H176	Built on rocks	Soil, seeds	*Poa rodwayi, Themeda triandra*
H180	*Poa rodwayi*	Stones, small sticks	
H183	Rock (10x5cm), *Dianella brevicaulis*	Stones, soil, charcoal, seeds, small sticks	
H185	CWD - 6cm diameter	Soil	*Poa rodwayi*
H186	None	Soil	*Themeda triandra*

Figure 4.12: Nest at site H29.

Figure 4.13: Nest at site H31.

Figure 4.14: Nest at site H44.

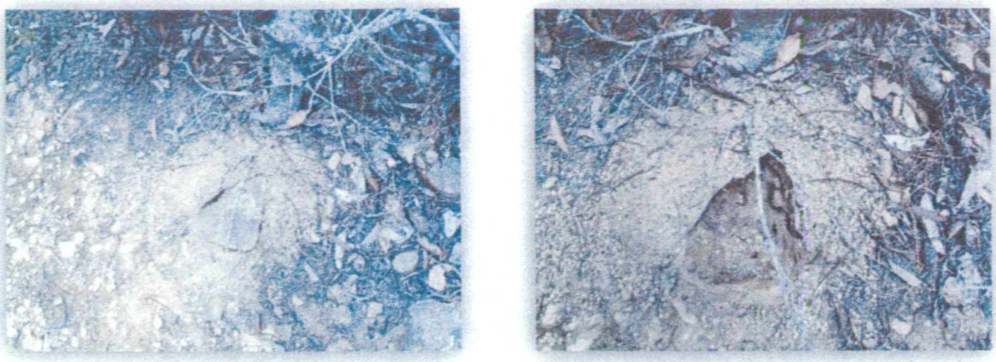


Figure 4.15: Nest at site H117.

Figure 4.16: Nest at site H127.

Figure 4.17: Nest at site H131.

Figure 4.18: Nest at site H155.

Figure 4.19: Nest at site H176.

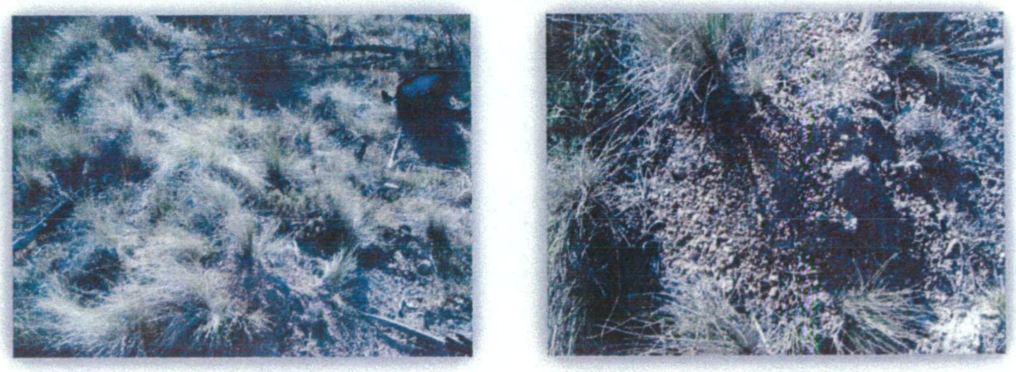


Figure 4.20: a) and (b): Nest at site H180

Figure 4.21: Nest at site H183.

4.2 Hobart Properties survey

4.2.1 Responses

A total of 210 completed questionnaires were returned via email and post from the 29th of January until the 15th of April 2008, and 68 of the completed surveys fell within the study boundaries of Hobart City Council and were therefore kept for analysis in this study. The remaining questionnaires were put aside to use in an extended study after the completion of the thesis, when more time allowed.

4.2.2 Section A: The participant's property

The only strong relationships between the variables were between property size and building cover and native bush and building cover (Table 4.13, Table 4.14 and Appendix XVI).

Table 4.13: Correlation of participant's estimates (Bold values indicate strong relationship > 0.5, < -0.5)

	Property size	Buildings	Concrete	Bitumen	Paving	Lawn	Trees	Veg patch	Native bush
Buildings	**-0.7121**								
Concrete	-0.1491	0.1933							
Bitumen	0.0263	-0.0440	-0.1218						
Paving	-0.2324	0.1658	-0.0697	-0.0720					
Lawn	0.2855	-0.3559	-0.1223	-0.3516	-0.1213				
Trees	0.0463	-0.1244	-0.1248	-0.0658	-0.0038	0.1252			
Veg patch	0.2090	-0.0591	-0.1103	0.2000	-0.1217	-0.0358	-0.1571		
Native bush	0.3973	**-0.6045**	-0.3816	0.0441	-0.1729	-0.2652	-0.1827	-0.1491	
Flower garden	-0.0654	0.0281	0.3111	-0.0518	0.1772	-0.1870	0.1363	-0.2806	-0.1834

Table 4.14: Non- parametric correlation test (Spearman ρ) highlighting the collinearity of certain participants' estimates (Only values with strong relationship > 0.5, < -0.5 and significance p < 0.05 are shown. For complete table see Appendix XVII).

Covariates		Spearman ρ	Prob>|ρ|
Buildings	Property size	-0.6703	< 0.0001
Native bush	Buildings	-0.5808	<0.0001

Nests and ants were more likely to be found on larger properties than smaller properties (Table 4.15).

Table 4.15: Chi^2 test of percentage of properties in each size category (Bold p-values indicate significant results).

Property Size	Number of sites	Nest Presence (%)	Nest Absence (%)	Chi^2	P
Small	7	14.29	85.71	8.042	**0.005**
Medium	21	57.14	42.86	0.485	0.486
Large	40	75	25	5.783	**0.016**

The 2-dimensional NMDS ordination of the participants' properties shows that there was a trend of more properties without ants with a decrease of natural bush cover and an increase of building cover (Figure 4.22). However, the properties with some nests were still apparent with a decrease in natural bush cover and an increase in building cover.

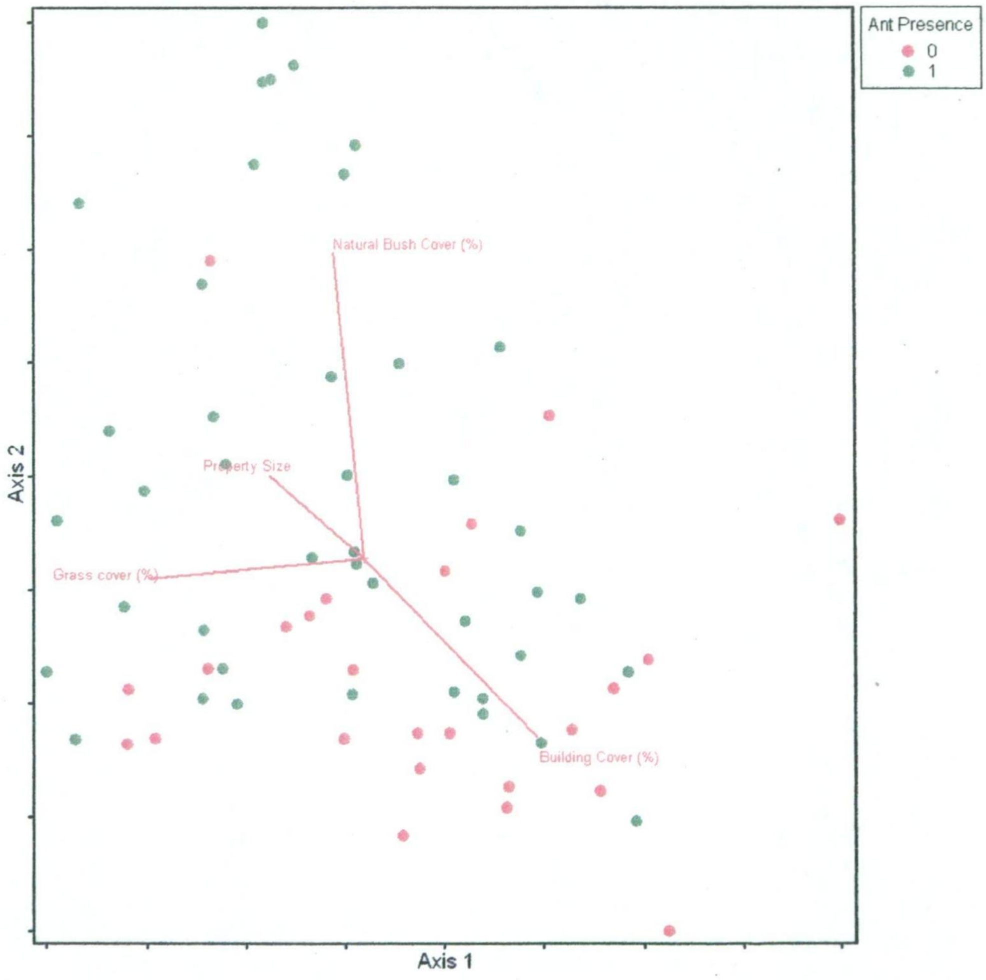


Figure 4.22: NMDS ordination of participants' properties based upon a range of environmental variables in Section A. The occurrence of nests is indicated (Stress in 2D=16.57%, R^2 cut off= 0.200).

The analyses of the participant's estimated property percentages revealed no correlation between ant/nest presence and concrete cover, bitumen, paving, lawn/grass, flower garden and non-native tree cover (Table 4.16). The relationships between ant/nest presence and building cover, vegetable patch cover and native vegetation cover were highly significant. Presence of ants was negatively correlated with greater building cover. The logistic regression plot shows that in this survey there was a probability of 0.75 of finding nests when the estimated building cover was below 20% and a 0.25 probability of finding a nest when the cover was 60% (Figure 4.23). Vegetable patch cover was shown to be negatively correlated with ant presence. The logistic plot of vegetable patch cover shows this trend but the resulting ROC value (0.622) fell below the acceptable level of the model's ability to discriminate presence from absence of sites with nests (0.7)(Figure 4.24). Properties with a higher percentage of native vegetation were correlated with ants/nests. The mean cover for absences was 7.22% and the mean for presences 26.02%. The logistic regression plot shows the same pattern (Figure 4.25).

Table 4.16: Property survey participants' estimated environmental variables ANOVA and Wilcoxon (Bold p-values indicate significant results) (For histograms of residuals and boxplots see Appendix XXIII and Appendix XXIV).

Cover (%)	Ant presence				Ant absence				ANOVA		Wilcoxon	
	Mean	SD	Low	High	Mean	SD	Low	High	F ratio	P > F	Z	P > |z|
Building	26.86	18.63	1	80	43.12	19.13	10	95	$F_{1,66}$=11.7107	**0.0011**	3.26225	**0.0011**
Concrete	7.65	7.20	0	25	9.24	10.85	0	40	$F_{1,66}$=0.5172	0.4746	0.29638	0.7669
Bitumen	1.93	4.29	0	15	2.00	5.20	0	20	$F_{1,66}$=0.0037	0.9517	-0.23285	0.8159
Paving	3.00	4.39	0	20	2.31	3.30	0	10	$F_{1,66}$=0.4635	0.4984	-0.46599	0.6412
Lawn/grass	17.93	18.81	0	69	17.24	16.7339	0	55	$F_{1,66}$=0.0228	0.8806	-0.15666	0.8755
Flower garden	5.48	6.62	0	25	4.07	4.81	0	20	$F_{1,66}$=0.8558	0.3583	-0.62190	0.5340
Vegetable patch	3.05	3.96	0	20	8.30	12.06	0	50	$F_{1,66}$=6.7976	**0.0113**	1.70583	0.0880
Non-native tree	5.81	6.67	0	25	6.50	7.33	0	30	$F_{1,66}$=0.1559	0.6942	0.38345	0.7014
Native vegetation	26.02	26.50	0	85	7.22	13.81	0	59	$F_{1,66}$=10.7974	**0.0016**	-3.69170	**0.0002**

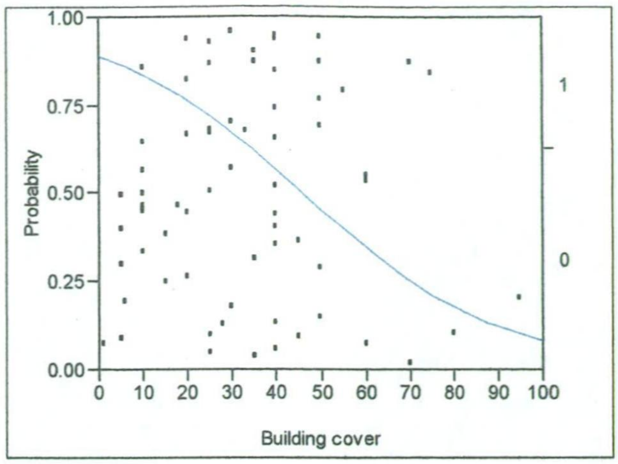


Figure 4.23: Logistic regression showing probability of ant/nest occurrence against % of building cover ($P=0.011$, $R^2=0.1209$, ROC=0.739).

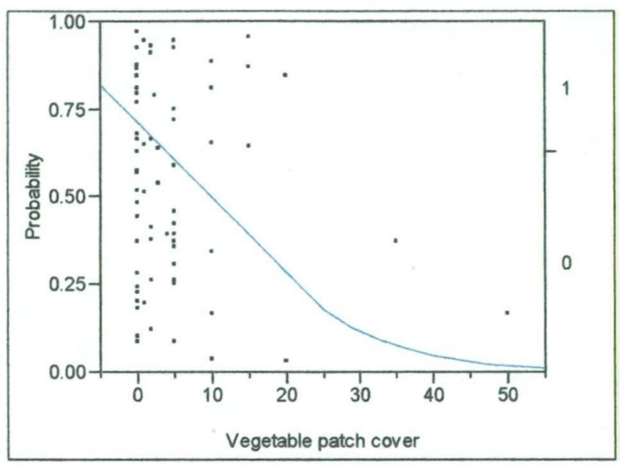


Figure 4.24: Logistic regression showing probability of ant/nest occurrence against % of vegetable patch cover ($P=0.083$, $R^2=0.0787$, ROC=0.622).

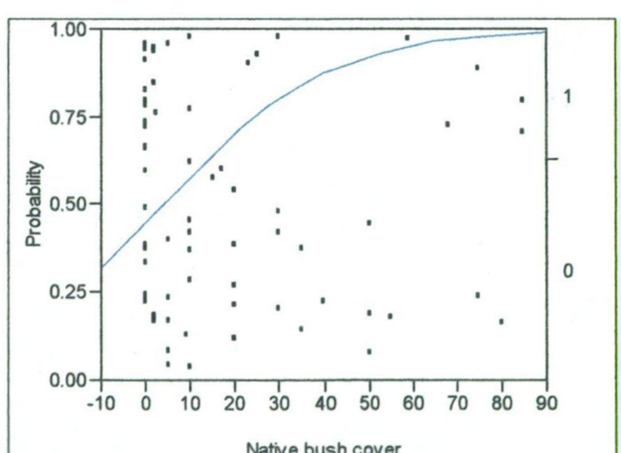


Figure 4.25: Logistic regression showing probability of ant/nest occurrence against % of native bush cover ($P=0.0004$, $R^2=0.1396$, ROC=0.768).

4.2.3 Section B: Jack jumpers on the participant's property

The participant's comments indicated that an encounter with a nest occurred in a variety of places (Figure 4.26). Some notable locations were rocky environments such as block walls and rockeries, under paving stones and on driveways or paths. Participants also noted that nests can be found on grass, in gravel and near non-native bush. Nests were also frequently found in dry and sandy soil/dirt. One participant wrote that:

> *'..numerous nests have been located over the years mostly in the vicinity of a long rock wall and surrounding garden where the ground is very dry and crumbly and there are quite a few tiny pebbles around which they seem to use for their nest. They seem to like making nests between the rocks on the freestone wall'* (Participant No. 2 = P2).

Another found nests in both sandy and clayey locations:

> *'In rough lawn, clay soil, under concrete (entrance through crack/space where 2 slabs joined) and in a sand filled besser block (entrance through open blocks at top)* (P42).

Native bush was a constant theme as well as the proximity of nests to native trees. One participant noted that the nests were found:

> *'...approx 5m from the bush, 4m from the house. (There are) many gum trees in the area'* (P24).

In another property nests were found near:

> *'...native cherry, E. ovata, E. globulus and E. amygdalina'* (P27).

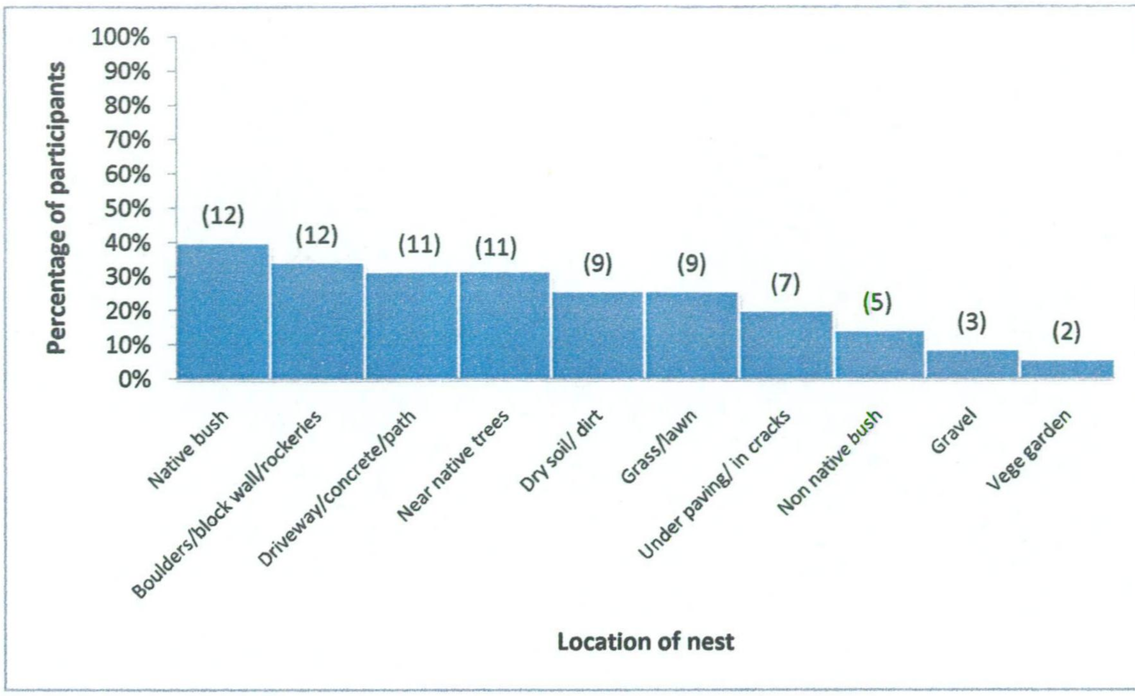


Figure 4.26: Percentage of participants who recorded certain localities for jack jumpers nests (number of participants in brackets).

Encounters with ants followed a number of themes (Figure 4.27). The most common place to see a jack jumper ant was walking along hard ground such as bitumen, concrete or paving. The next most common sightings were in eucalypt trees and native bush. Ants were also commonly encountered in non-native bush and lawn or grass as well as in vegetable gardens. One participant commented that they were found:

> *'...in the vegetable garden (e.g. climbing on raspberry bushes)'* (P59).

Interestingly, jack jumpers were also encountered on clothes lines as well as inside the participant's house. One participant saw a jack jumper climbing on a clothes line and another noted that they had spotted them:

> *'...on the steps, wheelie bins, on the gum tree and the birch, on the driveway on the hose, on the asparagus, fern and they like the blackcurrant bush too! One in the car. Occasionally on the carpet of the living room in the height of summer* (P36).

In contrast, some participants also noted that they had never seen a jack jumper ant inside their house. One participant despaired at finding them in:

> *'...trees, bitumen, rocks, grass, windows, floor, car, bloody everywhere!'* (P19).

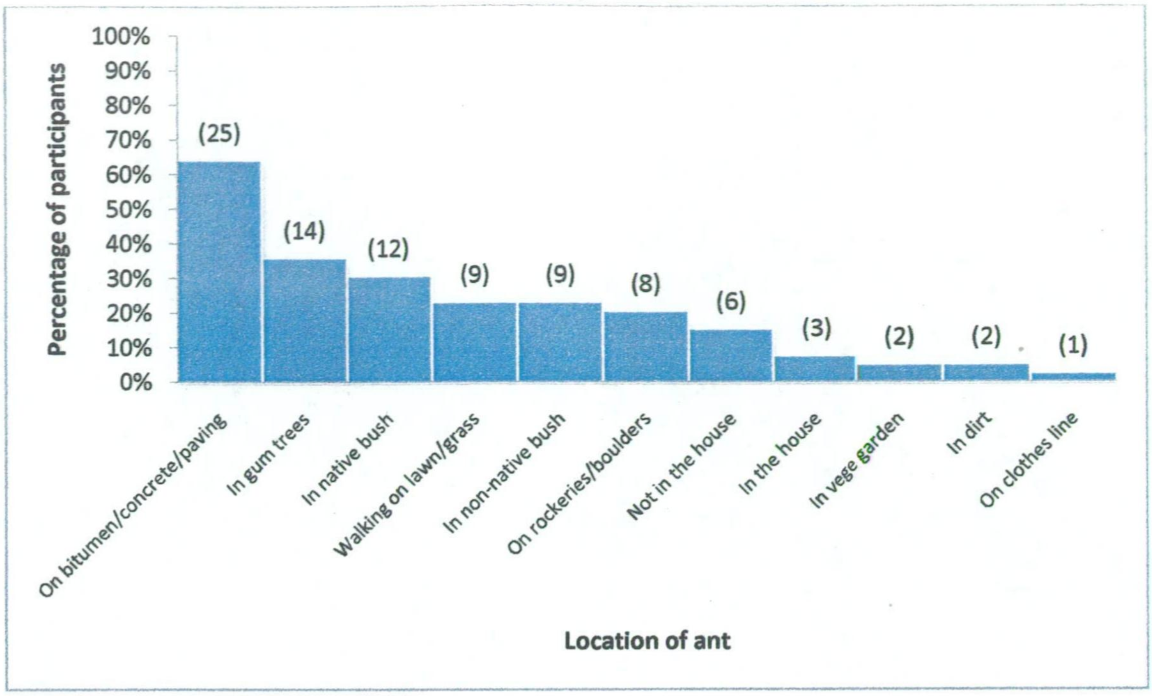


Figure 4.27: Percentage of participants who recorded certain localities for jack jumper ants (number of participants in brackets).

By far the most common activity that resulted in a jack jumper sting was gardening (Figure 4.28). One participant wrote that they had been stung:

> *'...three times, twice on hands - pulling out passion fruit, pruning roses, once on foot - walking down steps near nest'* (P41).

A sting whilst walking in the garden with bare feet was common, as too was a painful encounter on grass or lawn. Another notable theme was ants dropping from both native and non-native vegetation onto participants to then administer a sting. One participant noted that:

> *'...my son was stung by jack jumper which was in my hair. Probably fell from raspberry cane into my hair when I walked passed them. Son gave me hug'* (P6).

Painful encounters with ants occurred in a whole host of interesting places. One participant stated that while they were:

> *'...feeding our pet rabbit two ants got in my daughters shoe and stung her numerous times'* (P18).

Another participant has been stung:

'...weeding (many times), washing the car, watering the garden (it ran up hose), x2 digging (they ran up leg), one fell from the gum tree and stung me when it got caught under my watch band' (P36).

One participant even claims that:

'They seem to chase me and I have to be very careful. Under no circumstances would I ever go out in summer bare-footed. Gardening and weeding is not recommended either' (P22).

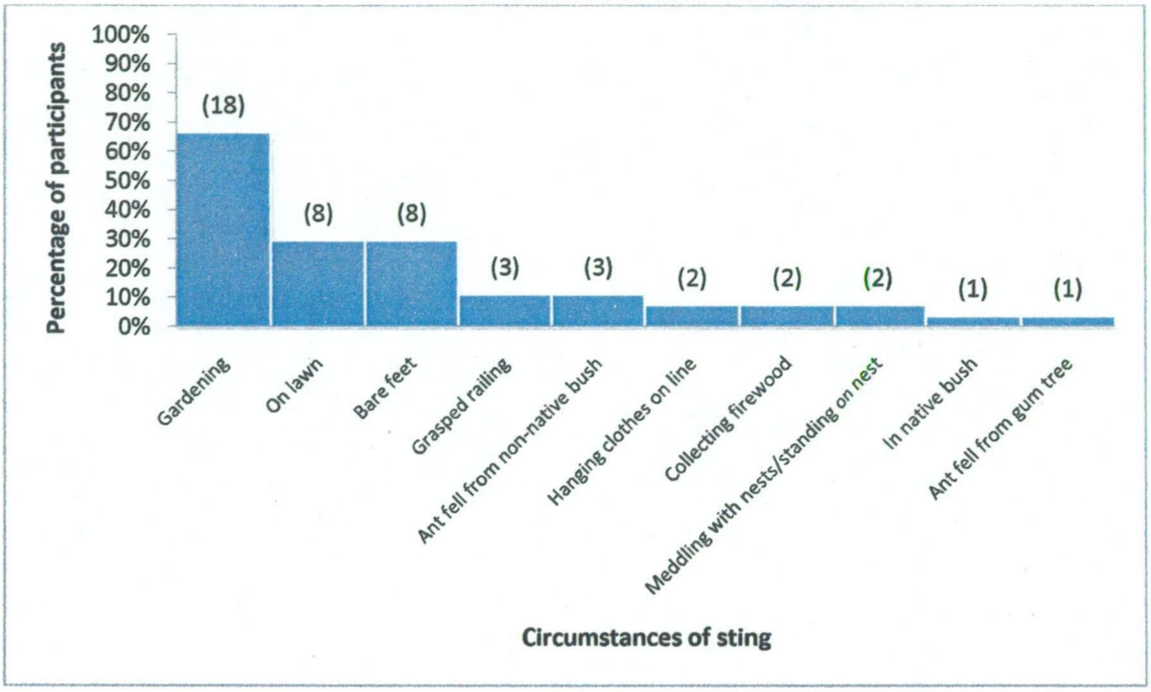


Figure 4.28: Percentage of those stung to report a particular circumstance of that sting (number of participants in brackets).

4.2.4 Section C: The participant's address

The locations of addresses containing nests were all closer to native bush than those without, which tended to be located in the built up areas of central Hobart (Figure 4.29).

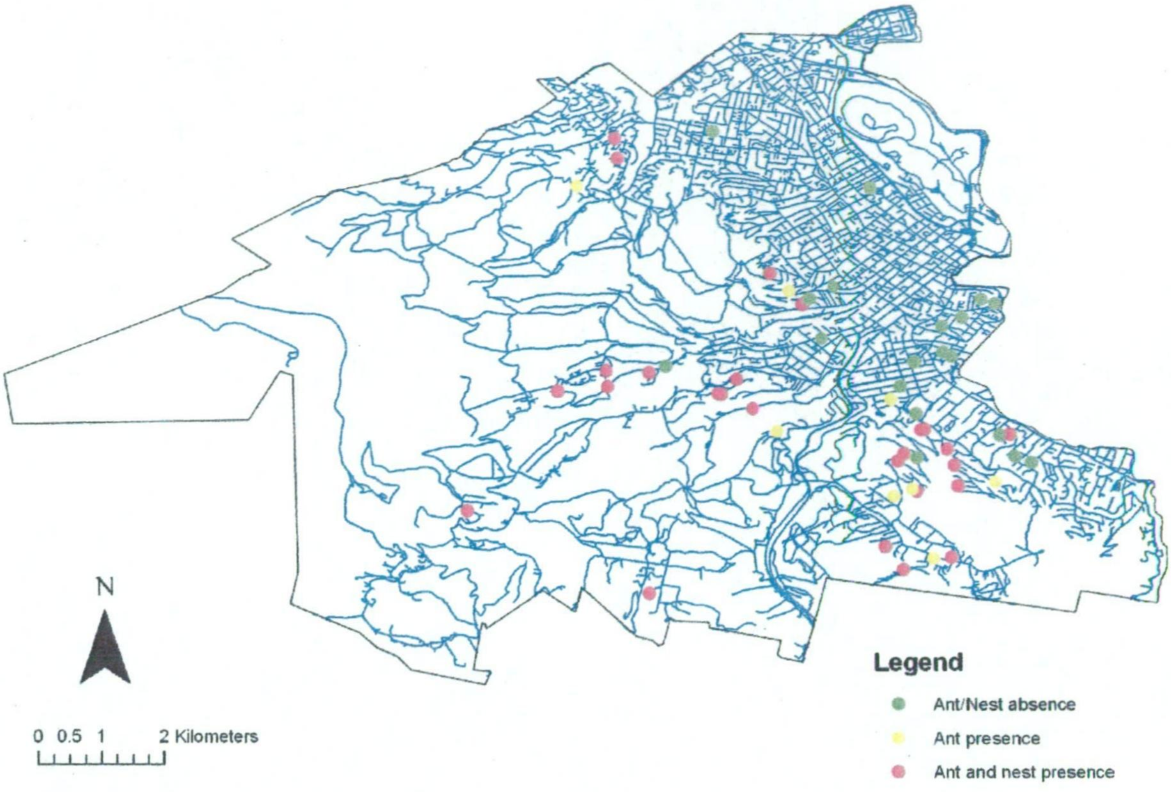


Figure 4.29: Locations of the participant's properties. Please note: locations were obtained using Google Earth and may be inaccurate up to 30 metres. Properties where the occupier did not supply the full address were omitted from the map (10 properties) (Google Earth 2008) (Base data from theLIST, © State of Tasmania. Projection: UTM, Zone 55. Datum: GDA 94).

As expected, there were strong correlations between a number of the circle environmental variables and distance to nearest native vegetation (Table 4.17, Table 4.18 and Figure 4.30).

Table 4.17: Correlation between the circle environmental variables and nearest native vegetation (Bold values indicate strong relationship > 0.5, < -0.5)

	Distance to native veg	Native veg	Hard surfaces	Soft surfaces	Grass	Non-native vegetation
Native veg	**-0.5114**					
Hard surfaces	**0.5580**	**-0.7149**				
Soft surfaces	-0.3741	0.1753	-0.0759			
Grass	-0.1550	**-0.3430**	-0.0718	-0.0694		
Non-native vegetation	**0.3332**	**-0.6872**	0.3494	-0.4270	0.0705	
Buildings	**0.6621**	**-0.7581**	**0.5418**	-0.3566	-0.1171	**0.5072**

Table 4.18: Non- parametric correlation test (Spearman ρ) highlighting the collinearity of certain circle environmental variables and distance to native vegetation (Only values with strong relationship > 0.5, < -0.5 and significance p < 0.05 are shown. For complete table see Appendix XVIII)

Variable 1	Variable 2	Spearman ρ	Prob>|ρ|
Native vegetation	Distance to native vegetation	-0.8960	<0.0001
Hard surfaces	Distance to native vegetation	0.7045	<0.0001
Hard surfaces	Native vegetation	-0.8094	<0.0001
Non-native vegetation	Distance to native vegetation	0.7810	<0.0001
Non-native vegetation	Native vegetation	-0.7870	<0.0001
Non-native vegetation	Hard surfaces	0.5244	0.0001
Buildings	Distance to native vegetation	0.7711	<0.0001
Buildings	Native vegetation	-0.8100	<0.0001
Buildings	Hard surfaces	0.6299	<0.0001
Buildings	Non-native vegetation	0.6527	<0.0001

Ant presence was strongly correlated with distance to nearest patch of native vegetation. The mean for the presence of ants was 26.6 metres with a relatively small standard deviation, yet the mean for absence of the ant was 594 m with a very large standard deviation.

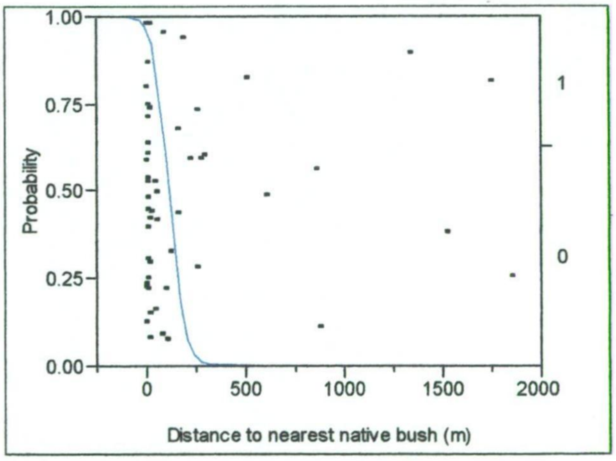


Figure 4.30: Logistic regression showing probability of ant/nest occurrence against distance to nearest patch of native bush cover (P=0.001, R^2=0.6529, ROC=0.931).

The 3-dimensional ordination of the circle environmental variables (native vegetation, non-native vegetation, hard surfaces, soft surfaces, grass and buildings) shows that absences were strongly correlated with a higher percentage of buildings and hard surfaces and that presence of nests was correlated with an increase in native vegetation cover and soft surface cover (Figure 4.31).

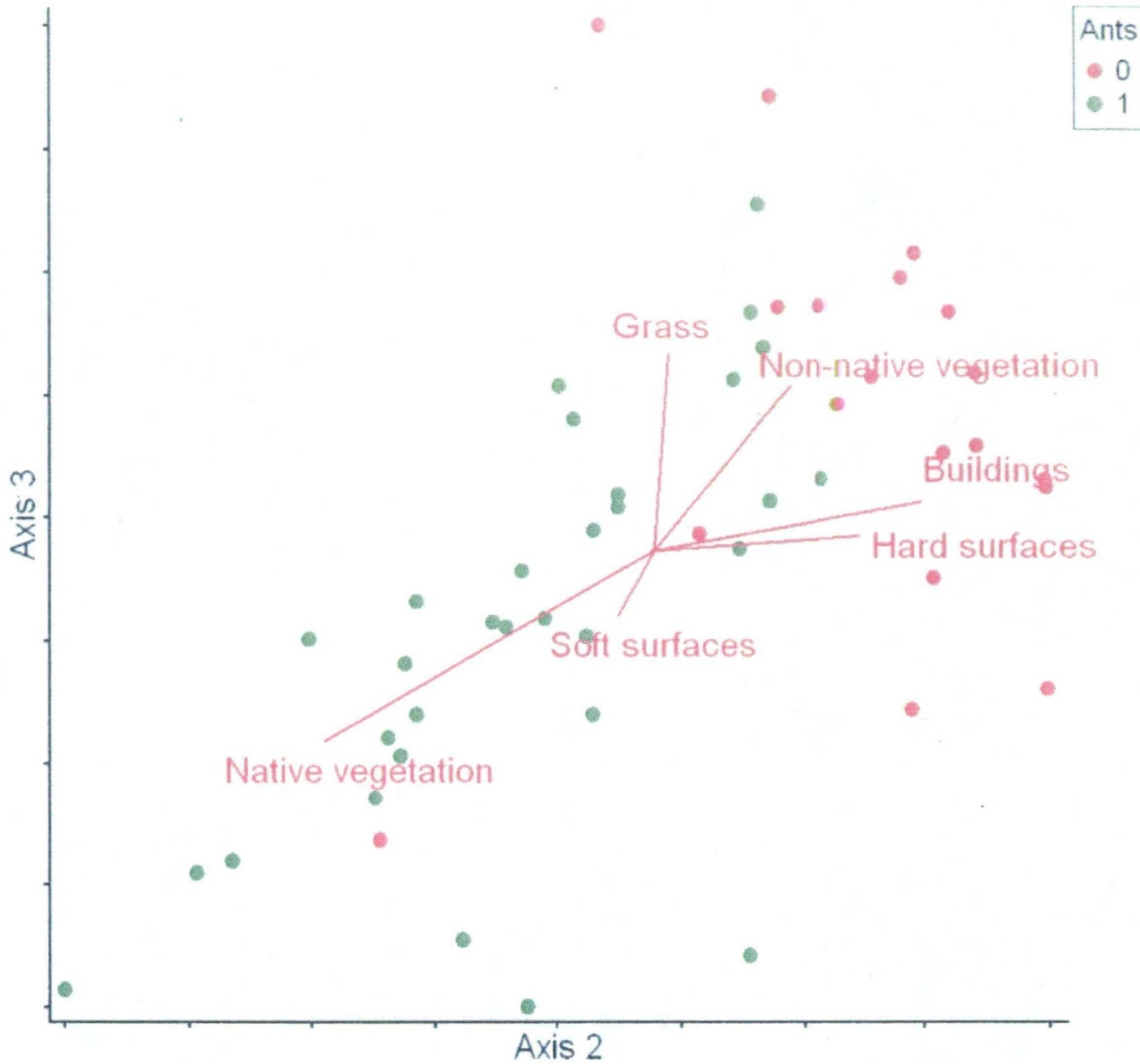


Figure 4.31: NMDS ordination of properties based on estimated percentages of circle environmental variables in Section C against the occurrence of ants (Stress in 3D=9.936%, R^2 cut off= 0.200)

The ANOVA and Wilcoxon tests of the circle environmental variables against ant and nest presence, with the exception of grass cover percentage, reveal that the data were highly significant (Table 4.19). Ant presence was shown to be strongly associated with a larger percentage cover of native vegetation cover, with the presence of ants always associate with some amount of native vegetation within the 100m radius circle. The logistic regression plot also shows that, in this survey, the probability of ant presence sharply rose from 0 to 60% (Figure 4.32). Ants were also associated with a larger cover of soft surfaces such as sand and dirt (Figure 4.34). Ant presence was correlated with a smaller amount of non-native vegetation, hard surfaces such as bitumen and concrete and building cover. Logistic regression plots for all of these variables show similar patterns (Figure 4.33, Figure 4.35 and Figure 4.36). Grass cover did not show any correlation to presence of nests.

Table 4.19: Property survey estimated circle environmental variables ANOVA and Wilcoxon (Bold p-values indicate significant results) (For histograms of residuals and boxplots see Appendix XXV and Appendix XXVI).

Variable	Ant presence				Ant absence				ANOVA		Wilcoxon	
	Mean	SD	Low	High	Mean	SD	Low	High	F ratio	P > F	Z	P > |z|
Distance to native vegetation (m)	26.6	32.2	0	122.6	594.00	601.6	5	1853	$F_{1,50}$=28.7241	**0.0001**	5.09516	**0.0001**
Building cover (%)	17.1	7.77	5	30	35.00	12.50	5	55	$F_{1,50}$=40.1182	**0.0001**	4.61034	**0.0001**
Soft surface cover (%)	8.06	6.23	0	25	3.42	3.36	0	10	$F_{1,50}$=8.9474	**0.0043**	-3.15567	**0.0015**
Hard surface cover (%)	12.03	6.20	0	25	20.53	10.12	10	45	$F_{1,50}$=13.8777	**0.0005**	3.27574	**0.0011**
Grass cover (%)	18.84	10.60	0	40	18.95	11.13	5	50	$F_{1,50}$=0.0011	0.9737	-0.22738	0.8201
Non-native vegetation cover (%)	5.63	6.445	0	30	17.11	9.33	0	10	$F_{1,50}$=27.8486	**0.0001**	4.49889	**0.0001**
Native vegetation cover (%)	38.34	22.20	2	85	5.53	14.71	0	60	$F_{1,50}$=32.8081	**0.0001**	-5.12604	**0.0001**

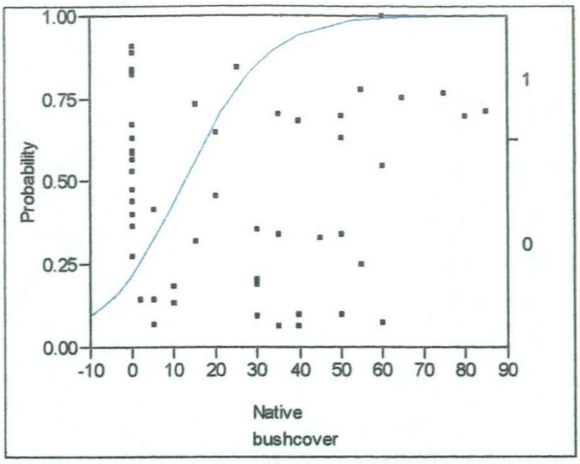


Figure 4.32: Logistic regression showing probability of ant/nest occurrence against % of native vegetation cover (P=0.0001, R^2=0.4130, ROC=0.928).

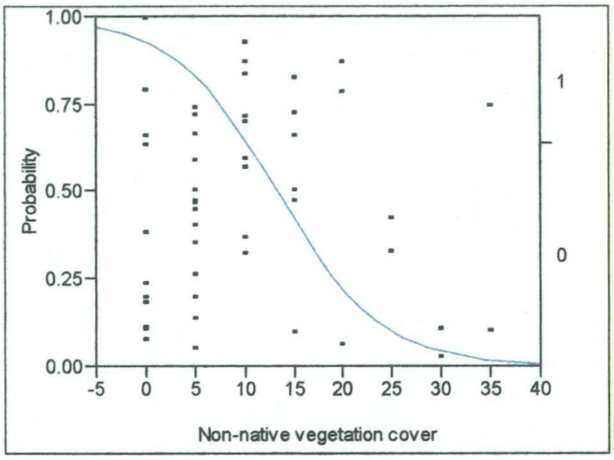


Figure 4.33: Logistic regression showing probability of ant/nest occurrence against % of non-native vegetation cover (P=0.0001, R^2=0.3183, ROC=0.878).

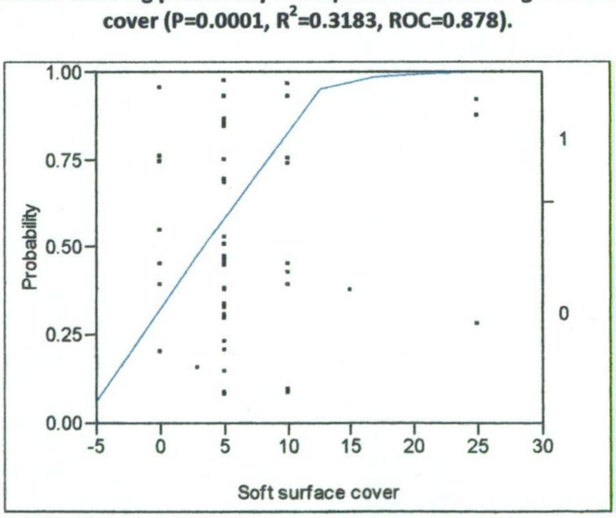


Figure 4.34: Logistic regression showing probability of ant/nest occurrence against % of soft surface cover (P=0.0004, R^2=0.1836, ROC=0.743).

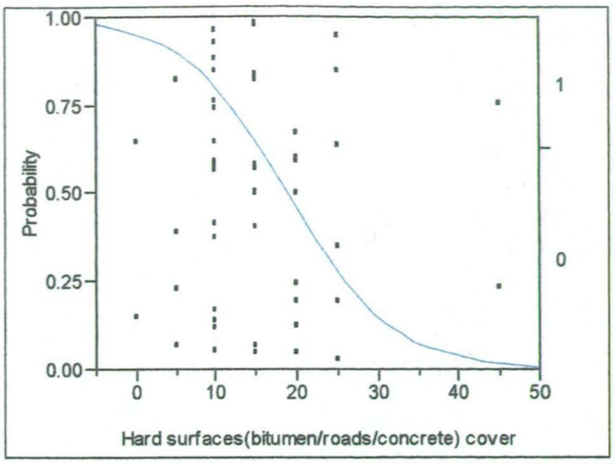


Figure 4.35: Logistic regression showing probability of ant/nest occurrence against % of hard surface cover (P=0.0003, R^2=0.1932, ROC=0.770).

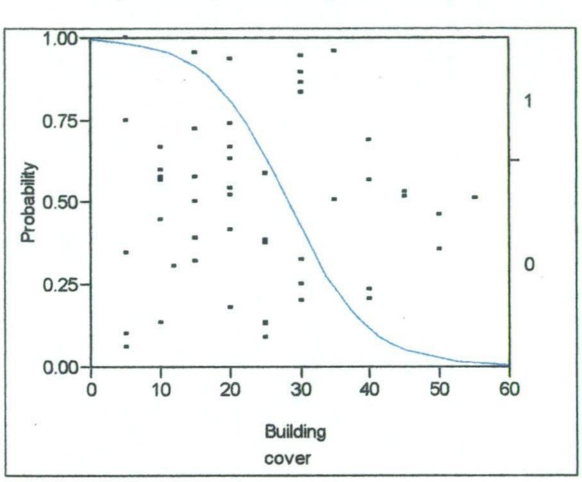


Figure 4.36: Logistic regression showing probability of ant/nest occurrence against % of building cover (P=0.001, R^2=0.416, ROC=0.887).

5 Discussion

This chapter will address the questions in chapter 2 by discussing the findings of both of the studies and attempting to synthesise these findings. Following this, the limitations and biases of the study will be addressed as well as suggestions made for further research. At the end of the chapter, the conclusion to the thesis will complete the study.

5.1 What environmental conditions do *Myrmecia pilosula* prefer to nest in?

5.1.1 Vegetation type and structure

As discussed in chapter 2, most previous ant studies have concentrated on the relationship between ant diversity and vegetation types (Lassau & Hochuli 2004; Morrison 1998; Sanders *et al.* 2003). These studies relied on pitfall trapping, which has shown to yield insufficient *Myrmecia* catches from which to draw any ecological meaning (Hoffmann & Andersen 2003). This study, however, used a nest search to explore associations between vegetation types and the *M. pilosula* species group, resulting in novel findings.

This study has shown that *M. pilosula* occurrence was found to be related to the occurrence of species of plants that prefer a dry environment (Reid & Potts 1999). These include the dry sclerophyll vegetation types of *E. pulchella, E. rubida, E. amygdalina, E. tenuiramis, E. coccifera* and *E. viminalis* forests and woodlands (Figure 5.1). Exceptions to this were where nests were found in association with *E. ovata,* that is usually found in sites that are dry but prone to waterlogging, and *E. globulus,* that is usually found in relatively moist coastal sites (Reid & Potts 1999).

Only one nest was found in *Themeda triandra* grassland. This vegetation type was encountered at the Domain, where it survives in small patches and often in close proximity to *E. viminalis* trees in vegetation types considered as grassy woodland. The nest in question was found within ten metres of a eucalypt tree and, if the transect was pointing in another direction, the vegetation might be considered as *E. viminalis* grassy open woodland. This would be consistent with the finding that nests are associated with dry eucalypt woodlands.

Figure 5.1: Example of habitat preferred by jack jumper (*E. pulchella* woodland at Ridgeway) (Photograph: Author).

One dry sclerophyll vegetation type that did not contain nests was *Allocasuarina verticillata* forest and woodland. These environments, located on the Domain and on Mt. Nelson, are usually considered to be almost monospecific communities having a low diversity of plants and invertebrates (Jackson 1999; McQuillan 2007a pers. comm.). Understorey vegetation is sparse with a dense litter layer of needles (Jackson 1999). The *A. verticillata* forest and woodland communities surveyed were typical in this sense, usually consisting of little more than an *A. verticillata* canopy with an *Austrostipa spp.* understorey. This low diversity may explain the absence of nests as it might not offer enough food in the form of nectar and invertebrate prey for the jack jumper. Another reason for the absence of nests in this vegetation type could be the lack of light due to the dense stands (the significance of light and canopy cover will be discussed below). In addition, jack jumpers may find this environment unsuitable because of the volume of needle litter that falls from the canopy possibly covering the nest, insulating it from the heat of the sun (the significance of litter and temperature will be discussed below).

In contrast, nests were almost completely absent in the wetter eucalypt types of *E. regnans, E. obliqua,* and *E. delegatensis* forests and woodlands. The one exception was a nest found in a *E. obliqua* transect, although this vegetation type is considered by some to be a dry eucalypt type (Harris & Kitchener 2005), or at the very least towards the drier end of the spectrum of wet eucalypt types (Reid *et al.* 1999). Also, nests were not found in any of the non-eucalypt vegetation types considered wetter than dry eucalypt forests; i.e. the sites dominated by *Pomaderris apetala*, *Olearia argophylla* and *Bedfordia salicina*. All these plants are dominant in moist areas such as fern gullies and stream verges or as the dense undergrowth of wet eucalypt forests (Simmons *et al.* 2008; Whiting *et al.* 2004). The results of this study therefore indicate that those environments are unsuitable for jack jumper ants.

There are several possible explanations for why jack jumpers were found to be associated with drier rather than wetter vegetation types. The first is vegetation structure. The vegetation structure in dry eucalypt forest and woodland is usually not as dense as in wet vegetation types. Most nests were found when cover in stratum 1 or 2 was 10-30% and, when cover reached higher than 30% in these strata, the likelihood of finding a nest was considerably less. This correlation between an open canopy and nest occurrence is supported by the data from the canopy cover photographs. The mean canopy cover when nests were present was 28%, whereas when they were absent it was 47%.

The most compelling explanation for this could be that the ants need a certain amount of direct insolation for warmth. As described in chapter 2, ants are poor thermoregulators and are strongly thermophilic (Holldobler & Wilson 1990). The greater penetration of sunlight through open canopy would provide them with a crucial source of warmth in a temperate area such as Hobart. This hypothesis supports Andersen (1995) who considers low temperature to be the principle abiotic stress influencing ant community structure and vegetation structure as a principle factor determining temperature. Vegetation structure determines the level of insolation at ground level and therefore regulates microclimate. Low temperature stress is high in cool and shaded habitats such as those dominated by the wetter vegetation types and moderate in cool and open habitats. Conversely, low temperature stress is low in warm and open habitats such as dry open woodlands, where exposure to wind and solar radiation is greater, resulting in a drier and warmer habitat (Andersen 1990, 1995; Arnan *et al.* 2007; Lassau *et al.* 2005). The relationship between canopy cover, typical of dry eucalypt forest and woodland, and nest occurrence noted in the nest survey indicates that low temperature stress may affect the occurrence of jack jumper nests.

The aspect data also indicates that jack jumper ants might prefer warmer spots. Nest presence was strongly correlated with aspect class 2 (north and west aspects), which is considered to be at the warmer and drier end of the aspect class range (Kirkpatrick & Nunez 1980). However, this could be a result of the fact that, around Hobart, most of the colder aspects (south, south-east, and east) are colonised by wetter vegetation types, where, as previously discussed, nests were not found.

5.1.2 Habitat complexity

The findings of the nest survey echo, more than any other study, the findings of Lassau and Hochuli (2004). Their findings were that habitat complexity, i.e. canopy cover, ground herb cover, leaf litter cover, other litter cover and soil moisture were negatively correlated with ant diversity. In this study, litter cover and litter depth have a strong negative relationship with the occurrence of nests. There are a number of possible explanations for this relationship. The first is that, litter cover and depth, as the study shows, correlate with canopy cover. This might be expected due to the greater volume of potential litter material in a denser canopy as well as the higher frequency of fire in dry eucalypt environments (Harris & Kitchener 2005). The negative relationship between canopy cover and nest occurrence may therefore also explain the negative relationship between litter cover and depth and nest occurrence which was shown to negatively influence nest presence.

Figure 5.2: Jack jumper nest with surrounding moss and leaf litter (Photograph: Author)

There are, however, a number of other reasons why litter may influence the presence of nests. Again, the relationship to temperature may be a factor. Leaf litter may insulate the nest from the sun, therefore making the site not warm enough for jack jumpers. Also, more moisture is retained when litter is denser, which negatively affects the temperature of the habitat (Lassau & Hochuli 2004).

Another possible reason why there is a relationship between litter and nest occurrence is that ant movement is more energy efficient in less complex areas where ground cover is more easily negotiable. Low complexity may make foraging, as well as the construction and guarding of nests, simpler and more efficient, although, this is speculative (Kaspari & Weiser 1999; Lassau & Hochuli 2004). According to the size-grain hypothesis , the larger the ant, and therefore the larger its legs, the flatter environment it needs for travel (Kaspari & Weiser 1999, 2007). As jack jumpers are among the largest of ants, it could be hypothesised that they prefer a less complex environment to negotiate whilst foraging and constructing and maintaining nests. This hypothesis is supported by the findings of the properties survey: there is a positive relationship between nests and bare ground cover. Also, bare ground cover was a factor in the first nest and control with ants nests found in sites with more bare ground cover than the control sites. Similarly, in the properties survey, jack jumpers were most frequently found on the bare surfaces of bitumen, concrete or paving.

However, the results do not conclusively demonstrate a less complex environment as a prerequisite for nest occurrence. Litter was observed in the environs of some nests (Figure 5.2). Also, in the properties survey, people were as likely to be stung on grass, a more complex surface, than on the bare surface of bitumen, concrete or paving. This result in a sense contradicts the other results of the property survey which noted a higher incidence of sightings on bare surfaces. It is possible that the greater number of sightings on bare surfaces is a result of a greater visibility of the ant on bare surfaces rather than evidence of actual abundance. Furthermore, those who have observed jack jumper ants know that they are extremely agile, often leaping down from heights and capable of jumping several centimetres at a time. Surface complexity therefore, would not necessarily be a prohibitive factor in nest location for the ants. However, as it is a lot less efficient to negotiate a more complex habitat, a simpler environment might be preferable for the ant.

A more speculative reason for the negative relationship between litter and nest occurrence could be the life forms of leaf litter. Litter contains a diversity of life forms including a myriad of invertebrates, fungi, lichens, protozoa and bacteria (Gray 2008). Jack jumpers may be compromised by or be uncompetitive against some of these life forms. For example, there could be life forms that are parasitic on jack jumpers, disadvantaging them against other species (Holldobler & Wilson 1990). Although there is a lack of knowledge regarding the pathobiology of ants, Holldobler and Wilson (1990) discuss that the bodies of ants can be occupied by endoparasites, including nematodes, trematodes, cestodes and ectosymbionts including mites. Crosland (1988), for example, discovered lemon-shaped objects on jack jumpers, which appeared to be spores of a protozoan gregarine parasite. It is unknown and possible that litter and moisture could result in an increased parasitic fauna and therefore disadvantage jack jumpers, but this argument is speculative.

5.1.3 Altitude

My results show that jack jumpers are adapted to survive over a considerable altitudinal range within Hobart City Council. At their highest elevation, 900 metres, they were found to be associated with *E. coccifera* woodland. In Tasmania, subalpine rainforest or eucalypt forest gradually gives way to alpine heath with the boundary roughly checked by the limitations of *E. coccifera* (Kirkpatrick 1997). This boundary appears to be the limit of the jack jumper as nests were not discovered in association with the alpine heathland and shrubland of Mt. Wellington. The altitudinal limit of nest occurrence, therefore, is likely due to vegetation type changes at that altitude, rather than a direct relationship between altitude and nest occurrence. However, their limit could also be temperature related. Despite this, colonies are able to survive at these altitudes because they exploit the fact that, at depths below a few centimetres, temperature and humidity vary very little throughout the year (Holldobler & Wilson 1990). The finding that nests were larger at higher altitudes might suggest that this ability of ants to maintain a preferred temperature within the nest is increased by a larger nest. Other reasons why jack jumpers are found at such altitudes could be that there are fewer predators, such as echidnas, as a whole throughout the year, increasing their likelihood of survival or that there is potentially less competition from other species that are less adapted to these climes.

5.1.4 The importance of vegetation for food

One of the most compelling findings of the habitat survey was that *M. pilosula* preferred to nest nearer to eucalypt trees. This might indicate that species of *Myrmecia* use trees as a resource for prey and nectar (Gray 1971b, 1971a; Holldobler & Wilson 1990). This could help explain why a canopy cover of around 30% is preferred rather than 0%; as a food source is required as well as an open canopy – and dry eucalypt open woodlands provide this environment. It could also explain why no ants were found in *Poa spp.* grassland; an environment with few sources of food for the ant to forage in.

The Hobart properties survey also indicated that the ants need vegetation as a food source and as expected, they were often seen in eucalypt trees and native bush. In addition, most properties containing nests contained native bush or native trees. The comments also indicated that jack jumpers may not discriminate between native and non-native vegetation as a food source. The ant was observed on raspberry bushes, rose bushes, apple trees, climbing plants, vegetable gardens and in non native flower gardens.

Some of the places that jack jumpers were observed indicates the species' noteworthy foraging behaviour and is a testament to its adventurous activity. One participant saw a jack jumper climbing on a clothes line, on a wheelie bin and in the car. Seeing the ants in such a wide ranging places may indicate that the ant, as described by Gray (1971b) about the closely related *M. desertorum,* spends significant amounts of energy foraging for food in a variety of places. No other study has given such interesting results on the behaviour of the ant. These answers are not comprehensive results on the behaviour of the ant; however, they do give worthwhile insights as to where the ants and humans might encounter each other.

This study has found that the effect of vegetation on ant communities is dual: vegetation affects availability of food resources and the degree of ground cover, which in turn determines the microclimatic conditions of the habitat (Andersen 1990; Arnan *et al.* 2007; New & Hanula 1998). Just as in previous studies, it is difficult to uncouple the effects of shade and food resource, the two main aspects of vegetation structure that affect ants (Arnan *et al.* 2007).

5.2 What are the characteristics of a typical *Myrmecia pilosula* nest?

5.2.1 Materials and location of nest

Nests were frequently found built next to rocks. According to Holldobler and Wilson (1990), in temperate areas, ants build nests next to and under rocks for their thermoregulatory properties, with the most effective rock shape being flat and set shallowly into the soil. When these rocks are dry they have a low specific heat, requiring only a small amount of solar energy to raise their temperature. The soil underneath the rocks then heats a lot more quickly than the surrounding soil (Holldobler & Wilson 1990). This allows colonies to initiate egg laying and brood rearing much earlier than would be otherwise possible (Holldobler & Wilson 1990). The properties survey gave weight to this hypothesis. Nests were commonly described as being underneath paving stones, cracks in concrete and also in the vicinity of rocks and boulders.

The tests of geology, soil drainage and soil content did not suggest that jack jumpers prefer certain soil types apart from the finding that nests were not present in the talus rock fields of Mt. Wellington. This environment had little or no vegetation, and there was nowhere to nest other than between boulders on the rock fields. However, it is important to be mindful that, although every attempt was made to search comprehensively, nests would have been more difficult to spot in these environments and therefore could have been missed. The properties survey did, however, reveal the range of locations and environments in which nests are located when found by participants. In this survey, there was also a perception that nests are to be found in dry soils, whether they are sandy or clayey. Nests were also consistently found under rocks or cracks or in gravel, all places that could be considered warmer and drier.

Participants also found nests on the edge of paths or driveways. Reasons for this could be that the disturbed nature of the edge of a road provides suitable holes or is crumbly enough for the ants to construct a nest. Also, the open canopy of paths might provide the colony with the thermal energy from the sun it requires. Along with this, roads and paths provide thermal energy of their own. The reduction of water vapour transport on roads with hard surfaces increases the temperature of the road (Asaeda & Ca 1993). The heat is stored and released into the atmosphere overnight creating heat islands around roads and some animals, such as snakes, are known to aggregate on or near roads for this reason (Asaeda & Ca 1993; Trombulak & Frissell 2000).

5.2.2 Nest decoration and mound

Gray's (1974a) observations that nests are camouflaged with leaf litter, debris and grass were confirmed in the study, although the decorations observed of pebbles, stones, seeds, grass, soil, charcoal and on one occasion vertebrate bones, rather than camouflaging the nests, made them more conspicuous than their surrounds. According to Holldobler and Wilson (1990), this behaviour of decorating nests with dry materials that heat rapidly provides the nest with solar energy traps (Figure 5.3).

Figure 5.3: Jack jumper nest built around rocks showing plants and nest decoration (Photograph: Author)

From the results of this study, it is unclear whether Jack jumpers construct what could be considered a 'true mound' (Holldobler & Wilson 1990). True mounds are symmetrical shaped piles of excavated soil, rich in organic materials, containing interconnected galleries and chambers that serve as the living quarter (Holldobler & Wilson 1990). They are often thatched with bits of leaves and stems or sprinkled with pebbles or pieces of charcoal. True mounded nests are often confused with simple craters which are no more than rings of excavated soil around nest entrances (Holldobler & Wilson 1990). Although there were nests with symmetrical mounds (Figure 5.4), there were also nests built around rocks with no real mound. The results of this study therefore support what Gray (1974a)described; that there are two types of nests for *M. pilosula*, i.e. a simple nest structure with a shaft lacking in a mound, and a more complex structure with a mound. The ant could use cracks in concrete, brickwork and rocks as surrogates for shafts. As there were nests found that did not clearly belong to either type of nest, this study has indicated that there could also be structures that utilise the advantages of pebbles, rocks and shafts.

Figure 5.4: Jack jumper nest with symmetrical 'mound' (Photograph: Author)

5.2.3 Plants associated with nest

Nests were also found built around plants such as *Poa spp.* , *Pultenaea juniperina, Themeda triandra, Dianella revoluta* and *Dianella brevicaulis*. Plants such as *Austrodanthonia caespitosa, Lepidosperma concavum, Themeda triandra, Leptospermum scoparium* and *Astroloma humifusum,* were also found in the surrounds of the nests. These may provide structure, but most probably, as in the case of *Leptospermum scoparium,* provide the ants with a food source.

Another reason for plants surrounding the nest could be that the plants may be 'choosing' to grow there. Soil dwelling ants are important soil engineers and have a large impact on the soil ecosystem (Cammeraat & Risch 2008). They create macro-voids, galleries, chambers, organo-mineral soil aggregates and changing composition of carbon, nutrients and soil microbes within the nests (Cammeraat & Risch 2008; Lavelle 1997; Lobry de Bruin 1999). They also hold the ambient temperature and humidity at moderate levels and larger nests have been shown to usually contain more species rich and luxuriant vegetation (Holldobler & Wilson 1990). It follows, therefore, that nests are nutrient sinks (Cammeraat & Risch 2008), and this could be why there were often plants sprouting from the nest and in the surrounds.

Ants are important seed dispersal agents and can have a major effect on the success or failure of a plant species (Brew *et al.* 1989; Handel 1977). Although jack jumpers are not thought to eat any part of plant seeds, seeds were observed as part of the decoration on twelve of the nests (Figure 5.5). Plants that utilise harvester ants are known as mymecochores and in sclerophyll vegetation growing on sterile soils, there are thought to be about 1500 Australian myrmechochore species (Berg 1975). These plants employ attractive seed appendages and chemicals that induce the ants to transport the seed and are common in Australian dry heath and sclerophyll forests (Holldobler & Wilson 1990). It is not known whether myrmecochory is part of the ecology of *Myrmecia* ants, and indeed, in a test by Andersen (1988), jack jumpers did not respond to seeds of *Acacia suaveolens,* a known mymecochore . Yet it can be speculated that jack jumpers play a role in seed dispersal when they accumulate seeds on their nests as well as, in all likelyhood, drop seeds whilst in the environs of the nest as indicated by the frequency of occurrence of seeds on the nests.

Figure 5.5: Jack jumper nest decoration (Photograph: Felix Wilson)

Many participants in the properties survey stated that nests were found in grassy areas. The grass was often described as dry and in one case browned off. Grassy areas were also cited as places that people were stung by the jack jumper. Perhaps, these dry areas provide enough bare ground at the ant level to be suitable for foraging or movement. Also, the root structure of lawn may also provide a structure for the ants to build a nest around. The canopy of lawn areas is also typically open, therefore maximising access to solar energy.

5.3 How does *Myrmecia pilosula* respond to urbanisation?

In an urban and suburban context, the results of this study point to the conclusion that jack jumper ants are associated with suburbs that contain patches of native vegetation and are not associated with more heavily built up areas that do not contain native vegetation. This association is demonstrated plainly by the map of the participants' addresses which showed that ants and nests were found in most areas of Hobart except the densely built up areas of Battery Point, North Hobart, Sandy Bay and Central Hobart.

Proximity to native vegetation was shown to have a significant relationship with ant and nest presence, possibly again showing the importance of vegetation as a food source and preying grounds for the jack jumper ant. This confirms, as for ant diversity in Abensperg-Traun *et al.'s* (1996) findings, that the likelihood of jack jumpers in an area decreases with an increase in distance to nearest remnant vegetation.

According to the environmental estimates given by the participants of the Hobart properties survey, nests were more likely to be found on properties categorised as large as those categorised as small. These smaller properties were more likely to be found in the centre of Hobart, whereas larger properties are more likely to be found in the leafy suburbs of Hobart. This could indicate that jack jumpers cannot survive in the densely built up environments of Hobart city centre. However, as building cover was negatively correlated with native vegetation cover, it is difficult to say for certain that building cover rather than native vegetation cover has the major effect on jack jumper occurrence. Also, the simple fact that a larger property increases the chance of a nest being present renders this finding tenuous.

The circle environmental variables also showed that the more urbanised an area the less likely that jack jumpers are found in the area. Non-native vegetation was shown to be a negatively associated with nest presence; however, this was shown to be negatively correlated with native vegetation. Indeed, the correlation analyses showed that most of the variables used in this test were correlated with native vegetation, making it difficult to uncouple the more relevant variables from the less relevant ones. Another issue, as described earlier, could be that the decreased likelihood of finding ants or nests in a property of smaller size. Nevertheless, the finding that jack jumpers are negatively correlated with urbanisation, does suggest that jack jumpers are 'decreasers' with this kind of disturbance (Hoffmann & Andersen 2003).

This study suggests that jack jumpers do not respond well to urbanisation. However, as in previous studies of species diversity (Blair & Launer 1997; Bolger *et al.* 2000; Dickman 1987), jack jumpers do seem to be aided by patches of habitat in human dominated environments. Possibly, the mix of native vegetation, disturbed soil or rock for nest construction, and opening of the canopy that urbanisation brings, is advantageous to the ant. Also, trees on the edge of forests have been shown to produce higher concentrations of nitrogen and soluble sugars which are positively correlated with insect performance and complex boundaries among habitat types can act to increase diversity (Hunter 2002). Therefore, it is possible to speculate that the more edges of native vegetation present, the more suitable the habitat for jack jumpers, although; this hypothesis is speculative and would require testing.

One question of importance to this study might be whether this distribution will change over time. Ant species richness has been found to increase with increased site age and increased time from disturbance (Majer 1983; Majer & Brown 1986), however increased site age is associated with an increase in site complexity (Majer & Brown 1986), and as discussed previously, jack jumpers are associated less with complex habitats.

5.4 What habitats increase the risk of humans receiving a sting from *Myrmecia pilosula* and how could this risk be reduced?

5.4.1 Avoidance

The most common circumstance in which people were stung was overwhelmingly when gardening. Allergy sufferers might consider avoiding gardening altogether, or if doing so, showing extra vigilance by constantly looking for jack jumpers, and also wearing appropriate clothing such as thick gloves, thick trousers and long sleeved shirts. Another common circumstance for a sting was when walking bare foot on lawn or hard surfaces such as concrete, showing the importance of wearing shoes outside.

Many of the activities being carried out when the sting occurred were everyday activities which may be hard to avoid. For example, some participants were stung when a jack jumper was climbing on hand railings or when one fell from vegetation onto the victim. These circumstances are hard to avoid, and may happen rarely, however this demonstrates again that vigilance is needed whilst outside in an area known to contain jack jumpers. Some participants experienced stings whilst interfering with the nest, possibly indicating that the aggression from the ant is a defence mechanism and that this activity should be avoided at all costs. Experiencing a sting whilst hanging out clothes could indicate that jack jumpers may forage accidentally on clothes lines, or could also show that the concrete used to ground the clothes line offers the warmth and structure needed for a nest in close proximity to the clothes line. Avoiding climbing through vegetation and spending time under trees is a further recommendation to avoid a sting from an ant falling from above.

When on grass, sufferers should also be vigilant not to sit near a nest and also be aware that the ants can be associated with grass and wear appropriate footwear as well as avoiding sitting or rolling around on the grass.

Avoiding localities where jack jumpers may occur within Hobart City Council is very difficult. For those wishing to live where they are unlikely to encounter jack jumpers, the heavily built up areas of Hobart, such as Battery Point, or central Hobart are recommended. It may also be possible to reduce the risk by living in properties on cooler and moister south and south-west facing slopes. Recreational activities such as bush walking or cycling could be restricted to the wetter vegetation types at localities such as Fern Tree Gully on Mt. Wellington and the Truganini Reserve, and the alpine heathlands at the top of Mt. Wellington. However, there is no guarantee that suitable habitats will not be available to the ant on human modified environments in proximity to these areas (such as paths). Also, even though some alpine and sub-alpine environments might not contain ant nests, a confrontation might occur during a jack jumper nuptial flight. I witnessed such an event at the pinnacle of Mt. Field West (1434 metres high - under 100 km outside the boundaries of the study area (Chapman & Chapman 2003)), and two of my walking companions were stung on this occasion.

5.4.2 Habitat management

It is difficult to manage a property to minimise the risk of jack jumpers taking up residence. Maintaining a dense vegetation cover would help, although an adjacent property might harbour the ants which would then forage on the vegetation in the managed property. Also, this may create a fire hazard, which is not permitted within Hobart City Council (HCC 2008). Regularly watering the garden may help, as well as maintaining a litter or mulch layer. Minimising the materials that jack jumpers might use for nest building such as gravel and rocks would also reduce the risk. Yet, these measures can never guarantee that jack jumpers won't find a spot to nest in, therefore; being vigilant to avoid places where they might be expected, such as under rocks, in cracks, in dry bush or in dry lawns will be the most effective way to avoid a confrontation. However, in reality, this may be very difficult.

5.5 Speculations

Throughout the research process, I have learnt a great deal about jack jumpers and made several personal observations about their preferred habitat that are worth mentioning in this thesis.

One striking observation, made when walking to and from the study sites, was that the ants appear to favour the habitat provided by footpaths and roads to nest in. Nests were observed on paths in close proximity to wet vegetation at Wellington Park. The nests had used the gravel left at the side of a gravel road and the ants appeared to be foraging on the edge of the *Eucalyptus regnans* forest. Very large colonies were observed in the cuttings of a dirt track in the north east corner of Wellington Park. Again, the ants used the crumbly cuttings and open canopy to set up nests and appeared to be foraging on the edge of the *E. obliqua* and *E. regnans* forest. There was one very large nest with several smaller 'satellite' nests in which the ants appeared to be travelling between. Nests were also observed in the gravel on the side of the road that snakes up Mt. Wellington. There are piles of gravel placed at intervals on the edge of the road, and jack jumpers have used some of these piles to make nests (Figure 5.6). The thermal properties of the gravel, road and open canopy, along with the resources that the nearby vegetation has to offer, may combine to make these ideal locations for jack jumpers to make nests. They may also use the road to travel between nests and relocate to the next gravel pile.

Figure 5.6: Example of gravel piles near the Springs on the Mt. Wellington road (Photograph: Author).

At Knocklofty, around seven nests, each about 15 metres apart were observed on the western side of a 4wd track that climbs the western side of the hill. This could be explained by either subcolonies or budding. Many ant species expand their foraging domain by dividing into subcolonies that disperse to extra nest sites (Elias *et al.* 2005; Holldobler & Wilson 1990). The satellite colonies are inhabited by supernumery queens, but may also only contain workers and brood (Holldobler & Wilson 1990), which they may transport back and forth. Budding is considered to be different to this (Holldobler & Wilson 1990). These polygynous colonies send a cohort of workers and one or more inseminated queens that establish peripheral nests that develop into their own colony. It can also occur in some species with normal alate queens (Elias *et al.* 2005; Holldobler & Wilson 1990). It is not proven that this is occurring with jack jumpers, but Haskins and Haskins (1950) observations that some nests contain up to seven fertile queens could suggest, along with my observations described above, that this may happen.

Although I did not count the number of jack jumper individuals in any of the nests, my observations do, on the whole, echo Gray's (1974a) findings that their colonies range from 30 to 350. However, one nest was encountered in a cutting next to a 4wd track in Wellington Park, where I estimated there to be up to a thousand jack jumpers. This would concur with Higashi and Peeters (1990) who suggested that some colonies of *Myrmecia* can reach over 1000. However, such claims are tenuous, without proof by counting.

Jack jumpers were found in the Queen's Domain, which if the hypothesis is true that jack jumpers do not exist in the densely built up areas that surround the Domain, could be considered a habitat island. In the theory of island biogeography, Wilson (1967), stated that the smaller the island, the less species are able to survive on that island. The ratio of habitat to interior, the isolation of habitat fragments, patch area, patch quality all determine the abundance of insect richness in islands (Hunter 2002). Isolation of native vegetation remnants in suburban environments may result in loss of habitat for the species (Hobbs & Hopkins 1990). However, if habitat complexity decreases the likelihood of the ant occuring, perhaps there may be an optimal disturbance range in which it prefers. This may indicate that the Domain is large enough to sustain jack jumpers. However, hypothesising that the Domain is an island may be a false presumption, as jack jumpers may fly during their nuptial flight over the city to reach the high point of the Domain, but again this is speculative.

5.6 Limitations and biases

As in most studies, this study contained a number of limitations and biases. The limited time and resources meant that a more comprehensive study was not possible and therefore this study was restricted to the boundaries of Hobart City Council. The reader should be wary when applying the results to areas and environments outside the Hobart City Council boundary that were not included in this study. In this broader context, it might be possible to hypothesise where jack jumpers may occur by using the results of this study, yet jack jumpers were not studied in several habitats including exotic parklands, agricultural lands, beaches, car parks and other vegetation communities such as moorlands, sedgelands, peatlands to name just a few. Jack jumpers also occur on the mainland of Australia where the climate is, in general, warmer which may have implications for their distribution. Coupled with this, the ant fauna of the mainland is considerably more diverse than that of Tasmania, which could have an effect on the distribution of jack jumpers through less competition (McQuillan 2007a pers. comm.).

Biases regarding the location of sites in the habitat survey were hard to avoid when only small areas of certain vegetation types are present within the boundaries of the study. Examples include *Acacia dealbata* forest, *Notelaea-Pomaderris-Beyeria* forest and *Eucalyptus subcrenulata* forest and woodland. These vegetation types were restricted to a few locations making the spacing of sites within these communities sometimes very close possibly resulting in spatial autocorrelation, a problem that can arise when sites have a lack of independence from each other (Diniz-Filho *et al.* 2003; Legendre 1993). A more comprehensive study outside the boundaries of Hobart City Council would remedy this.

It is important to be mindful that the responses given in the properties survey are an indication of where jack jumpers nest in places where humans are likely to encounter them, rather than in places where people might not visit. An example of this is that the ants are often thought to nest on the edge of paths and roads. They are encountered regularly in these environments; however the likelihood of humans encountering the ants on paths is far greater that the likelihood of encountering them in native vegetation off the path, simply because humans are less likely to stray far from the path. Nevertheless, if an aim of the thesis was to understand the interaction between humans and jack jumpers, the answers provided are relevant.

Observer bias was possible throughout the study. In the habitat survey, I was extremely aware of the possibility that jack jumper nests might be hidden in cracks or under leaf litter in more complex habitats so vigilance was employed in every nest search so as not to miss nests within transects. Despite this, it was inevitable that some nests may not have been discovered resulting in false negatives. Observer bias was possible in the properties survey as it was inevitable that some participants had not seen ants or nests in their properties, where there were ants or nests, creating false negatives. Also, there was a small chance that participants misidentified other species of ants, such as *Camponotus consobrinus*, as jack jumpers. This possibility was reduced by providing participants with a picture of a jack jumper ant with the survey. It is also important to understand that the participants who submitted questionnaires were not selected randomly possibly creating biases towards a certain demographic that occupy certain types of property. The circle environmental variables were only crude representatives of the actual covers, which arguably generates relatively broad comparative data on the cover.

5.7 Recommended future research

While answering some questions, this study has also raised many. To gain more comprehensive knowledge of the jack jumpers preferred habitat, the habitat survey could be extended outside of the study area to encompass a broader range of vegetation types, including moorlands, peatlands and rainforest vegetation types. It should also be extended into urban parklands, agricultural land and other human occupied environments. These studies should be done on the Australian mainland as well as Tasmania. The properties survey could be extended to include suburbs of Hobart that are beyond the Hobart City Council boundary, which includes suburbs on the eastern side of the River Derwent.

Further investigation should be made into the hypothesis that the ants use paths as suitable habitats in preference for other environments, as well as investigation into whether the species uses paths to spread through budding or colony dividing. This could have important implications into whether the ant is extending its range into environments that it would not normally be associated with by using human modified environments such as roads. In order to understand the requirements of nesting sites, a detailed study of their nest architecture similar to Tschinkel (2004, 2005) should be undertaken.

There is still a very large gap in the knowledge of the ecology and biology of the *M. pilosula* species group, and this should be remedied through further research. This could include studies on their ecology such as determining their temperature and humidity envelope, investigating their foraging and defence behaviour, as well as understanding how they interact with other species of ants and other fauna. Further investigation into the role that jack jumpers play in seed dispersal should also be undertaken. There also needs to be studies on their biology such as understanding their use of chemical and visual signals as well as descriptions of the undescribed species within the group, including genetic analysis.

5.8 Conclusions

In their natural habitat, jack jumper ants (*Myrmecia pilosula*) prefer dry eucalypt open woodland. These dry open environments provide the ant with a combination of light for warmth and vegetation for food resource such as nectar and invertebrate prey. They tend to find warm spots to construct a nest such as on or under rocks, or in dry dirt, and often enhance the thermal properties of the nest with nest decorations of seeds, soil, charcoal, stones, sticks and sometimes small vertebrate bones. By utilising the sun, materials and vegetation in this way, they are able to survive in colonies at altitudes of up to 900 metres.

Habitat complexity may also be negatively correlated with jack jumper presence as, according to the size-grain hypothesis, jack jumpers find it more difficult to forage in complex habitats than more simple habitats. However, the results indicate that jack jumpers do not *require* a bare environment for foraging and nest building, but might *prefer* such environments. Although the ability for the ant to efficiently travel is important, this preference for less complex habitats is more than likely due to their thermal requirements than their foraging requirements. They require an open canopy and dry environment in order to gain the most energy from the sun.

As well as requiring a warm spot to nest in, jack jumpers also need vegetation to forage for food in. Indeed, the effect of vegetation has both a negative effect on the ant (it shades them from the sun) and a positive effect (it provides them with food). Therefore, jack jumpers require both an open canopy and a suitable resource for foraging close by. Perhaps this could indicate that paths intersecting native vegetation are an ideal habitat for the ant.

In a suburban context, jack jumpers may utilize cracks in concrete, walls, rockeries, dry dirt and dry grassy areas to construct nests. Their presence positively correlated with native vegetation, although when foraging, they do not discriminate between native vegetation, non-native vegetation and even human built structures such as cars, railings or clothes lines. They exist in all of the bush parks in the study but are not prevalent in the highly urbanised areas of Hobart such as Battery Point or Hobart city centre. The suburbs that contain a matrix of native vegetation such as Mt. Nelson, Fern Tree or West Hobart all contain the ants.

Humans are most likely to be stung by a jack jumper ant in their property when carrying out outdoor activities such as gardening or collecting firewood. They may also be stung whilst walking bare foot. A common sense approach should be employed in order to avoid a sting from a jack jumper. For those wishing to live in areas that do not contain the ant, the more built up suburbs are recommended.

This study has not offered a 'silver bullet' to managing habitat in order to avoid jack jumpers taking up residence. However, it has given new insights into the ants' habitat preference. The study adds significantly to the sparse knowledge base available on the species group and opens many avenues for further research to understand this fascinating animal and its interaction with humans.

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Appendix I TASVEG Communities Summary (DPIW Tasmania 2007; Harris & Kitchener 2005)

TASVEG Code	TASVEG map colour	Full Name	General description of community, site characteristics, habitat and ecology	Example locality within Hobart City Council municipality
DAS		*Eucalyptus amygdalina* forest and woodland on sandstone	A dry sclerophyll community that is characterised by an open canopy and trees uneven in age and not exceeding 25 m in height. The understorey is tall and shrubby with a shrubby, sedgy or sometimes grassy ground layer. It Occurs on sandstones or sandstone derived soils which tend to be deep and well drained. The community ranges from 0 m to 600m in altitude.	Sandstone areas at the eastern part of Knocklofty.
DCO		*Eucalyptus coccifera* forest and woodland	This community is widespread in subalpine plateaus and steep mountain sides up to 1200 m in altitude. It is primarily associated with dolerite substrates where it commonly occurs on rocky sites. *E.coccifera* has a high frost/drought tolerance which allows them to grow in exposed sites. The understorey usually has a significant heathy or shrubby component.	Upper slopes of Mt. Wellington.
DDE		*Eucalyptus delegatensis* dry forest and woodland	This community usually forms an open canopy with the understorey's composition and structure varying greatly, depending on the frequency of exposure to fire. It is usually associated with dolerite and occurs on well drained sites of between 500 m and 900m in altitude.	Mid to high slopes of Mt. Wellington.
DGL		*Eucalyptus globulus* dry forest and woodland	The community is dominated by *E. globulus* that vary in height from about 40 m to less than 20 m on poor soils. The understorey is dominated by native grasses and *Lomandra longifolia*. The community grows on dolerite ridges, slopes and flats.	Knocklofty.
DOB		*Eucalyptus obliqua* dry forest	The community is dominated by *E. obliqua* of medium height (20-30 m). The understorey is shrubby and usually dense, diverse with the ground layer sparse. It is associated with dolerite, mudstone, granites and sandstones.	North East section of Wellington Park
DOV		*Eucalyptus ovata* forest and woodland	The community is dominated by *E. ovata* with the understorey is usually shrubby or sedgy, although grassy and broad leaved facies occur. It is associated with poorly drained flats and moderate to poorly drained fertile soils with the substrate often alluvium. It occurs in lowland areas (<600 m), although much of the community has been cleared for agriculture.	Hobart College grounds, Mt. Nelson.
DPU		*Eucalyptus pulchella* forest and woodland	This dry sclerophyll community is dominated by *E. pulchella* that rarely exceed 25 m in height. The understorey is dominated by native grasses and *Lomandra longifolia*. It occurs on dolerite ridges and highly insulated north-west facing slopes which are subject to drought stress at altitudes below 600 m.	Ridgeway.
DTO		*Eucalyptus tenuiramis* forest and woodland on sediments	A dry sclerophyll community dominated by *E. tenuiramis* that rarely exceed 25 m in height. The trees are often shorter on nutrient poor sites. The understorey is shrubby with low cover and diversity. It is strongly associated with Triassic sandstone and Permian mudstones. It reaches from sea level to 650 m in altitude.	Lenah Valley, North East corner of Wellington Park.
DVG		*Eucalyptus viminalis* grassy forest and woodland	An open forest community that is dominated by low to medium (15-25 m) *E. viminalis*. The understorey is grassy and sometimes rocky. It occurs on well drained sites, generally on dolerite or basalt and is well adapted to dry conditions below 700 m in altitude.	Queen's Domain.
GTL		Lowland *Themeda triandra* grassland	This grassland community is dominated by *Themeda triandra*. It occurs on treeless flats and well drained slopes usually on dolerite, and sometimes basalt and deep sands.	Queen's Domain
HUE		Eastern alpine vegetation (undifferentiated)	This community is generally treeless and dominated by shrubby heathland, with small areas of sedgeland and grassland above 700 m in altitude. It can be found on undulating plateaus, ridges, block-fields and cliffs. It is associated with dolerite and soils that vary from almost bare rock to moderately deep and fertile mineral soils.	Mt. Wellington Plateau

NAD		*Acacia dealbata* forest	This community is common on sites disturbed by fire where it replaces wet forests and damp sclerophyll forest. The understorey is variable being dependent on the situation in which the community arises. It occurs on a variety of substrates, but more often on fertile soils.	Fern Glade Track, South East of Wellington Park.
NAV		*Allocasuarina verticillata* forest	This community varies from pure stands of trees with 100% litter or little else but leaf litter beneath the trees, to woodlands in which umbrageous trees are interspersed in a species-rich sward dominated by tussock grasses. It can grow in very dry situations, but is usually found on heavy, black clay soils derived from dolerite.	Queen's Domain.
NNP		*Notelaea-Pomaderris-Beyeria* forest	This community is usually 8-12 m in height and dominated by one or more of the tree species *N. ligustrina, P. apetala,* and *Beyeria viscosa*. The canopy is closed but the undestorey is open. It develops in locations that experience fire infrequently such as rock gullies, steep scree slops, talus pediments and the base of sea cliffs at altitudes ranging from 0 m to 600 m.	Truganini Reserve, Mt. Nelson.
ORO		Lichen lithosere	This community appears as blockfields of dolerite. Lichens are the most prevalent forms; however mosses can become more significant in wetter areas.	Slopes of Mt. Wellington
SBR		Broad-leaf scrub	This closed scrub community of sites with low fire frequencies is dominanated by a combination of *Pomaderris apetala, Beyeria viscosa, Nematolepis squamea, Prostanthera lasianthos* and *Bedfordia salicina.*It occasionally has emergent *Eucalyptus* species. It usually occurs in gullies or ontalus slopes or boulder fields on mountain sides and near sea cliffs. It can occur at altitudes form 0 m to 500 m.	New Town Falls, Wellington Park
SHS		Subalpine heathland	This community varies from being tall (1-3m) with nearly closed canopy to short (1m) and sparse on very rocky sites. The species are quite variable, but dominants are from the families Proteaceae, Epacridaceae and Fabaceae, with the species of *Melaleuca* and/or *Leptospermum.* Occurs on gently to moderately steep slopes in exposed, high rainfall subalpine areas. The substrate is usually sparse organic soils over quartzite or quartz conglomerate to Cambrian volcanic and granite rocks	Mt. Wellington Plateau
WOU		*Eucalyptus obliqua* wet forest (undifferentiated)	A tall to very tall wet sclerophyll or mixed forest community dominated by *E. obliqua*. It is one of the most widespread forest communities in Tasmania, and does not show strong associations with any particular soil type. It requires relatively high rainfall.	South section of Wellington Park
WRE		*Eucalyptus regnans* forest	A tall forest community dominated by *E. regnans,* with a dense, shrubby or forested understorey. It grows on deep, fertile soils in high rainfall areas, from sea–level to 600 m in altitude.	South section of Wellington Park
WSU		*Eucalyptus subcrenulata* forest and woodland	This community usually occurs with different *Eucalyptus* species as sub or co-dominants. It can occur on all substrates, but the best stands are on fertile soils derived from sandstone. It is generally found from 300 m to 1100 m in altitude, depending on the species of tree that it co-occurs with.	The Springs, Wellington Park

Appendix II Nest survey proforma

Myrmecia pilosula **nest search survey** **Date: .... /......../........**
Maldwyn John Evans **Time:**

................................E, ...N)	Aspect	TAS VEG
.ocation	Slope	Altitude (m)

Non- rainforest Vegetation				
Statum	Dom. Species	Growth form[1]	Height (m)	Crown/ Foliage cover class
1			<2, 2-8, 8-30, >30	<10%, 10-30, 30-70, >70%
2			<2, 2-8, 8-30, >30	<10%, 10-30, 30-70, >70%
3			<2, 2-8, 8-30, >30	<10%, 10-30, 30-70, >70%
4			<2, 2-8, 8-30, >30	<10%, 10-30, 30-70, >70%
5			<2, 2-8, 8-30, >30	<10%, 10-30, 30-70, >70%

Rainforest Vegetation						
Complexity	Leaf size	Floristic composition of tallest stratum	Indicator growth forms	Height (m)	Crown/ Foliage cover class	Emergents
;, X, C		M, S, X		<2, 2-8, 8-30, >30	<10%, 10-30, 30-70, >70%	

Soil		
Type	Field texture grade (mineral soils)	Field texture grade (organic)
	S, LS, CS, SL,L, ZL, SCL, CL, CLS, ZCL, LC, LMC, MC, MHC, HC	IP, HP, AP, SP, LP, CP, GP
	Soil drainage: Very poor, poor, imperfectly, moderately well, well, rapidly	

Other conditions (average)	
Rock cover: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	Average litter depth (cm)
Bare ground: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
CWD cover: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
Litter cover: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
Moss cover: 0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	

Notes:

[1] **T** Tree, **M** Tree mallee, **S** Shrub, **Y** Mallee shrub, **Z** Heath shrub, **C** Chenopod shrub, **H** Hummock grass, **G** Tussock grass, **D** Sod grass, **V** Sedge, **R** Rush, **F** Forb, **E** Fern, **O** Moss, **N** Lichen, **W** Liverwort, **L** Vine, **X** Xanthorrhoea, **P** Palm, **A** Cycad

Myrmecia pilosula nest search survey

First nest in transect

Nest variables		
Max dimensions of nest (cm) (……………………, ……………………)	Nest height (cm)	Outline shape
Nest built around emergent structure?	Decoration material: stones, soil, charcoal, seeds, small sticks, grass, other….	
Other plants around nest?		
Distance to nearest tree (m)	Type of tree	

Conditions around nest (approx circular 2m radius)		
Rock cover:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	Average litter depth (cm)
Bare ground:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
CWD cover:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
Litter cover:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
Moss cover:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	

Other notes:

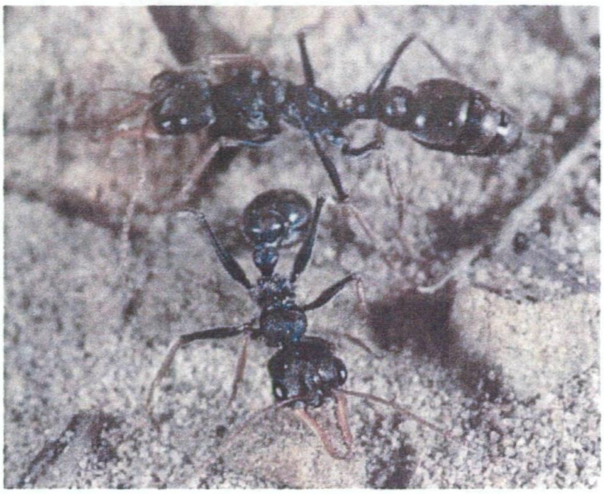
Control variables (approx circular 2m radius)	
Distance to nearest tree (m)	Type of tree

Conditions around Control (approx circular 2m radius)		
Rock cover:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	Average litter depth (cm)
Bare ground:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
CWD cover:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
Litter cover:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	
Moss cover:	0, <1%, 1-5%, 5-25%, 25-50%, 50-75%, 75-100%	

Other notes:

Appendix III Hobart properties survey questionnaire

Hobart suburban properties and the jack jumper ant



(Photo: Felix Wilson)

The presence or absence of jack jumper ants questionnaire

UTAS

Introduction

Your answers regarding jack jumpers and your property are very important to our research. Please note that your answers will be just as valid if you have never seen a jack jumper ant or nest on your property.

The questionnaire contains questions regarding various environmental variables on your property (yard and buildings) and the presence or absence of the jack jumper ant on your property. For the purposes of this survey, your property is classed as your total block of land which includes garden, driveway and buildings (e.g. your house).

The questionnaire should take no longer than 20 minutes to complete.

Section A: Your property

(Please note for the purposes of this survey, your property is classed as your total block of land which includes garden, driveway and buildings (e.g. your house).)

Question 1. Roughly how big is your property? (please tick)

Small (10metres by 10metres or smaller)	
Medium (Larger than 10metres by 10metres, smaller than 20metres by 20metres)	
Large (20metres by 20metres or larger)	

Question 2. Please estimate the cover of each of the following on your property (imagine you are looking down on your property from above).

Buildings (house, shed etc..)	%
Concrete	%
Bitumen	%
Paving	%
Grass/lawn/paddock	%
Trees (non-native)	%
Vegetable patch	%
Native bush (including native trees)	%
Flower garden	%
Other (please specify below)	
	%
	%
	%
	%
	%
TOTAL	**100%**

Example answer

Buildings (house, shed etc..)	25 %
Concrete	5 %
Bitumen	0 %
Paving	0 %
Lawn	50 %
Trees (non-native)	5 %
Vegetable patch	0 %
Native bush (including native trees	0 %
Flower garden	5 %
Other (please specify below)	
Swimming pool	10 %
	%
	%
	%
	%
TOTAL	**100%**

Section B: Jack jumpers on your property

Question 3. Have you ever seen a jack jumper ***nest***(s) on your property? (please circle or highlight)

(A typical nest is an obvious mound covered in small pebbles. The mound ranges from the size of a saucer in diameter to the size of a dustbin lid. However, the ants can nest under paving stones, in sandy outcrops and on path sidings. A nest is usually easily spotted because of the activity of a number of ants in close proximity to the nest entrance hole.)

Yes — Go to Question 4   No — Go to Question 5

Question 4. Where on your property was the nest(s) located? (e.g. in area of native bush, about 4 metres from a gum tree)

____

____

____

____

____

____

Question 5. Have you ever seen a jack jumper ***ant*** (s) on your property? (please circle or highlight)

Yes — Go to Question 6   No — Go to Section C

Question 6. Where have you seen jack jumper ants on your property? (e.g. on the kitchen bench, on a gum tree, around the nest)

____

____

____

____

____

____

Question 7. Have you ever been stung by a jack jumper ant on your property? (please circle or highlight)

Yes — Go to Question 8   No — Go to Section C

Question 8. Where in your property were you stung by a jack jumper ant and what were you doing at the time? (e.g. in the bush on our property while I was collecting firewood)

____

____

____

____

____

____

Section C: Your address

Please provide your address below. Providing your address is voluntary. However, providing your address will help identify localities where the jack jumper resides around Hobart. Providing your street name and suburb will suffice should you feel uncomfortable with providing the street number.

____

____

____

____

____

____

Thank you for completing the jack jumpers in Hobart properties questionnaire.

Please email the completed questionnaire to evansmj@utas.edu.au .

or print a hard copy and forward to:

Maldwyn John Evans, School of Geography and Environmental Studies, University of Tasmania, Private Bag 78, Hobart, Tasmania 7001

If you have any further comments, please feel free to use the space below.

Appendix IV Hobart properties survey questionnaire cover sheet

Private Bag 78 Hobart
Tasmania 7001 Australia
evansmj@postoffice.utas.edu.au

UTAS

SCHOOL OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

19th of March 2008

Invitation to participate in a survey regarding the presence or absence of the jack jumper ant in Hobart properties.

Dear participant,

We are writing to invite you to participate in a research project investigating the preferred habitat of the jack jumper ant around Hobart.

Purpose of the study
The research project's main aim is to ascertain the preferred habitat of the jack jumper ant. The attached questionnaire contains questions regarding your garden and whether the jack jumper ant is present or absent. Please note that it is important that we receive questionnaires from participants who have gardens without the ant just as much as we receive them from participants who have seen ants in their gardens. So even if you have never seen a jack jumper ant in your garden, we are still interested in the answers you may provide.

Investigators
The project is being undertaken by Maldwyn Evans, as part of the requirements for a Master of Environmental Management. The Chief Investigator, and Maldwyn's supervisor for the project, is Dr Peter McQuillan.

Importance of your participation
An understanding of the behaviour and habitat as well as the circumstances in which jack jumper stings are likely to occur may provide information to help to reduce the likelihood of jack jumper stings. The answers that you provide will guide future management recommendations to minimise the threat to humans from jack jumper stings by helping to predict and identify areas of Hobart and surrounds where there is a high risk of a human–jack jumper encounter. Your answers may also help offer management guidelines for allergy sufferers to minimise the risk of jack jumpers taking up residence in their gardens and properties.

What you are asked to do
You are asked to fill out the attached questionnaire. The questionnaire contains questions regarding various environmental variables on your property (yard and buildings) and the presence or absence of the jack jumper ant in your garden. The questionnaire should take no longer than 20 minutes to complete. Please note: your answers will be just as valid if you have never seen a jack jumper ant or nest on your property as if you have.

Voluntary and anonymous
The questionnaire is anonymous and your personal details are not requested. However, section C of the survey asks you for your address. The information provided in this section will help us to calculate the proximity to native bush of your garden as well as help identify locations within Hobart that jack jumpers reside in. Your address will not be published in any way. Only the proximity to native bush and suburb will be recorded in the data and the thesis or published work. Entering your address is completely voluntary and if you wish to leave this field blank then you are free to do so. Your consent to participate in this study is evidenced by your completion and return of the questionnaire.

No risk in participation
There are no risks involved in the study. You are being asked to note the presence or absence of the jack jumper ant or jack jumper ant nests on your property. The jack jumper ant can administer a painful and sometimes dangerous sting. In no way are you being asked to interfere with the ant or nest and therefore put yourself at risk of a jack jumper sting.

Contacts
If you have any comments of questions, please feel free to contact:
Dr Peter McQuillan; Tel: (03) 62262840 Email: p.b.mcquillan@utas.edu.au
or
Maldwyn John Evans; Email: evansmj@utas.edu.au

Results of the study
As a participant in the study, you will be given the opportunity to read the final thesis. This will be available in the School of Geography and Environmental Studies, University of Tasmania towards the beginning of September 2008.

Concerns or complaints
This project has received ethical approval from the Human Research Ethics Committee (Tasmania) Network. If you have any concerns of an ethical nature or complaints about the manner in which the project is conducted, please contact the Executive Officer of the Network (telephone: 03 6226 7479, email human.ethics@utas.edu.au.)

Thank you for your time, and we hope that you are willing to spend the 5-20 minutes it will take to answer the questionnaire.

Kind regards,

Maldwyn John Evans
Investigator

Appendix V Ethics approval documents

Tasmania
DEPARTMENT *of* HEALTH *and* HUMAN SERVICES

Human Research
Ethics Committee (Tasmania) Network

UTAS

Social Sciences - Minimal Risk Application Form

An electronic version of Minimal Risk form and attachments must be emailed to Marilyn.Knott@utas.edu.au
This will accelerate the approval process – send a signed hard copy in the mail.

SECTION 1 – Researchers (Note separate section below for Student researchers)

Title of Research project	The preferred habitat of the jack jumper ant (*Myrmecia pilosula*)

School/Department/Centre:	Geography and Environmental Studies

Chief Investigator/Supervisor: (Not the student investigator)	Dr Peter McQuillan
Phone	03 62262840
Email address	p.b.mcquillan@utas.edu.au
Signature	

Other Investigator	Maldwyn John Evans
Phone	0407224032
Email address	johnmacken@gmail.com
Signature	

STUDENT Investigator(s) STUDENT DETAILS MUST BE COMPLETED

Student Name	Student ID No.	Date of birth	Honours, PhD etc.
Maldwyn John Evans	074717	27/11/1978	Masters
Student email address: johnmacken@gmail.com		Phone:0407224032	Mobile:0407224032

Student Name	Student ID No.	Date of birth	Honours, PhD etc.

Student email address:	Phone:	Mobile:

By signing the above, all investigators are confirming the following statements:

1. I confirm that I have read and abide by the principles as explained in the *National Statement on Ethical Conduct Involving Humans* (NH&MRC)
2. That all the following responses are true and accurate.
3. I confirm that all data (video and audio tapes, questionnaires etc) will be kept securely stored during the research, and retained under lock and key in the School to which I belong for a period of at least 5 years after completion of the research. Your School/Institution will have policies in relation to the retention of data.
4. I undertake to use the data and information collected in the research only for the purposes of the research, to make no unauthorised disclosure of that data or information, and to maintain the anonymity of all participant data except pursuant to the express consent of the relevant participant(s).

SECTION 2 – STATEMENT OF METHODOLOGICAL MERIT

The **Head of School*** is required to sign the following statement:

This proposal has been considered and is sound with regard to **its merit and methodology**.
The Head of School's (or Head of Discipline's) signature on the application form indicates that:

he/she has read the application and confirms that it is sound with regard to

(i) educational and/or scientific merit and
(ii) research design and methodology.

If the Head of School/Discipline is one of the investigators this statement must be signed by an appropriate person. This will normally be the Head of School/Discipline in a related area.

This does not preclude the Committee from questioning the research merit or methodology of any proposed project where if feels it has the expertise to do so.

Name of Head of School	***Signature***	***Date***

* Where the Head of School is an investigator, In some schools the signature of the Head of Discipline may be more appropriate. * An investigator on the project may not give the certification of scientific merit.

SECTION 3 - DATA STORAGE

Indicate the School at which the data will be retained.	Geography and Environmental Studies

SECTION 4 - FUNDING

	YES	NO
Is the research being funded by an agency outside the University?		✓
If 'YES' is ticked provide funding/grant details:		
If 'NO' is ticked, Indicate how and by whom the research will be funded if costs are involved and there is not external funding as above:		

SECTION 5 - RECRUITMENT

	YES	NO
Recruitment by advertisement information sessions and/or email. (please append the advertisement if 'yes'),	✓	
Recruitment by contacting people via their publicly listed email addresses		✓
Recruitment via a third party or agency		✓
Will the Information Sheets and/or Consent Forms be sent to a contact within that organisation and disseminated there?		✓

NOTE: Please be aware that **under no circumstances** must researchers receive a list of names and addresses from third parties or agencies, as this would contravene the Privacy Act 1988 (Cth). Researchers may have their Information Sheet and Consent Forms sent to possible participants through the third parties and agencies. This will allow potential participants to volunteer without any coercion.

An Information Sheet needs to be sent to the head of agencies/businesses/associations/clubs etc introducing the research and politely enlisting their help in distributing the Information Sheet and Consent Forms to the intended cohort.

If your recruitment method is different from that above, please detail below:

Letter drop.

SECTION 6 - RISK ASSESSMENT

A. Are any of the following topics to be covered in part or in whole?

Research about/involving/investigating:	YES	NO
Parenting practices		✓
Sensitive personal issues		✓
Sensitive cultural issues		✓
Grief, death or serious/traumatic loss		✓
Depression, mood states, anxiety		✓
Gambling		✓
Eating disorders		✓
Illicit drug taking		✓
Substance abuse		✓
Self report of criminal behaviour		✓
Any psychological disorder		✓
Suicide		✓
Gender identity		✓
Sexuality		✓
Race or ethnic identity		✓
Any disease or health problem		✓

Fertility		✓
Termination of pregnancy		✓

B. Are any of the following procedures to be employed?

	YES	NO
Use of personal data obtained from Commonwealth or State Government Department/Agency **without the consent** of the participants e.g. getting a list of addresses from the Australian Electoral Commission		✓
If you answered yes, please state which Commonwealth Agency is involved and what information is being sought:		

	YES	NO
Deception of participants		✓
Concealing the purposes of the research		✓
Covert observation		✓
Audio or visual recording **without consent**		✓

C. Will any of the following procedures be used on participants?

	YES	NO
Withholding from one group specific treatments or methods of learning, from which they may "benefit" (e.g., in medicine or teaching)		✓
Any psychological interventions or treatments		✓
Administration of physical stimulation		✓
Invasive physical procedures		✓
Infliction of pain		✓
Administration of drugs		✓
Administration of other substances		✓
Administration of ionising radiation		✓
Tissue sampling or blood taking		✓
Collecting body fluid		✓
Genetic testing		✓
Use of medical records where participants can be identified or linked		✓
Drug trials and other clinical trials		✓
Administration of drugs or placebos		✓

D. Other Risks

	YES	NO
Any risks to researcher, (eg. research undertaken in unsafe environments or trouble spots)?		✓

SECTION 7 - PARTICIPANTS - VULNERABILITY ASSESSMENT

A. Do any of the participants fall within the following targeted categories?

	YES	NO
Suffering a psychological disorder		✓
Suffering a physical vulnerability		✓
People highly dependent on medical care		✓
Minors without parental or guardian consent where they are the focus of the research		✓
People whose ability to give consent is impaired		✓
Resident of a custodial institution		✓
Unable to give free informed consent because of difficulties in understanding information statement (eg language difficulties)		✓
Members of a socially identifiable group with special cultural or religious needs or political vulnerabilities		✓
Those in dependent relationship with the researchers (eg lecturer/student, doctor/patient, teacher/pupil, professional/client)		✓
Participants be able to be identified in any final report when specific consent for this has not been given		✓
Indigenous Australians where Indigenous Australians are the focus of the research		✓

SECTION 8 - RESEARCH IN OVERSEAS SETTINGS. Does research involve any of the following?

1. **It is important for Chief Investigators to ensure that they or the other researchers involved in the research have adequately addressed any research requirements of the countries in which their research is being undertaken.**
2. **A native speaking interpreter must verify Information Sheets provided in another language.**

	YES	NO
Research being undertaken in a politically unstable area		✓
Research involving sensitive cultural issues		✓
Research in countries where criticism of government and institutions might put participants and/or researchers at risk		✓

SECTION 9 – RESEARCH INVOLVING COMMERCIAL-IN-CONFIDENCE INFORMATION OR SENSITIVE POLITICAL/COMMERCIAL ISSUES

	YES	NO
Does your research explore potentially confidential business practices or seek to elicit potentially confidential commercial information from participants?		✓
If you have answered 'YES', please describe how you will protect the confidentiality of each participant's information:		
Does your research explore potentially divergent political views, or involve the collection of politically sensitive information?		✓
If you have answered 'YES', please describe how you will protect the confidentiality of each participant's information:		

CHECKLIST FOR MINIMAL RISK APPLICATIONS

Supporting documentation for your application is ESSENTIAL. Failure to attach relevant documentation may result in delays in the processing of your application.

Please ensure that the following documents are included with your application as necessary:

Documents for Inclusion with Application	
Information sheet/s (if applicable)	✓
Consent form/s (if applicable)	
Questionnaires (if applicable)	✓
Interview schedules (if applicable)	
A copy of any permissions obtained i.e. Department of Education, Other Ethics Committees, Other Institutions (if applicable)	
All documents relevant to the study, including all information provided to subjects.	
Telephone Preambles (if applicable)	
Recruitment Advertisements (if applicable)	
Draft of Emails to be sent to prospective participants (if applicable)	✓

Appendix VI UTas media release

MEDIA RELEASE

NEWS FROM THE UNIVERSITY OF TASMANIA
DATE: TUESDAY 1 APRIL 2008
ATTENTION: Chiefs of Staff, News Directors

UTAS

New study aims to take sting out of ant allergy

The jack jumper ant is well known for its large size and painful, sometimes deadly, sting.

Myrmecia pilosula is appropriately nicknamed the jack jumper as they cover ground with a series of fast jumps. A particularly aggressive ant, jack jumpers will attack when their nests are threatened.

Masters student John Evans, from the UTAS School of Geography and Environmental Studies, is conducting a survey to find out where jack jumpers prefer to live in Hobart, as well as where the ants are not found.

By finding out where jack jumpers make their nests, jack jumper hot-spots can be more easily avoided by those with potentially life-threatening ant allergies.

"Although the jack jumper ant is well known to Tasmanians, there are few published studies of its biology or ecology- I'm attempting to address this lack of research," John said.

"Stings from the jack jumper ant pose a significant risk to people who are allergic to ant venom- jack jumpers cause over 90 per cent of ant venom anaphylaxis in Australia."

Between 1980 and 1999 there were six recorded ant sting related deaths in Australia- the jack jumper was responsible for all of them.

John said an understanding of the behaviour and habitat as well as the circumstances in which jack jumper stings are likely to occur, will provide information to help to reduce the likelihood of jack jumper stings.

"I hope to be able to offer recommendations for those wishing to avoid a confrontation with a jack jumper, as well as understand their distribution in Hobart.

"I also want responses from people who have never seen an ant in their garden," he said.

To fill in John's jack jumper survey and find out more information about ant allergy, go to www.antallergy.org.

For information and interviews, contact John Evans; mobile: 0407 224 032.

Information Released by:
Media Office, University of Tasmania
Phone: 6226 2124 Mobile: 0417 517 291
Email: Media.Office@utas.edu.au

Appendix VII Media engagement report

UTAS

Mediaportal Report

02/04/2008

▷ Hunting jack jumpers' home turf
Hobart Mercury, 02/04/08, General News, Page 13
By: Tim Martain

Clip Ref: 00034999133
285 words

31/03/2008

▷ **ABC 936 Hobart (Hobart)**
Drive - 31/03/2008 4:25 PM
Louise Saunders

Demographics	
Male:	2600
Female:	3900
AB:	1000
GB:	3900
All People:	6500

A research student from the Uni of Tas is studying the Jack Jumper ant. Saunders last saw this breed of ants on Bruny Island. John Evans, research student, Uni of Tas, says that many Tasmanians are allergic to the Jack Jumper ant and outlines his research on them. Evans explains what information he needs to complete the study, how he will go about collecting it and how he will use it.

Interviewees: John Evans, research student, Uni of Tas
Duration: 6.12
Summary ID: M00030153264

▷ **ABC 936 Hobart (Hobart)**
12:30 News - 31/03/2008 12:33 PM
Newsreader

Demographics	
Male:	3600
Female:	4700
AB:	1200
GB:	4700
All People:	8300

John Evans, masters student, University of Tasmania, hopes information collected from Tasmanian home residents about the Jack Jumper Ant will help people to minimise the risk of exposure to the ant.

Interviewees: John Evans, masters student, University of Tasmania
Duration: 1.00
Summary ID: M00030149927

▷ **ABC 936 Hobart (Hobart)**
10:00 News - 31/03/2008 10:03 AM
Newsreader

John Evans, student at the University of Tasmania, is investigating the jack-jumper ant which can deliver a possibly lethal sting. Those with allergies can suffer a fatal reaction to the ant. A questionnaire has been issued to determine the habitat preferences of the ant, and is available on www.antallergy.org.

Interviewees: John Evans, student at the University of Tasmania
Duration: 0.53
Summary ID: M00030147630
This program or part thereof is syndicated to the following 1 station(s):-
Radio National (Hobart)

Demographics

Male:	3900
Female:	5800
AB:	1300
GB:	6200
All People:	9600

▷ **ABC Northern Tasmania (Launceston)**
07:30 News - 31/03/2008 7:33 AM
Bronwyn Perry

New research into Tasmanian jack jumpers is hopeful of helping those allergic to the ant. John Evans, Masters Student, University of Tasmania [UTAS] has developed a survey to establish types of soil, vegetation & climate types the ant prefers and hopes information collected will help those with allergies minimise exposure to ants.

Interviewees: John Evans, Masters Student, UTAS
Mentions: www.antallergy.org
Duration: 0.45
Summary ID: 600030143851

Demographics

Demographics are not available as the media outlet has not commissioned audience research into this timeslot.


Bargain house quiz too taxing

Hobart Mercury
02/04/2008
Page: 13
General News
Region: Hobart Circulation: 46985
Type: Capital City Daily
Size: 405.78 sq.cms
MTWTFS-

Hunting jack jumpers' home turf

TIM MARTAIN

RESEARCHER John Evans is compiling a survey of where potentially deadly jack jumper ants prefer to live in Hobart and is calling for public assistance.

A masters student from the University of Tasmania's School of Geography and Environmental Studies, Mr Evans is also interested in recording where the ants are not found.

By finding out where jack jumpers tend to make their nests, hot-spots can be more easily avoided by those with potentially life-threatening ant allergies.

"Although the jack jumper ant is well known to Tasmanians, there are few published studies of its biology or ecology," Mr Evans said.

"I hope to be able to offer recommendations for those wishing to avoid a confrontation with a jack jumper, as well as understand their distribution in Hobart."

Mr Evans, of West Hobart, said no comprehensive study had been done on exactly where jack jumpers preferred to live and what environmental factors they needed to become established.

Stings from the jack jumper ant pose a significant risk to people who are allergic to ant venom.

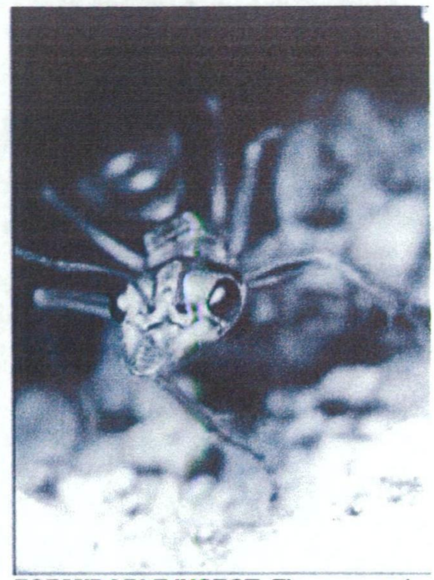
Between 1980 and 1999, there were six recorded ant sting-related deaths in Australia, all caused by the jack jumper.

A particularly aggressive ant, jack jumpers are well-known for their large size and painful, sometimes fatal, sting.

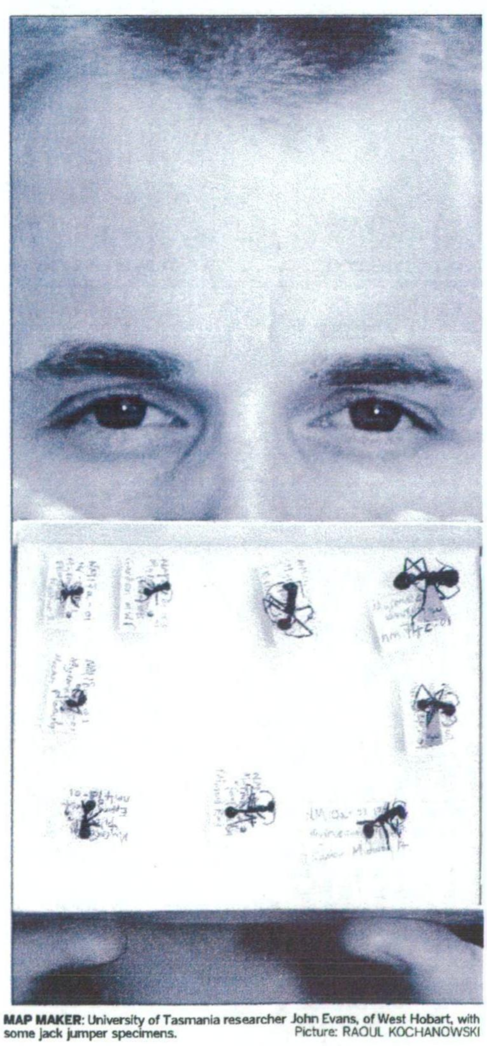
Jack jumpers will attack when their nests are threatened.

Mr Evans would like to hear from people who have jack jumper nests on their properties and those who have never encountered one at their home.

To fill in Mr Evans' survey and find out more information about ant allergy, go to www.antallergy.org.



FORMIDABLE INSECT: The aggressive jack jumper ant. Picture: FELIX WILSON



MAP MAKER: University of Tasmania researcher John Evans, of West Hobart, with some jack jumper specimens. Picture: RAOUL KOCHANOWSKI

Ref: 34999133

Appendix VIII Nest survey data sheet – vegetation type and structure

Site number	Nests	Location	TASVEG	Easting	Northing	Dom. Species (Stratum 1)	Height (Stratum 1)	Cover (Stratum 1)	Dom. Species (Stratum 2)	Height (Stratum 2)	Cover (Stratum 2)	Dom. Species (Stratum 3)	Height (Stratum 3)	Cover (Stratum 3)	Dom. Species (Stratum 4)	Height (Stratum 4)	Cover (Stratum 4)	Dom. Species (Stratum 5)	Height (Stratum 5)	Cover (Stratum 5)
H1	0	Domain	DVG	525806	5254651	*Poa rodwayi*	<2	30-70	*Themeda triandra*	<2	30-70	*Austrostipa spp.*	<2	10-30						
H2	0	Domain	DVG	526189	5254565	*Eucalyptus viminalis*	8-30	10-30	*Allocasuarina verticillata*	2-8	10-30	*Austrostipa spp.*	<2	30-70	*Themeda triandra*	<2	30-70	*Poa rodwayi*	<2	10-30
H3	0	Domain	NAV	526395	5254557	*Allocasuarina verticillata*	2-8	>70	*Austrostipa spp.*	<2	10-30									
H4	1	Domain	DVG	525870	5254501	*Eucalyptus rubida*	8-30	10-30	*Themeda triandra*	<2	30-70									
H5	0	Domain	NAV	525745	5254482	*Allocasuarina verticillata*	2-8	>70	*Austrostipa spp.*	<2	30-70									
H6	0	Domain	NAV	526353	5254465	*Allocasuarina verticillata*	2-8	30-70	*Austrostipa spp.*	<2	10-30									
H7	0	Domain	NAV	526200	5254422	*Allocasuarina verticillata*	8-30	10-30	*Allocasuarina verticillata*	2-8	30-70									
H8	0	Domain	DVG	526107	5254413	*Eucalyptus rubida*	8-30	10-30	*Allocasuarina verticillata*	2-8	10-30	*Themeda triandra*	<2	30-70						
H9	0	Domain	NAV	526260	5254372	*Allocasuarina verticillata*	2-8	10-30	*Austrostipa spp.*	<2	30-70									
H10	0	Domain	GTL	525926	5254325	*Themeda triandra*	<2	10-30	*Plantago lanceolata*	<2	10-30									
H11	0	Domain	DVG	525963	5254309	*Themeda triandra*	<2	>70												
H12	1	Domain	DVG	525921	5254286	*Themeda triandra*	<2	>70												
H13	0	Domain	DVG	526170	5254163	*Eucalyptus viminalis*	8-30	10-30	*Acacia mearnsii*	8-30	10-30	*Elymus spp.*	<2	30-70						
H14	0	Domain	DVG	526667	5253967	*Eucalyptus viminalis*	8-30	10-30	*Acacia dealbata*	2-8	10-30	*Themeda triandra*	<2	30-70	*Plantago Lanceolota*	<2	30-70			
H15	1	Domain	DPU	526074	5253954	*Eucalyptus viminalis*	8-30	10-30	*Lomandra longifolia*	<2	10-30	*Themeda triandra*	<2	30-70						
H16	0	Domain	NAV	526660	5253920	*Allocasuarina verticillata*	2-8	10-30	*Themeda triandra*	<2	10-30									
H17	0	Domain	DGL	526076	5253845	*Eucalyptus globulus*	8-30	>70												
H18	0	Domain	GTL	526474	5253783	*Themeda triandra*	<2	>70												
H19	0	Domain	GTL	526707	5253579	*Eucalyptus viminalis*	8-30	10-30	*Allocasuarina verticillata*	2-8	10-30	*Themeda triandra*	<2	30-70	*Poa spp.*	<2	30-70	*Austrostipa spp*	<2	30-70
H20	0	Domain	GTL	526818	5253478	*Austrostipa spp.*	<2	30-70	*Themeda triandra*	<2	30-70									
H21	0	Domain	GTL	526827	5253476	*Austrostipa spp.*	<2	30-70	*Themeda triandra*	<2	30-70									
H22	0	Domain	DVG	526834	5253435	*Austrostipa spp.*	<2	30-70	*Themeda triandra*	<2	30-70									
H23	0	Domain	GTL	526852	5253350	*Austrostipa spp.*	<2	30-70	*Themeda triandra*	<2	30-70									
H24	0	Domain	GTL	526915	5253187	*Austrostipa spp.*	<2	30-70	*Themeda triandra*	<2	30-70									
H25	0	Knocklofty	DVG	524042	5252941	*Eucalyptus rubida*	8-30	10-30	*Lomandra longifolia*	<2	10-30	*Themeda triandra*	<2	10-30	*Poa spp.*	<2	10-30			
H26	0	Domain	GTL	526842	5252855	*Themeda triandra*	<2	>70												
H27	0	Domain	GTL	526850	5252855	*Themeda triandra*	<2	>70												
H28	0	Domain	GTL	526846	5252830	*Eucalyptus viminalis*	8-30	10-30	*Themeda triandra*	<2	>70									
H29	1	Wellington Park	DTO	520930	5252699	*Eucalyptus tenuiramis*	8-30	30-70	*Pultenaea gunnii variety bechiodes*	<2	10-30									
H30	0	Wellington Park	WRE	520256	5252645	*Eucalyptus obliqua*	8-30	>70	*Pultenaea juniperina*	<2	30-70									
H31	1	Wellington Park	DTO	520130	5252548	*Eucalyptus tenuiramis*	8-30	10-30	*Pultenaea juniperina*	<2	10-30	*Pteridium esculentum*	<2	10-30						

Site number	Nests	Location	TASVEG	Easting	Northing	Dom. Species (Stratum 1)	Height (Stratum 1)	Cover (Stratum 1)	Dom. Species (Stratum 2)	Height (Stratum 2)	Cover (Stratum 2)	Dom. Species (Stratum 3)	Height (Stratum 3)	Cover (Stratum 3)	Dom. Species (Stratum 4)	Height (Stratum 4)	Cover (Stratum 4)	Dom. Species (Stratum 5)	Height (Stratum 5)	Cover (Stratum 5)
H32	0	Wellington Park	DTO	521216	5252482	*Eucalyptus tenuiramis*	8-30	30-70												
H33	0	Wellington Park	DTO	520160	5252469	*Acacia dealbata*	8-30	10-30	*Pomaderris apetala*	2-8	30-70	*Olearia argophylla*	2-8	30-70	*Eucalyptus obliqua*	8-30	<10			
H34	0	Wellington Park	SBR	519470	5252419	*Eucalyptus obliqua*	8-30	30-70	*Pomaderris apetala*	2-8	10-30									
H35	0	Knocklofty	DGL	524098	5252415	*Eucalyptus globulus*	8-30	30-70	*Acacia dealbata*	<2	10-30	*Lomandra longifolia*	<2	10-30	*Poa spp.*	<2	>70			
H36	0	Wellington Park	SBR	519422	5252400	*Eucalyptus regnans*	8-30	10-30	*Bedfordia salicina*	2-8	>70									
H37	0	Wellington Park	DOB	520112	5252342	*Acacia dealbata*	8-30	10-30	*Pomaderris apetala*	2-8	30-70	*Olearia argophylla*	2-8	30-70	*Goodenia ovata*	<2	10-30	*Eucalyptus obliqua*	8-30	<10
H38	0	Wellington Park	SBR	519981	5252319	*Eucalyptus obliqua*	8-30	10-30	*Olearia argophylla*	2-8	10-30	*Bedfordia salicina*	2-8	10-30						
H39	0	Wellington Park	WRE	521036	5252315	*Eucalyptus obliqua*	8-30	>70	*Oxylobium ellipticum*	2-8	10-30	*Phebalium squameum*	2-8	10-30	*Pteridium esculentum*	<2	10-30			
H40	0	Wellington Park	WOU	519635	5252299	*Eucalyptus obliqua*	8-30	30-70	*Bedfordia salicina*	2-8	10-30	*Goodenia ovata*	2-8	10-30						
H41	0	Wellington Park	DTO	520543	5252280	*Eucalyptus obliqua*	>30	10-30	*Goodenia ovata*	<2	>70									
H42	0	Wellington Park	DOB	519708	5252269	*Eucalyptus obliqua*	8-30	30-70												
H43	0	Knocklofty	DOV	523616	5252267	*Eucalyptus ovata*	8-30	10-30	*Danthonia caespitosa*	<2	10-30									
H44	1	Knocklofty	DOV	523676	5252264	*Eucalyptus ovata*	8-30	10-30	*Lomandra longifolia*	<2	10-30	*Danthonia caespitosa*	<2	10-30						
H45	0	Wellington Park	SBR	519278	5252250	*Eucalyptus obliqua*	8-30	10-30	*Bedfordia salicina*	<2	30-70									
H46	1	Wellington Park	DTO	520950	5252231	*Eucalyptus obliqua*	2-8	<10	*Pteridium esculentum*	<2	10-30									
H47	0	Wellington Park	SBR	519975	5252204	*Bedfordia salicina*	2-8	30-70	*Goodenia ovata*	2-8	30-70	*Pomaderris apetala*	2-8	10-30	*Olearia argophylla*	2-8	10-30			
H48	1	Knocklofty	DPU	524139	5252202	*Eucalyptus pulchella*	8-30	10-30	*Eucalyptus globulus*	8-30	10-30	*Acacia dealbata*	<2	10-30	*Lomandra longifolia*	<2	10-30	*Poa rodwayi*	<2	10-30
H49	0	Wellington Park	SBR	519231	5252195	*Eucalyptus obliqua*	8-30	10-30	*Prostanthera lasianthos*	<2	30-70									
H50	0	Wellington Park	SBR	519830	5252171	*Eucalyptus regnans*	>30	30-70	*Bedfordia salicina*	2-8	30-70	*Goodenia ovata*	2-8	30-70						
H51	0	Knocklofty	DGL	524175	5252167	*Eucalyptus pulchella*	8-30	30-70	*Eucalyptus globulus*	>30	<10	*Lomandra longifolia*	<2	10-30	*Poa rodwayi*	<2	30-70			
H52	0	Knocklofty	DAS	524476	5252132	*Eucalyptus amygdalina*	8-30	30-70	*Ozothamnus obcordatus*	<2	10-30	*Lomandra longifolia*	<2	10-30						
H53	0	Knocklofty	DGL	524223	5252123	*Eucalyptus globulus*	>30	30-70	*Acacia dealbata*	2-8	10-30	*Lomandra longifolia*	<2	10-30	*Poa spp.*	<2	10-30			
H54	0	Wellington Park	SBR	519913	5252088	*Eucalyptus regnans*	>30	30-70	*Bedfordia salicina*	2-8	30-70	*Goodenia ovata*	2-8	30-70						
H55	0	Knocklofty	DAS	524491	5252083	*Eucalyptus amygdalina*	8-30	30-70	*Ozothamnus obcordatus*	<2	10-30	*Dianella revoluta*	<2	<10						
H56	0	Wellington Park	WRE	521165	5252075	*Eucalyptus regnans*	>30	10-30	*Bedfordia salicina*	2-8	>70									
H57	0	Wellington Park	SBR	519010	5252073	*Eucalyptus obliqua*	8-30	10-30	*Bedfordia salicina*	<2	30-70									
H58	0	Wellington Park	DTO	520833	5252064	*Eucalyptus obliqua*	8-30	30-70	*Pultenaea juniperina*	<2	10-30									

Site number	Nests	Location	TASVEG	Easting	Northing	Dom. Species (Stratum 1)	Height (Stratum 1)	Cover (Stratum 1)	Dom. Species (Stratum 2)	Height (Stratum 2)	Cover (Stratum 2)	Dom. Species (Stratum 3)	Height (Stratum 3)	Cover (Stratum 3)	Dom. Species (Stratum 4)	Height (Stratum 4)	Cover (Stratum 4)	Dom. Species (Stratum 5)	Height (Stratum 5)	Cover (Stratum 5)
H59	0	Wellington Park	WRE	521245	5252033	*Eucalyptus regnans*	>30	10-30	*Pomaderris apetala*	2-8	>70									
H60	0	Wellington Park	SBR	519031	5251961	*Eucalyptus obliqua*	8-30	10-30	*Bedfordia salicina*	<2	30-70	*Goodenia ovata*	<2	30-70						
H61	0	Knocklofty	DPU	523970	5251951	*Eucalyptus pulchella*	8-30	10-30	*Lomandra longifolia*	<2	10-30	*Poa rodwayi*	<2	10-30						
H62	0	Wellington Park	DDE	519865	5251865	*Eucalyptus regnans*	>30	30-70	*Eucalyptus obliqua*	8-30	30-70	*Goodenia ovata*	2-8	10-30						
H63	0	Wellington Park	DTO	521629	5251803	*Eucalyptus tenuiramis*	>30	10-30	*Pultenaea juniperina*	<2	10-30									
H64	0	Knocklofty	DGL	524392	5251774	*Eucalyptus tenuiramis*	8-30	30-70	*Lepidosperma laterale*	<2	10-30	*Austrostipa spp.*	<2	>70						
H65	0	Knocklofty	DOB	524587	5251705	*Eucalyptus amygdalina*	8-30	30-70	*Acacia dealbata*	2-8	10-30	*Lomandra longifolia*	<2	30-70	*Austrostipa spp.*	<2	10-30			
H66	0	Knocklofty	DAS	524561	5251639	*Eucalyptus amygdalina*	8-30	30-70	*Acacia dealbata*	2-8	<10	*Lomandra longifolia*	<2	10-30	*Themeda triandra*	<2	10-30	*Austrostipa spp*	<2	10-30
H67	0	Wellington Park	DOB	520345	5251613	*Eucalyptus obliqua*	8-30	30-70	*Pultenaea juniperina*	<2	30-70									
H68	0	Wellington Park	DDE	520107	5251568	*Eucalyptus obliqua*	8-30	30-70	*Pteridium esculentum*	<2	10-30	*Amperea xiphoclada*	<2	10-30						
H69	0	Wellington Park	DDE	519553	5251508	*Eucalyptus delegatensis subspecies tasmaniensis*	8-30	10-30	*Bedfordia salicina*	<2	10-30									
H70	0	Wellington Park	DDE	519236	5251503	*Eucalyptus delegatensis subspecies tasmaniensis*	8-30	10-30	*Bedfordia salicina*	2-8	10-30	*Pteridium esculentum*	<2	10-30						
H71	0	Knocklofty	DAS	524435	5251482	*Eucalyptus amygdalina*	8-30	30-70	*Pultenaea juniperina*	<2	30-70	*Poa spp.*	<2	30-70						
H72	0	Wellington Park	ORO	519676	5251429															
H73	0	Wellington Park	DDE	519143	5251424	*Eucalyptus delegatensis subspecies tasmaniensis*	8-30	10-30	*Bedfordia salicina*	2-8	10-30	*Gonocarpus humilis*	<2	10-30	*Dianella tasmanica*	<2	10-30			
H74	0	Wellington Park	ORO	518959	5251376															
H75	0	Wellington Park	DCO	518052	5251260	*Eucalyptus coccifera*	2-8	10-30	*Epacris serpyllifolia*	<2	10-30									
H76	0	Wellington Park	ORO	517962	5251257															
H77	0	Wellington Park	WRE	520595	5251194	*Eucalyptus obliqua*	8-30	30-70	*Pultenaea juniperina*	2-8	30-70	*Dianella longifolia*	<2	10-30						
H78	0	Wellington Park	ORO	519413	5251140															
H79	0	Wellington Park	DCO	517924	5251125	*Epacris serpyllifolia*	<2	10-30	*Empodisma minus*	<2	10-30									
H80	0	Wellington Park	DCO	519230	5251108	*Eucalyptus coccifera*	8-30	30-70	*Hakea lissosperma*	2-8	10-30	*Pentachondra involucrata*	<2	10-30						
H81	0	Wellington Park	ORO	518255	5251045															
H82	0	Wellington Park	HUE	517581	5250907	*Epacris serpyllifolia*	<2	30-70	*Gleichenia alpina*	<2	30-70									
H83	0	Wellington Park	HUE	518267	5250861	*Epacris serpyllifolia*	<2	30-70	*Empodisma minus*	<2	10-30	*Poa spp.*	<2	10-30						
H84	0	Wellington Park	DCO	519296	5250747	*Eucalyptus coccifera*	<2	10-30	*Orites revoluta*	<2	10-30	*Ozothamnus ledifolius*	<2	10-30						

Site number	Nests	Location	TASVEG	Easting	Northing	Dom. Species (Stratum 1)	Height (Stratum 1)	Cover (Stratum 1)	Dom. Species (Stratum 2)	Height (Stratum 2)	Cover (Stratum 2)	Dom. Species (Stratum 3)	Height (Stratum 3)	Cover (Stratum 3)	Dom. Species (Stratum 4)	Height (Stratum 4)	Cover (Stratum 4)	Dom. Species (Stratum 5)	Height (Stratum 5)	Cover (Stratum 5)
H85	0	Wellington Park	HUE	518088	5250707	*Baeckea gunniana*	<2	30-70	*Hakea epiglottis*	<2	10-30									
H86	0	Wellington Park	SHS	518324	5250679	*Ozothamnus ledifolius*	<2	10-30	*Hakea epiglottis*	<2	10-30	*Epacris serpyllifolia*	<2	10-30	*Astelia alpina*	<2	10-30			
H87	0	Wellington Park	SHS	518779	5250672	*Hakea epiglottis*	<2	10-30	*Epacris serpyllifolia*	<2	10-30	*Poa spp.*	<2	10-30						
H88	0	Wellington Park	ORO	517046	5250636															
H89	0	Wellington Park	ORO	516731	5250619															
H90	0	Wellington Park	WRE	521456	5250610	*Eucalyptus regnans*	>30	10-30	*Bedfordia salicina*	<2	30-70									
H91	0	Wellington Park	WRE	521698	5250579	*Eucalyptus obliqua*	8-30	10-30	*Bedfordia salicina*	2-8	10-30	*Pteridium esculentum*	<2	10-30						
H92	0	Wellington Park	SHS	519123	5250569	*Orites revoluta*	<2	10-30	*Ozothamnus ledifolius*	<2	10-30	*Epacris serpyllifolia*	<2	10-30	*Poa spp.*	<2	10-30			
H93	0	Wellington Park	SHS	516592	5250555	*Orites revoluta*	<2	10-30	*Epacris serpyllifolia*	<2	10-30									
H94	0	Wellington Park	SHS	518959	5250482	*Richea scoparia*	<2	10-30	*Hakea epiglottis*	<2	10-30	*Epacris serpyllifolia*	<2	10-30	*Poa spp.*	<2	10-30			
H95	0	Wellington Park	DCO	519815	5250439	*Eucalyptus coccifera*	8-30	10-30	*Nothofagus gunnii*	2-8	10-30	*Richea dracophylla*	<2	10-30						
H96	0	Wellington Park	HUE	517334	5250417	*Gleichenia alpina*	<2	10-30	*Epacris serpyllifolia*	<2	10-30	*Astelia alpina*	<2	10-30						
H97	0	Wellington Park	DDE	520168	5250411	*Eucalyptus coccifera*	8-30	10-30												
H98	0	Wellington Park	SHS	518167	5250405	*Ozothamnus ledifolius*	<2	10-30	*Orites revoluta*	<2	10-30	*Astelia alpina*	<2	10-30	*Poa spp.*	<2	30-70			
H99	0	Wellington Park	HUE	518052	5250401	*Epacris serpyllifolia*	<2	10-30	*Gleichenia alpina*	<2	10-30	*Empodisma minus*	<2	10-30						
H100	0	Wellington Park	ORO	516609	5250369															
H101	0	Wellington Park	SHS	516467	5250359	*Orites revoluta*	<2	10-30	*Epacris serpyllifolia*	<2	10-30									
H102	0	Wellington Park	HUE	517314	5250331	*Gleichenia alpina*	<2	10-30	*Epacris serpyllifolia*	<2	10-30	*Astelia alpina*	<2	10-30						
H103	0	Wellington Park	HUE	517743	5250316	*Ozothamnus hookeri*	<2	10-30	*Empodisma minus*	<2	30-70	*Gleichenia alpina*	<2	10-30						
H104	0	Wellington Park	SHS	518702	5250239	*Epacris serpyllifolia*	<2	10-30	*Poa spp.*	<2	10-30									
H105	0	Wellington Park	HUE	517341	5250184	*Empodisma minus*	<2	30-70	*Gleichenia alpina*	<2	10-30	*Astelia alpina*	<2	10-30	*Epacris serpyllifolia*	<2	10-30			
H106	0	Wellington Park	DDE	520155	5250036	*Eucalyptus delegatensis subspecies tasmaniensis*	8-30	30-70	*Pomaderris apetala*	2-8	30-70									
H107	0	Wellington Park	ORO	516497	5249996															
H108	0	Wellington Park	SHS	518820	5249924	*Orites revoluta*	<2	10-30	*Ozothamnus ledifolius*	<2	10-30									
H109	0	Wellington Park	ORO	518410	5249902															

Site number	Nests	Location	TASVEG	Easting	Northing	Dom. Species (Stratum 1)	Height (Stratum 1)	Cover (Stratum 1)	Dom. Species (Stratum 2)	Height (Stratum 2)	Cover (Stratum 2)	Dom. Species (Stratum 3)	Height (Stratum 3)	Cover (Stratum 3)	Dom. Species (Stratum 4)	Height (Stratum 4)	Cover (Stratum 4)	Dom. Species (Stratum 5)	Height (Stratum 5)	Cover (Stratum 5)
H110	0	Wellington Park	SHS	518631	5249837	*Baeckea gunniana*	<2	10-30	*Hakea epiglottis*	<2	10-30	*Epacris serpyllifolia*	<2	10-30						
H111	0	Wellington Park	WOU	521377	5249780	*Eucalyptus obliqua*	8-30	30-70	*Pteridium esculentum*	<2	10-30	*Goodenia ovata*	<2	10-30						
H112	0	Wellington Park	HUE	517707	5249690	*Epacris serpyllifolia*	<2	10-30	*Astelia alpina*	<2	10-30	*Ozothamnus hookeri*	<2	10-30						
H113	0	Wellington Park	DDE	520375	5249636	*Eucalyptus delegatensis subspecies tasmaniensis*	>30	10-30	*Bedfordia salicina*	2-8	10-30	*Microsorum pustulatum*	<2	10-30						
H114	1	Wellington Park	DCO	519801	5249618	*Eucalyptus coccifera*	8-30	10-30	*Bedfordia salicina*	<2	10-30	*Microsorum pustulatum*	<2	10-30						
H115	0	Wellington Park	HUE	518089	5249613	*Empodisma minus*	<2	30-70	*Gleichenia alpina*	<2	10-30	*Astelia alpina*	<2	10-30	*Epacris serpyllifolia*	<2	10-30			
H116	0	Ridgeway	DOB	523566	5249611	*Eucalyptus obliqua*	>30	10-30	*Pteridium esculentum*	<2	>70									
H117	1	Wellington Park	DCO	519473	5249564	*Eucalyptus coccifera*	8-30	10-30	*Hakea lissosperma*	2-8	10-30	*Gonocarpus tetragynus*	<2	10-30						
H118	0	Wellington Park	WOU	521234	5249538	*Eucalyptus obliqua*	8-30	>70	*Bedfordia salicina*	2-8	30-70									
H119	0	Ridgeway	WOU	523972	5249498	*Eucalyptus obliqua*	8-30	30-70	*Pultenaea daphnoides*	2-8	30-70									
H120	0	Wellington Park	DDE	520000	5249478	*Eucalyptus delegatensis subspecies tasmaniensis*	8-30	30-70	*Hakea lissosperma*	2-8	30-70									
H121	0	Ridgeway	WOU	523774	5249453	*Eucalyptus obliqua*	8-30	>70	*Bedfordia salicina*	2-8	30-70									
H122	0	Ridgeway	WOU	523573	5249367	*Eucalyptus obliqua*	8-30	>70	*Olearia argophylla*	2-8	10-30	*Goodenia ovata*	2-8	10-30						
H123	0	Ridgeway	WOU	523329	5249243	*Eucalyptus obliqua*	8-30	30-70	*Acacia dealbata*	8-30	30-70	*Olearia argophylla*	2-8	10-30	*Polystichum proliferum*	<2	30-70			
H124	0	Wellington Park	NAD	520165	5249222	*Pomaderris apetala*	8-30	>70	*Bedfordia salicina*	2-8	>70	*Dicksonia antartica*	<2	10-30						
H125	0	Wellington Park	NAD	520156	5249219	*Eucalyptus regnans*	>30	10-30	*Acacia dealbata*	8-30	10-30	*Pomaderris apetala*	2-8	10-30	*Olearia argophylla*	2-8	10-30			
H126	0	Wellington Park	NAD	521227	5249183	*Eucalyptus obliqua*	8-30	30-70	*Phebalium squameum*	2-8	30-70									
H127	1	Wellington Park	DCO	519620	5249079	*Eucalyptus coccifera*	8-30	10-30	*Hakea lissosperma*	2-8	10-30									
H128	0	Wellington Park	NAD	521052	5249050	*Eucalyptus obliqua*	>30	30-70	*Bedfordia salicina*	2-8	30-70	*Goodenia ovata*	<2	10-30						
H129	0	Wellington Park	WRE	520165	5249026	*Eucalyptus regnans*	>30	10-30	*Bedfordia salicina*	2-8	30-70	*Pomaderris apetala*	2-8	30-70						
H130	0	Wellington Park	WRE	520638	5248961	*Eucalyptus regnans*	8-30	30-70	*Phebalium squameum*	2-8	30-70	*Pultenaea juniperina*	<2	10-30						
H131	1	Ridgeway	DAS	523746	5248947	*Eucalyptus amygdalina*	8-30	10-30	*Lomandra longifolia*	<2	10-30									
H132	0	Ridgeway	DTO	523179	5248939	*Eucalyptus tenuiramis*	8-30	10-30	*Lepidosperma concavum*	<2	10-30									
H133	0	Ridgeway	DTO	523068	5248937	*Eucalyptus tenuiramis*	8-30	10-30	*Pultenaea juniperina*	<2	30-70	*Lomandra longifolia*	<2	30-70						
H134	1	Ridgeway	DOB	523513	5248896	*Eucalyptus obliqua*	8-30	30-70	*Lomandra longifolia*	<2	10-30									
H135	0	Uni reserve	DPU	525925	5248850	*Eucalyptus pulchella*	8-30	30-70	*Lomandra longifolia*	<2	30-70	*Poa rodwayi*	<2	30-70						
H136	0	Ridgeway	WOU	522791	5248841	*Acacia dealbata*	8-30	10-30	*Eucalyptus obliqua*	8-30	10-30	*Olearia argophylla*	2-8	10-30	*Bedfordia salicina*	2-8	10-30	*Pteridium esculentum*	<2	10-30
H137	0	Wellington Park	WOU	520865	5248837	*Eucalyptus obliqua*	8-30	30-70	*Pultenaea juniperina*	<2	30-70									

Site number	Nests	Location	TASVEG	Easting	Northing	Dom. Species (Stratum 1)	Height (Stratum 1)	Cover (Stratum 1)	Dom. Species (Stratum 2)	Height (Stratum 2)	Cover (Stratum 2)	Dom. Species (Stratum 3)	Height (Stratum 3)	Cover (Stratum 3)	Dom. Species (Stratum 4)	Height (Stratum 4)	Cover (Stratum 4)	Dom. Species (Stratum 5)	Height (Stratum 5)	Cover (Stratum 5)
H138	0	Uni reserve	NAV	525421	5248834	*Eucalyptus pulchella*	8-30	10-30	*Allocasuarina verticillata*	2-8	10-30	*Themeda triandra*	<2	30-70						
H139	0	Ridgeway	DAS	523620	5248828	*Eucalyptus amygdalina*	8-30	30-70												
H140	1	Mt Nelson	DGL	526784	5248745	*Eucalyptus globulus*	8-30	10-30	*Eucalyptus pulchella*	2-8	10-30	*Lepidosperma concavum*	<2	10-30	*Austrostipa spp.*	<2	10-30			
H141	0	Mt Nelson	DGL	526833	5248727	*Eucalyptus globulus*	>30	10-30	*Bedfordia salicina*	<2	10-30	*Poa spp.*	<2	10-30						
H142	1	Ridgeway	DAS	523534	5248713	*Eucalyptus amygdalina*	8-30	30-70	*Acacia dealbata*	2-8	10-30	*Poa rodwayi*	<2	10-30						
H143	0	Ridgeway	DAS	523591	5248703	*Eucalyptus amygdalina*	8-30	30-70	*Acacia dealbata*	<2	10-30	*Themeda triandra*	<2	10-30						
H144	0	Wellington Park	DCO	519342	5248691	*Eucalyptus coccifera*	8-30	30-70	*Hakea lissosperma*	2-8	30-70	*Bauera ruboides*	2-8	10-30						
H145	0	Ridgeway	DAS	523351	5248677	*Eucalyptus pulchella*	8-30	10-30	*Pultenaea juniperina*	<2	30-70	*Themeda triandra*	<2	10-30						
H146	0	Wellington Park	DDE	519812	5248549	*Eucalyptus delegatensis* subspecies *tasmaniensis*	8-30	10-30	*Bedfordia salicina*	2-8	10-30									
H147	0	Wellington Park	WSU	520199	5248479	*Eucalyptus subcrenulata*	8-30	>70	*Phebalium squameum*	2-8	30-70									
H148	0	Wellington Park	WSU	520104	5248463	*Eucalyptus subcrenulata*	8-30	>70	*Phebalium squameum*	2-8	30-70									
H149	0	Ridgeway	DAS	523520	5248444	*Eucalyptus pulchella*	8-30	10-30	*Lomandra longifolia*	<2	10-30	*Themeda triandra*	<2	30-70						
H150	0	Wellington Park	WSU	520274	5248429	*Eucalyptus subcrenulata*	8-30	30-70	*Phebalium squameum*	2-8	30-70									
H151	1	Ridgeway	DPU	524365	5248414	*Eucalyptus pulchella*	8-30	10-30	*Pultenaea juniperina*	<2	10-30	*Lomandra longifolia*	<2	<10	*Poa rodwayi*	<2	10-30	*Themeda triandra*	<2	10-30
H152	0	Hobart College	DOV	525442	5248367	*Eucalyptus ovata*	8-30	10-30	*Eucalyptus globulus*	>30	<10	*Ozothamnus ferrugineus*	2-8	10-30	*Epacris impressa*	<2	10-30	*Poa rodwayi*	<2	10-30
H153	0	Hobart College	DOV	525531	5248331	*Eucalyptus ovata*	8-30	10-30	*Leptospermum scoparium*	<2	10-30	*Lomandra longifolia*	<2	10-30	*Lepidosperma laterale*	<2	10-30	*Poa spp.*	<2	<10
H154	0	Wellington Park	WSU	520004	5248323	*Eucalyptus subcrenulata*	8-30	>70	*Leptospermum lanigerum*	2-8	30-70									
H155	1	Ridgeway	DPU	523912	5248317	*Eucalyptus pulchella*	8-30	10-30	*Themeda triandra*	<2	30-70									
H156	0	Wellington Park	WSU	520217	5248310	*Eucalyptus subcrenulata*	8-30	>70	*Phebalium squameum*	2-8	30-70									
H157	0	Wellington Park	WSU	520352	5248286	*Eucalyptus subcrenulata*	2-8	10-30	*Leptospermum scoparium*	<2	>70									
H158	0	Hobart College	DOV	525495	5248275	*Eucalyptus ovata*	8-30	10-30	*Leptospermum scoparium*	<2	10-30	*Epacris impressa*	<2	10-30	*Themeda triandra*	<2	30-70			
H159	0	Wellington Park	WSU	520205	5248270	*Eucalyptus subcrenulata*	8-30	>70	*Gahnia grandis*	<2	30-70									
H160	0	Wellington Park	WSU	520246	5248228	*Eucalyptus subcrenulata*	8-30	>70	*Phebalium squameum*	2-8	30-70									
H161	0	Wellington Park	NAD	521088	5248181	*Eucalyptus delegatensis* subspecies *tasmaniensis*	>30	<10	*Acacia dealbata*	8-30	10-30	*Olearia argophylla*	2-8	30-70	*Bedfordia salicina*	2-8	10-30	*Polystichum proliferum*	<2	10-30
H162	1	Mt Nelson	DOV	525955	5248181	*Eucalyptus ovata*	8-30	30-70	*Lomandra longifolia*	<2	>70	*Themeda triandra*	<2	10-30						
H163	0	Hobart College	DOV	525727	5248178	*Eucalyptus globulus*	8-30	<10	*Allocasuarina littoralis*	2-8	<10	*Poa rodwayi*	<2	>70	*Themeda triandra*	<2	10-30			
H164	0	Wellington Park	WSU	520189	5248160	*Eucalyptus subcrenulata*	8-30	30-70	*Phebalium squameum*	2-8	30-70									
H165	0	Wellington Park	DCO	519796	5248153															
H166	0	Wellington Park	WSU	520240	5248123	*Eucalyptus subcrenulata*	8-30	30-70	*Phebalium squameum*	2-8	30-70									

Site number	Nests	Location	TASVEG	Easting	Northing	Dom. Species (Stratum 1)	Height (Stratum 1)	Cover (Stratum 1)	Dom. Species (Stratum 2)	Height (Stratum 2)	Cover (Stratum 2)	Dom. Species (Stratum 3)	Height (Stratum 3)	Cover (Stratum 3)	Dom. Species (Stratum 4)	Height (Stratum 4)	Cover (Stratum 4)	Dom. Species (Stratum 5)	Height (Stratum 5)	Cover (Stratum 5)
H167	0	Hobart College	DOV	525710	5248122	*Themeda triandra*	<2	30-70	*Poa rodwayi*	<2	10-30									
H168	1	Hobart College	DOV	525616	5248080	*Eucalyptus ovata*	8-30	10-30	*Leptospermum scoparium*	<2	30-70	*Lomandra longifolia*	<2	30-70	*Themeda triandra*	<2	10-30			
H169	0	Ridgeway	DOB	524114	5248016	*Eucalyptus obliqua*	8-30	30-70	*Acacia verticillata*	2-8	10-30	*Goodenia ovata*	2-8	30-70	*Lepidosperma laterale*	<2	10-30			
H170	0	Wellington Park	NAD	520778	5247986	*Acacia dealbata*	8-30	30-70	*Olearia argophylla*	2-8	30-70	*Dicksonia antartica*	2-8	10-30						
H171	0	Ridgeway	DOB	524053	5247985	*Eucalyptus obliqua*	8-30	30-70	*Acacia verticillata*	2-8	10-30	*Pultenaea daphnoides*	2-8	10-30	*Diplarrena moraea*	<2	10-30	*Poa spp.*	<2	10-30
H172	0	Wellington Park	NAD	521091	5247941	*Bedfordia salicina*	8-30	>70	*Polystichum proliferum*	<2	10-30	*Microsorum pustulatum*	<2	10-30						
H173	0	Hobart College	DGL	525436	5247931	*Eucalyptus pulchella*	8-30	10-30	*Lepidosperma concavum*	<2	10-30	*Epacris impressa*	<2	10-30	*Poa spp.*	<2	10-30			
H174	0	Hobart College	DOV	525939	5247909	*Eucalyptus ovata*	8-30	30-70	*Lomandra longifolia*	<2	30-70	*Austrostipa spp.*	<2	10-30	*Poa spp.*	<2	10-30			
H175	0	Wellington Park	NAD	520885	5247876	*Acacia dealbata*	8-30	30-70	*Olearia argophylla*	2-8	30-70	*Dicksonia antartica*	<2,2-8	10-30						
H176	1	Hobart College	DGL	525374	5247871	*Eucalyptus ovata*	8-30	<10	*Eucalyptus ovata*	2-8	10-30	*Leptospermum scoparium*	2-8	10-30	Lomandra longifolia	<2	10-30	*Themeda triandra*	<2	10-30
H177	0	Wellington Park	NAD	520875	5247870	*Acacia dealbata*	8-30	30-70	*Olearia argophylla*	2-8	30-70	*Dicksonia antartica*	2-8	10-30						
H178	0	Wellington Park	WOU	520922	5247833	*Acacia dealbata*	8-30	30-70	*Olearia argophylla*	2-8	30-70	*Dicksonia antartica*	2-8	10-30						
H179	0	Wellington Park	NAD	520685	5247785	*Eucalyptus regnans*	>30	10-30	*Eucalyptus obliqua*	8-30	10-30	*Acacia verniciflua*	2-8	10-30	*Bedfordia salicina*	2-8	10-30	*Polystichum proliferum*	<2	10-30
H180	1	Hobart College	DPU	525209	5247766	*Eucalyptus pulchella*	8-30	10-30	*Poa rodwayi*	<2	30-70									
H181	0	Wellington Park	WRE	520983	5247657	*Eucalyptus delegatensis subspecies tasmaniensis*	>30	30-70	*Pittosporum bicolor*	2-8	10-30									
H182	0	Hobart College	DGL	525157	5247586	*Eucalyptus obliqua*	8-30	10-30	*Leptospermum scoparium*	<2	30-70	*Poa spp.*	<2	10-30						
H183	1	Mt Nelson	DPU	527245	5247525	*Eucalyptus pulchella*	8-30	10-30	*Allocasuarina littoralis*	2-8	<10	*Pultenaea juniperina*	<2	10-30						
H184	0	Hobart College	DOB	525787	5247509	*Eucalyptus obliqua*	8-30	>70	*Acacia verticillata*	2-8	10-30	*Goodenia ovata*	<2	10-30	*Lomandra longifolia*	<2	30-70	*Poa rodwayi*	<2	10-30
H185	1	Mt Nelson	DPU	528224	5247418	*Eucalyptus pulchella*	8-30	30-70	*Bedfordia salicina*	2-8	10-30	*Lomandra longifolia*	<2	10-30	*Poa rodwayi*	<2	>70			
H186	1	Mt Nelson	DPU	528366	5247396	*Eucalyptus pulchella*	8-30	10-30	*Allocasuarina verticillata*	2-8	10-30	*Lomandra longifolia*	<2	10-30	*Themeda triandra*	<2	>70			
H187	0	Mt Nelson	DOB	528415	5247332	*Eucalyptus obliqua*	8-30	10-30	*Bedfordia salicina*	2-8	>70	*Lomandra longifolia*	<2	<10	*Poa rodwayi*	<2	10-30			
H188	0	Truganini	NAV	528658	5247218	*Allocasuarina verticillata*	2-8	30-70	*Themeda triandra*	<2	10-30									
H189	0	Truganini	NAV	528633	5247125	*Allocasuarina verticillata*	2-8	30-70	*Themeda triandra*	<2	10-30									
H190	0	Truganini	NAV	528638	5246916	*Allocasuarina verticillata*	2-8	30-70	*Themeda triandra*	<2	10-30									
H191	0	Truganini	NNP	528302	5246757	*Pomaderris apetala*	8-30	30-70	*Notelaea ligustrina*	2-8	30-70	*Polystichum proliferum*	<2	10-30						
H192	0	Truganini	NNP	528402	5246755	*Pomaderris apetala*	8-30	30-70	*Notelaea ligustrina*	2-8	30-70	*Polystichum proliferum*	<2	10-30						
H193	0	Truganini	NNP	528204	5246751	*Pomaderris apetala*	8-30	30-70	*Notelaea ligustrina*	2-8	30-70	*Polystichum proliferum*	<2	10-30						
H194	0	Truganini	NNP	528450	5246743	*Notelaea ligustrina*	8-30	30-70	*Pomaderris apetala*	2-8	30-70									
H195	0	Truganini	NNP	528253	5246741	*Notelaea ligustrina*	8-30	30-70	*Pomaderris apetala*	2-8	30-70									
H196	0	Truganini	NNP	528248	5246736	*Pomaderris apetala*	8-30	30-70	*Notelaea ligustrina*	2-8	30-70	*Polystichum proliferum*	<2	10-30						
H197	0	Truganini	NNP	528496	5246705	*Notelaea ligustrina*	8-30	30-70	*Pomaderris apetala*	2-8	30-70									

Site number	Nests	Location	TASVEG	Easting	Northing	Dom. Species (Stratum 1)	Height (Stratum 1)	Cover (Stratum 1)	Dom. Species (Stratum 2)	Height (Stratum 2)	Cover (Stratum 2)	Dom. Species (Stratum 3)	Height (Stratum 3)	Cover (Stratum 3)	Dom. Species (Stratum 4)	Height (Stratum 4)	Cover (Stratum 4)	Dom. Species (Stratum 5)	Height (Stratum 5)	Cover (Stratum 5)
H198	0	Truganini	NNP	528541	5246683	*Notelaea ligustrina*	8-30	30-70	*Pomaderris apetala*	2-8	30-70									
H199	0	Truganini	NNP	528669	5246657	*Notelaea ligustrina*	8-30	30-70	*Pomaderris apetala*	2-8	30-70									
H200	0	Truganini	NNP	528810	5246629	*Notelaea ligustrina*	8-30	30-70	*Pomaderris apetala*	2-8	30-70									

Appendix IX Nest survey data sheet – environmental variables

Site number	Nests	Aspect	Slope	Altitude	Geology	texture	Clay content	Clay content midpoint	drainage	Rock cover	Bare ground	CWD cover	Litter cover	moss cover	average litter depth	Photographed Canopy cover of Transect (%)
H1	0	318	16	89	Jd	CL	30-35%	32.5	imperfectly	5-25	1-5	0	0	<1	0	<0.0001
H2	0	338	16	94	Jd	ZL	25%	25	well	<1	<1	<1	5-25	<1	0.25	2.6678
H3	0	52	20	55	Jd	L	25%	25	imperfectly	1-5	1-5	1-5	75-100	1-5	1	44.6048
H4	1	344	11	109	Jd	ZCL	30-35%	32.5	imperfectly	5-25	25-50	<1	0	5-25	0	<0.0001
H5	0	297	10	122	Jd	L	25%	25	imperfectly	1-5	1-5	1-5	25-50	5-25	0.25	6.8061
H6	0	13	7	88	Jd	L	25%	25	imperfectly	<1	<1	<1	75-100	0	1	38.8456
H7	0	345	12	112	Jd	L	25%	25	imperfectly	<1	1-5	1-5	75-100	0	1	59.9754
H8	0	300	20	113	Jd	L	25%	25	imperfectly	0	<1	1-5	<1	<1	0.25	17.5022
H9	0	20	16	109	Jd	L	25%	25	well	<1	<1	1-5	1-5	0	1	10.5992
H10	0	305	9	141	Jd	ZCL	30-35%	32.5	poor	1-5	5-25	<1	0	5-25	0	0.0000
H11	0	287	8	146	Jd	L	25%	25	imperfectly	<1	5-25	<1	0	5-25	0	0.0000
H12	1	270	9	145	Jd	L	25%	25	imperfectly	<1	5-25	<1	0	5-25	0	41.8042
H13	0	90	4	140	Jd	SL	10-20%	15.00	imperfectly	<1	5-25	1-5	<1	0	0.5	16.6954
H14	0	78	5	66	Jd	L	25%	25	rapidly	0	1-5	<1	<1	<1	0.1	0.0000
H15	1	160	10	121	Jd	ZCL	30-35%	32.5	imperfectly	<1	1-5	1-5	1-5	<1	1	19.5869
H16	0	48	8	60	Jd	ZL	25%	25	moderately well	0	25-50	0	<1	0	0.5	8.0466
H17	0	128	1	91	Jd	LS	5%	5	imperfectly	1-5	75-100	1-5	1-5	1-5	0.5	57.9592
H18	0	14	7	79	Jd	L	25%	25	imperfectly	0	5-25	0	0	0	0	0.0000
H19	0	44	8	70	Jd	ZL	25%	25	imperfectly	1-5	1-5	5-25	<1	<1	0.5	2.4746
H20	0	63	5	66	Jd	L	25%	25	poor	0	1-5	0	0	<1	0	0.0000
H21	0	54	6	66	Jd	L	25%	25	poor	0	5-25	0	<1	<1	0.25	0.0000
H22	0	64	4	68	Jd	L	25%	25	poor	0	5-25	0	<1	<1	0.25	0.0000
H23	0	64	6	66	Jd	L	25%	25	poor	0	1-5	0	0	<1	0	0.0000
H24	0	22	8	64	Jd	L	25%	25	poor	0	5-25	0	0	0	0	0.0000
H25	0	4	30	272	Jd	CL	30-35%	32.5	moderately well	5-25	25-50	1-5	<1	0	0.25	10.8120
H26	0	/	0	59	Jd	CL	30-35%	32.5	poor	0	1-5	0	0	0	0	0.0000
H27	0	/	0	59	Jd	CL	30-35%	32.5	poor	0	1-5	0	0	0	0	0.0000
H28	0	48	6	57	Jd	CL	30-35%	32.5	poor	0	1-5	0	0	1-5	0	0.0000
H29	1	304	24	333	Pum	CS	5-10%	7.5	moderately well	5-25	25-50	5-25	25-50	<1	2	33.6667
H30	0	6	26	391	Pum	SL	10-20%	15.00	poor	25-50	5-25	25-50	25-50	<1	2	36.1866
H31	1	364	20	433	Pum	KCS	5-10%	7.5	imperfectly	50-75	1-5	<1	25-50	5-25	1	16.6781
H32	0	321	24	417	Pua	KLMC	40-45%	42.5	rapidly	25-50	1-5	5-25	50-75	<1	3	40.6783
H33	0	96	40	514	Pum	ZL	25%	25	moderately well	0	0	25-50	50-75	5-25	7	48.1770
H34	0	36	22	430	Qpa	LS	5%	5	Very poor	5-25	<1	5-25	5-25	25-50	3	77.5519

Site number	Nests	Aspect	Slope	Altitude	Geology	texture	Clay content	Clay content midpoint	drainage	Rock cover	Bare ground	CWD cover	Litter cover	moss cover	average litter depth	Photographed Canopy cover of Transect (%)
H35	0	45	12	296	Jd	L	25%	25	imperfectly	<1	<1	1-5	5-25	1-5	1.5	24.1695
H36	0	332	11	545	Qpa	SCL	20-30%	25	poor	1-5	<1	25-50	25-50	5-25	3	86.1842
H37	0	52	40	390	Pum	CLS	30-35%	32.5	poor	0	5-25	5-25	50-75	1-5	7	90.2508
H38	0	88	32	506	Pua	L	25%	25	imperfectly	<1	0	5-25	25-50	5-25	3	75.9599
H39	0	130	16	396	Pua	AP	unknown		moderately well	<1	<1	1-5	50-75	25-50	2	Missing
H40	0	30	15	534	Pua	CS	5-10%	7.5	poor	5-25	25-50	1-5	25-50	<1	2.5	62.3261
H41	0	40	37	397	Pum	CLS	30-35%	32.5	imperfectly	<1	0	1-5	5-25	5-25	2	83.5216
H42	0	330	30	529	Pua	LMC	40-45%	42.5	poor	1-5	5-25	50-75	25-50	<1	4	Missing
H43	0	320	10	296	Jd	SCL	20-30%	25	Very poor	1-5	<1	5-25	1-5	0	0.2	69.2565
H44	1	289	20	302	Jd	SCL	20-30%	25	Very poor	<1	0	1-5	1-5	0	0.25	26.0816
H45	0	2	23	585	Qpa	SL	10-20%	15.00	poor	<1	<1	25-50	25-50	5-25	3	74.1243
H46	1	90	2	405	Pud	KLMC	40-45%	42.5	poor	5-25	75-100	<1	1-5	<1	1	4.8332
H47	0	58	40	529	Pua	LMC	40-45%	42.5	imperfectly	1-5	0	<1	25-50	50-75	2	82.1099
H48	1	52	12	300	Jd	CS	5-10%	7.5	imperfectly	25-50	5-25	5-25	5-25	<1	2	43.5893
H49	0	4	22	570	Qpa	SL	10-20%	15.00	poor	<1	<1	25-50	25-50	5-25	3	70.0225
H50	0	52	40	547	Pua	KMC	45-55%	50	Very poor	0	0	5-25	50-75	5-25	5	86.2514
H51	0	48	24	303	Jd	CS	5-10%	7.5	well	25-50	1-5	5-25	5-25	<1	1	22.4321
H52	0	50	8	208	Rqp	S	<5%	2.5	poor	25-50	25-50	1-5	5-25	<1	1	47.7042
H53	0	58	30	232	Jd	CL	30-35%	32.5	poor	1-5	50-75	<1	25-50	<1	2.5	21.7510
H54	0	68	35	529	Pua	LMC	40-45%	42.5	Very poor	1-5	0	<1	<1	25-50	3.5	81.7551
H55	0	348	10	224	Rqp	CS	5-10%	7.5	moderately well	5-25	5-25	5-25	5-25	0	2	54.2549
H56	0	350	18	330	Puo	SCL	20-30%	25	poor	<1	1-5	5-25	50-75	5-25	1.5	75.2392
H57	0	346	25	605	Qpa	LS	5%	5	poor	5-25	0	5-25	25-50	5-25	5	77.1067
H58	0	10	22	491	Pua	LS	5%	5	well	1-5	<1	5-25	50-75	<1	2.5	48.0278
H59	0	19	19	309	Puo	SL	10-20%	15.00	Very poor	<1	1-5	5-25	50-75	1-5	1.5	78.1572
H60	0	300	28	581	Qpa	LS	5%	5	poor	5-25	0	5-25	25-50	5-25	5	68.6475
H61	0	56	2	370	Jd	CLS	30-35%	32.5	Very poor	75-100	1-5	5-25	5-25	<1	1	Missing
H62	0	280	40	553	Pua	KCS	5-10%	7.5	imperfectly	5-25	<1	50-75	25-50	5-25	4	49.8949
H63	0	330	28	306	Puc	ZCL	30-35%	32.5	poor	<1	1-5	5-25	75-100	0	2	40.9879
H64	0	72	14	231	Rqp	CS	5-10%	7.5	moderately well	5-25	1-5	5-25	1-5	1-5	1	46.5547
H65	0	30	22	260	Rqp	LS	5%	5	Very poor	5-25	50-75	1-5	5-25	<1	1.5	64.7243
H66	0	0	29	217	Rqp	CS	5-10%	7.5	well	<1	0	1-5	5-25	0	3	27.7522
H67	0	5	15	603	Pch	CS	5-10%	7.5	poor	25-50	<1	5-25	50-75	0	1.5	58.5523
H68	0	345	20	735	Pch	S	<5%	2.5	poor	1-5	0	1-5	50-75	<1	3	59.1684
H69	0	350	35	850	Qpt	L	25%	25	moderately well	5-25	0	1-5	50-75	1-5	1.5	34.9279
H70	0	20	26	869	Jd	CL	30-35%	32.5	poor	50-75	0	1-5	25-50	25-50	2	Missing

Site number	Nests	Aspect	Slope	Altitude	Geology	texture	Clay content	Clay content midpoint	drainage	Rock cover	Bare ground	CWD cover	Litter cover	moss cover	average litter depth	Photographed Canopy cover of Transect (%)
H71	0	194	18	252	Jd	SL	10-20%	15.00	imperfectly	<1	<1	1-5	5-25	<1	2	47.2765
H72	0	340	32	803	Qptnv	rock	unknown		rock	75-100	0	0	0	0	0	47.2918
H73	0	336	24	912	Jd	KSL	10-20%	15.00	well	5-25	1-5	1-5	50-75	<1	1.5	42.0633
H74	0	350	36	1004	Qptnv	rock	unknown		rock	75-100	0	0	0	0	0	Missing
H75	0	0	9	1164	Jd	IP	unknown		poor	50-75	0	1-5	5-25	<1	1	2.7112
H76	0	12	32	1151	Qptnv	Rock	unknown		rock	75-100	0	0	0	0	0	0.0000
H77	0	97	7	606	Pua	SL	10-20%	15.00	poor	0	<1	5-25	50-75	25-50	8	66.0600
H78	0	344	32	1023	Qptnv	rock	unknown		rock	75-100	0	0	0	0	0	0.0000
H79	0	352	11	1157	Jd	IP	unknown		Very poor	5-25	0	0	0	<1	0	0.0000
H80	0	305	28	1036	Jd	AP	unknown		rapidly	25-50	0	<1	50-75	5-25	5	65.9035
H81	0	345	8	1187	Qptnv	Rock	unknown		Rock	75-100	0	0	0	0	0	0.0000
H82	0	86	1	1180	Jd	IP	unknown		Very poor	1-5	<1	0	0	0	0	0.0000
H83	0		0	1199	Jd	IP	unknown		Very poor	5-25	1-5	0	0	5-25	0	0.0000
H84	0	0	30	1246	Jd	IP	unknown		moderately well	50-75	1-5	<1	5-25	<1	2	53.2360
H85	0	230	2	1189	Jd	IP	unknown		Very poor	1-5	<1	0	0	<1	0	0.0000
H86	0	240	2	1201	Jd	IP	unknown		poor	1-5	0	0	0	<1	0	0.0000
H87	0		0	1251	Jd	IP	unknown		Very poor	5-25	1-5	0	0	5-25	0	0.0000
H88	0	15	19	1200	Qptnv	Rock	unknown		rock	75-100	0	0	0	0	0	0.0000
H89	0	55	16	1232	Qptnv	Rock	unknown		rock	75-100	0	0	0	0	0	0.0000
H90	0	122	18	350	Puc	SL	10-20%	15.00	rapidly	0	0	1-5	75-100	1-5	2.5	74.8003
H91	0	65	12	306	Qpa	SCL	20-30%	25	Very poor	0	1-5	<1	5-25	50-75	2.5	37.9854
H92	0		0	1258	Jd	HP	unknown		poor	50-75	1-5	0	0	<1	0	0.0000
H93	0	100	35	1241	Jdb	L	25%	25	well	50-75	1-5	0	0	0	0	0.0000
H94	0	230	3	1248	Jd	IP	unknown		poor	50-75	1-5	0	0	<1	0	0.0000
H95	0	75	36	950	Qpt	Rock	unknown		rapidly	75-100	0	1-5	5-25	25-50	2	26.2032
H96	0	121	1	1160	Qhad	IP	unknown		Very poor	0	0	0	0	0	0	0.0000
H97	0	70	27	803	Qpt	Rock	unknown		rock	75-100	0	<1	5-25	5-25	3	35.4668
H98	0	225	1	1189	Jd	HP	unknown		poor	5-25	1-5	0	0	5-25	0	2.0020
H99	0	240	2	1180	Jd	IP	unknown		Very poor	<1	0	0	0	<1	0	0.0000
H100	0	92	15	1235	Qptnv	Rock	unknown		rock	75-100	0	0	0	0	0	0.0000
H101	0	110	19	1234	Jd	L	25%	25	moderately well	50-75	1-5	0	0	0	0	0.0000
H102	0	145	3	1156	Qhad	IP	unknown		Very poor	0	0	0	0	0	0	0.0000
H103	0	166	1	1157	Qhad	IP	unknown		Very poor	<1	0	0	0	0	0	0.0000
H104	0	264	3	1253	Jd	IP	unknown		Very poor	25-50	1-5	0	0	<1	0	0.0000
H105	0	136	1	1146	Qhad	IP	unknown		Very poor	0	0	0	0	0	0	0.0000
H106	0	49	20	723	Qpt	L	25%	25	moderately well	5-25	<1	25-50	50-75	5-25	5	75.3886

Site number	Nests	Aspect	Slope	Altitude	Geology	texture	Clay content	Clay content midpoint	drainage	Rock cover	Bare ground	CWD cover	Litter cover	moss cover	average litter depth	Photographed Canopy cover of Transect (%)
H107	0	50	17	1237	Qptnv	Rock	unknown		rock	75-100	0	0	0	0	0	0.0000
H108	0	228	1	1260	Jd	SL	10-20%	15.00	moderately well	50-75	5-25	0	0	<1	0	0.0000
H109	0		0	1226	Qptnv	Rock	unknown		rock	75-100	0	0	0	0	0	0.0000
H110	0	250	2	1247	Jd	IP	unknown		Very poor	5-25	0	0	0	<1	0	0.0000
H111	0	22	12	356	Qpt	CL	30-35%	32.5	imperfectly	1-5	0	5-25	50-75	<1	7	65.8532
H112	0	226	2	1166	Jd	IP	unknown		Very poor	1-5	0	0	0	<1	0	0.0000
H113	0	62	16	585	Qpt	no soil	unknown		no soil	1-5	0	50-75	25-50	5-25	7	39.4373
H114	1	42	30	796	Qptq	Rock	unknown		Rock	75-100	0	1-5	5-25	5-25	3	25.6982
H115	0	135	1	1154	Qhad	IP	unknown		Very poor	0	0	0	0	0	0	0.0000
H116	0	100	25	174	Pua	SL	10-20%	15.00	well	0	<1	0	50-75	<1	5	68.6708
H117	1	50	38	942	Qptq	MC	45-55%	50	poor	25-50	50-75	0	<1	<1	0.1	27.9336
H118	0	2	7	390	Qpt	CL	30-35%	32.5	moderately well	0	0	5-25	75-100	1-5	10	75.8228
H119	0	116	32	261	Pudx	ZCL	30-35%	32.5	Very poor	<1	1-5	5-25	25-50	5-25	3	62.2162
H120	0	45	26	803	Rqp	SL	10-20%	15.00	well	1-5	0	25-50	50-75	5-25	7	76.9182
H121	0	97	28	170	Pudx	KCS	5-10%	7.5	well	<1	0	25-50	50-75	5-25	5	80.0563
H122	0	112	10	171	Pudx	CLS	30-35%	32.5	poor	0	0	5-25	25-50	25-50	3	77.3789
H123	0	89	20	169	Rqp	CL	30-35%	32.5	imperfectly	0	<1	5-25	50-75	25-50	2.5	73.4514
H124	0	95	31	613	Qpt	IP	unknown		moderately well	1-5	0	25-50	25-50	50-75	3	95.1575
H125	0	64	27	616	Qpt	CS	5-10%	7.5	well	0	0	5-25	75-100	5-25	6	83.2321
H126	0	330	21	360	Pum	CLS	30-35%	32.5	poor	0	5-25	5-25	50-75	<1	3	76.0076
H127	1	114	28	881	Qptq	CS	5-10%	7.5	moderately well	50-75	5-25	<1	1-5	25-50	0.1	58.3951
H128	0	50	12	409	Qpt	LC	35-40%	37.5	Very poor	<1	5-25	1-5	50-75	5-25	3	84.7772
H129	0	86	10	582	Qpt	AP	unknown		rapidly	1-5	1-5	5-25	50-75	25-50	4	82.3080
H130	0	310	19	486	Pua	CP	unknown		moderately well	5-25	5-25	5-25	50-75	25-50	3	58.6367
H131	1	297	16	220	Rqp	CS	5-10%	7.5	poor	1-5	50-75	5-25	5-25	5-25	1	22.5291
H132	0	285	26	230	Rqp	S	<5%	2.5	Very poor	5-25	5-25	<1	5-25	1-5	1.5	9.6669
H133	0	340	24	230	Rqp	S	<5%	2.5	Very poor	<1	<1	<1	5-25	1-5	1.5	11.7076
H134	1	280	19	187	Rqp	CS	5-10%	7.5	imperfectly	<1	25-50	5-25	5-25	<1	2.5	65.7515
H135	0	120	21	176	Jd	SCL	20-30%	25	poor	5-25	5-25	5-25	5-25	5-25	1	Missing
H136	0	252	20	216	Rqp	SL	10-20%	15.00	imperfectly	<1	<1	5-25	50-75	25-50	2	60.6220
H137	0	334	22	457	Pua	CL	30-35%	32.5	poor	0	1-5	25-50	50-75	5-25	7	63.0532
H138	0	278	20	252	Jd	CL	30-35%	32.5	poor	25-50	5-25	5-25	0	<1	0	0.3666
H139	0	238	28	244	Rqp	S	<5%	2.5	Very poor	50-75	5-25	1-5	25-50	1-5	1	54.1843
H140	1	52	30	110	Jd	L	25%	25	imperfectly	1-5	1-5	25-50	0	<1	0	22.2206
H141	0	48	25	80	Jd	L	25%	25	rapidly	50-75	1-5	5-25	5-25	1-5	2	34.4715
H142	1	318	23	266	Rqp	S	<5%	2.5	imperfectly	1-5	5-25	5-25	5-25	1-5	1	29.2713

Site number	Nests	Aspect	Slope	Altitude	Geology	texture	Clay content	Clay content midpoint	drainage	Rock cover	Bare ground	CWD cover	Litter cover	moss cover	average litter depth	Photographed Canopy cover of Transect (%)
H143	0	268	30	255	Rqp	S	<5%	2.5	Very poor	5-25	1-5	1-5	25-50	<1	1	21.0629
H144	0	62	26	998	Qptq	SL	10-20%	15.00	moderately well	0	0	0	5-25	1-5	2	71.7212
H145	0	290	24	268	Rqp	LMC	40-45%	42.5	Very poor	1-5	1-5	<1	<1	<1	0.25	Missing
H146	0	54	39	802	Qptq	Rock	unknown		Very poor	75-100	0	1-5	1-5	25-50	1	1.9603
H147	0	340	15	716	Rqp	HP	unknown		imperfectly	0	0	5-25	50-75	5-25	6	77.4523
H148	0	348	28	720	Rqp	SL	10-20%	15.00	imperfectly	0	0	5-25	50-75	5-25	3	79.6709
H149	0	250	2	368	Jd	CL	30-35%	32.5	poor	5-25	1-5	1-5	1-5	<1	0.5	21.2788
H150	0	336	12	702	Rqp	AP	unknown		moderately well	0	0	1-5	25-50	5-25	2	83.2107
H151	1	10	10	319	Jd	CLS	30-35%	32.5	poor	5-25	<1	1-5	1-5	<1	0.25	35.8688
H152	0	188	10	244	Puc	KCS	5-10%	7.5	imperfectly	1-5	1-5	1-5	1-5	<1	1	Missing
H153	0	225	2	256	Jd	CL	30-35%	32.5	poor	1-5	5-25	1-5	5-25	<1	1.5	Missing
H154	0	154	20	701	Rqp	SL	10-20%	15.00	moderately well	1-5	5-25	25-50	50-75	25-50	8	84.3256
H155	1	274	15	319	Jd	CLS	30-35%	32.5	poor	5-25	1-5	1-5	1-5	<1	0.25	11.2013
H156	0	82	14	701	Rqp	SL	10-20%	15.00	moderately well	5-25	0	0	75-100	5-25	0.1	80.2210
H157	0	124	2	708	Rqp	IP	unknown		imperfectly	<1	1-5	0	5-25	25-50	0.1	Missing
H158	0	181	23	260	Puc	LMC	40-45%	42.5	Very poor	1-5	<1	0	<1	<1	0.25	23.6379
H159	0	186	1	730	Rqp	SCL	20-30%	25	well	0	0	1-5	50-75	1-5	4	85.6169
H160	0	165	16	720	Rqp	SCL	20-30%	25	well	0	0	5-25	50-75	5-25	6	80.0988
H161	0	58	12	512	Pua	CS	5-10%	7.5	well	1-5	1-5	1-5	50-75	25-50	3	83.7157
H162	1	0	7	276	Jd	CL	30-35%	32.5	poor	<1	<1	<1	<1	<1	1	28.6178
H163	0	258	8	271	Jd	CL	30-35%	32.5	poor	5-25	<1	<1	<1	1-5	0.5	0.0000
H164	0	155	8	695	Rqp	KCS	5-10%	7.5	poor	<1	0	1-5	50-75	5-25	2	81.1999
H165	0	70	30	782	Qptq	Rock	unknown			75-100	1-5	<1	<1	25-50	0.1	0.0000
H166	0	160	9	689	Rqp	KCS	5-10%	7.5	poor	<1	0	1-5	50-75	1-5	4	77.6795
H167	0	260	8	265	Jd	L	25%	25	moderately well	1-5	<1	0	0	0	0	0.0000
H168	1	268	4	254	Jd	CLS	30-35%	32.5	poor	5-25	5-25	<1	1-5	1-5	1	9.6770
H169	0	120	20	298	Jd	LC	35-40%	37.5	Very poor	<1	<1	1-5	25-50	1-5	5	60.3725
H170	0	155	20	470	Pua	HP	unknown		well	<1	0	25-50	25-50	50-75	4	81.7633
H171	0	56	28	299	Jd	CLS	30-35%	32.5	imperfectly	<1	<1	1-5	5-25	<1	3	21.9829
H172	0	110	27	488	Pua	SP	unknown		well	5-25	1-5	5-25	50-75	25-50	2	78.6985
H173	0	210	10	269	Jd	SCL	20-30%	25	Very poor	<1	0	<1	1-5	<1	1	55.7778
H174	0	320	1	295	Jd	LC (with sand)	35-40%	37.5	Very poor	0	0	<1	5-25	<1	2.5	Missing
H175	0	150	21	460	Pua	HP	unknown		well	<1	<1	25-50	25-50	50-75	4	81.7633
H176	1	290	8	254	Jd	LC	35-40%	37.5	poor	<1	<1	1-5	1-5	<1	0	10.1000
H177	0	160	22	459	Pua	HP	unknown		well	<1	1-5	25-50	25-50	50-75	4	79.6148
H178	0	158	20	453	Pua	HP	unknown		well	<1	0	25-50	25-50	50-75	4	83.9640

Site number	Nests	Aspect	Slope	Altitude	Geology	texture	Clay content	Clay content midpoint	drainage	Rock cover	Bare ground	CWD cover	Litter cover	moss cover	average litter depth	Photographed Canopy cover of Transect (%)
H179	0	4	11	495	Pua	L	25%	25	rapidly	25-50	0	25-50	75-100	25-50	5	77.4383
H180	1	267	12	248	Pudx	CL	30-35%	32.5	poor	1-5	<1	1-5	1-5	<1	1	Missing
H181	0	56	22	490	Pua	KCS	5-10%	7.5	rapidly	<1	0	5-25	75-100	5-25	4	81.4561
H182	0	205	4	243	Pudx	MC	45-55%	50	Very poor	0	0	1-5	<1	0	2	0.1416
H183	1	25	18	288	Jd	CL	30-35%	32.5	poor	50-75	1-5	5-25	5-25	1-5	0.5	Missing
H184	0	162	16	254	Jd	L	25%	25	imperfectly	<1	1-5	5-25	25-50	1-5	1	54.4628
H185	1	60	28	287	Jd	ZSL	10-20%	15.00	well	<1	0	1-5	<1	0	0.5	42.4549
H186	1	344	21	244	Jd	CLS	30-35%	32.5	well	0	1-5	1-5	<1	0	1	47.9380
H187	0	82	28	250	Jd	SL	10-20%	15.00	well	25-50	5-25	5-25	5-25	1-5	2	55.9334
H188	0	276	32	132	Jd	L	25%	25	well	<1	1-5	<1	50-75	0	0.25	68.7522
H189	0	270	25	157	Jd	L	25%	25	well	<1	1-5	<1	50-75	0	0.25	77.7229
H190	0	193	31	122	Jd	L	25%	25	well	<1	1-5	<1	50-75	0	0.25	68.7522
H191	0	90	45	110	Jd	CLS	30-35%	32.5	poor	0	0	1-5	75-100	5-25	2	74.0300
H192	0	122	19	103	Jd	HP	unknown		well	5-25	0	<1	50-75	5-25	2	64.8950
H193	0	110	50	115	Jd	HP	unknown		well	<1	<1	1-5	75-100	5-25	2	72.4654
H194	0	175	12	79	Jd	CLS	30-35%	32.5	poor	0	1-5	1-5	50-75	25-50	2	66.5671
H195	0	170	10	78	Jd	CLS	30-35%	32.5	poor	25-50	1-5	<1	50-75	50-75	1	80.8350
H196	0	40	10	112	Jd	HP	unknown		well	1-5	0	1-5	25-50	5-25	3	79.7385
H197	0	345	35	68	Puo	CLS	30-35%	32.5	poor	<1	0	5-25	25-50	5-25	2	78.0711
H198	0	340	40	70	Jd	CLS	30-35%	32.5	poor	5-25	0	5-25	5-25	50-75	2	75.7148
H199	0	350	45	55	Puo	CLS	30-35%	32.5	poor	<1	<1	1-5	25-50	5-25	4	67.5853
H200	0	180	52	38	Qpa	CLS	30-35%	32.5	poor	<1	0	5-25	25-50	5-25	5	75.5432

Appendix X Nest survey data sheet – First nest recordings

Site number	Photographed Canopy Cover	Max dim. 1	Max dim. 2	Nest height	Emergent structure	Decoration material	Plants around nest	Nearest tree distance (m)	Type of tree	Rock cover	Bare ground	CWD cover	Litter cover	Moss cover	Average litter depth
H46	76.9728	25	30	15	None	stones, charcoal	none	1.9	*Eucalyptus obliqua*	25-50	25-50	<1	<1	0	0.25
H155	27.5191	32	33	17	None	Stones, soil, charcoal	*Dianella revoluta, Acacia myrtefolia*	5	*Eucalyptus pulchella*	5-25	25-50	<1	<1	<1	0.25
H114	3.7078	30	67	10	Mound of Grass	stones, soil, charcoal, seeds, small sticks, small leaves		1.8	*Eucalyptus coccifera*	1-5	25-50	0	5-25	5-25	1.5
H31	47.4172	41	38	6	*Pultenaea juniperina*	stones, charcoal		3.81	*Eucalyptus regnans*	50-75	1-5	<1	25-50	<1	0.5
H142	21.3300	32	21	9	CWD of about 5cm diameter, burnt CWD	stones, charcoal, seeds, small sticks, sand, leaves	none	0.41	*Eucalyptus pulchella*	<1	1-5	50-75	5-25	5-25	1.5
H131	33.1656	None	None	None	None	None	*Poa rodwayi*	0.27	*Eucalyptus amygdalina*	<1	50-75	<1	5-25	5-25	1
H117	75.9078	37	35	11	A rock	stones, soil, seeds, small sticks, Hakea needles	built around *Hakea lissosperma*	1.61	*Eucalyptus coccifera*	5-25	25-50	0	1-5	<1	0.1
H44	29.5545	20	22	7	*Danthonia caespitosa*	stones, soil, charcoal, small sticks	*Danthonia caespitosa*	1.22	*Eucalyptus ovata*	0	<1	1-5	5-25	0	0.25
H29	51.4409	39	42	8	Rock (19x19x19cm)	Stones, charcoal, small sticks	*Lepidosperma concavum*	2.82	*Eucalyptus tenuiramis*	5-25	5-25	1-5	25-50	0	2.5
H151	58.7636	13	14	7	Rock (15x10x6cm)	soil, charcoal, seeds, small sticks	*Themeda triandra, poa spp.*	1.8	*Eucalyptus pulchella*	1-5	5-25	1-5	50-75	<1	1
H134	61.6024	50	48	9	None	Charcoal, seeds, small sticks	Tufts of *Poa rodwayi* out of centre	3.42	*Eucalyptus obliqua*	0	50-75	5-25	5-25	1-5	1
H168	32.9506	18	17	5	*Dianella revoluta*	Stones, soil, seeds, small sticks	*Poa spp., Leptospermum scoparium*	2.21	*Eucalyptus pulchella*	<1	25-50	1-5	1-5	1-5	0.25
H140	23.7232	13	13	4	Boulder - 20 x20x20	Stones, soil, seeds		1	*Eucalyptus pulchella*	1-5	1-5	25-50	0	0	0
H127	5.2519	50	56	10	Rock	stones, soil, small sticks		0.81	*Eucalyptus coccifera*	5-25	25-50	0	1-5	<1	1

Appendix XI Nest survey data sheet – control recordings

Site number	Photographed Canopy Cover	Nearest tree distance (m)	Type of tree	Rock cover	Bare ground	CWD cover	Litter cover	Moss cover	Average litter depth
H46	4.8332	15	*Eucalyptus obliqua*	1-5	75-100	0	0	0	0
H155	7.4391	8.2	*Eucalyptus pulchella*	1-5	5-25	<1	5-25	<1	0.25
H114	11.2911	4.5	*Eucalyptus coccifera*	50-75	5-25	5-25	5-25	5-25	4
H31	16.6781	3.5	*Eucalyptus tenuiramis*	5-25	1-5	<1	5-25	<1	0.5
H142	18.1661	5	*Eucalyptus tenuiramis*	<1	25-50	<1	5-25	1-5	0.5
H131	22.5291	3.22	*Eucalyptus amygdalina*	1-5	25-50	1-5	50-75	25-50	1
H117	27.9336	2.25	*Eucalyptus coccifera*	0	0	1-5	1-5	<1	1
H44	36.8589	4.4	*Eucalyptus ovata*	5-25	<1	1-5	5-25	0	0.25
H29	38.5146	2.85	*Eucalyptus tenuiramis*	1-5	5-25	5-25	25-50	0	3
H151	42.0197	0.5	*Eucalyptus pulchella*	1-5	0	5-25	25-50	<1	2
H134	57.3065	1.69	*Eucalyptus amygdalina*	0	5-25	1-5	25-50	1-5	3
H168	57.7925	4.55	*Eucalyptus ovata*	<1	1-5	<1	5-25	<1	0.25
H140	70.3602	0.89	*Eucalyptus pulchella*	1-5	0	1-5	0	0	0
H127	88.2221	5	*Eucalyptus coccifera*	1-5	0	0	5-25	50-75	1

Appendix XII Hobart properties survey data sheet – participants' estimates

HCC COHORT CODE	Size of Property	Buildings	Concrete	Bitumen	Paving	Lawn	Trees	Vegetable patch	Native bush	Flower garden	SUM	Nest presence	Ant presence	Ever stung?
P1	Medium	40	0	10	10	10	30	0	0	0	100	0	0	0
P2	Large	10	0	15	0	1	20	0	50	4	100	1	1	1
P3	Medium	50	5	0	0	30	15	0	0	10	110	0	0	0
P4	Large	10	0	0	2	60	3	2	17	6	100	1	1	0
P5	Medium	50	5	10	10	10	5	0	0	10	100	1	1	0
P6	Large	10	1	14	5	0	0	20	50	0	100	1	1	1
P7	Medium	30	0	0	10	40	0	10	10	0	100	1	1	1
P8	Large	35	15	0	0	15	10	10	15	0	100	1	1	1
P9	Large	50	10	0	2	5	10	5	9	8	99	1	1	0
P10	Large	25	10	0	5	10	5	0	30	15	100	1	1	1
P11	Medium	70	4	0	10	3	3	2	5	3	100	0	1	1
P12	Large	25	5	0	0.25	55	10	0.01	0	0.25	95.51	0	0	0
P13	Large	25	10	0	10	40	0	5	0	10	100	1	1	1
P14	Large	35	5	0	0	35	5	10	10	0	100	0	0	0
P15	Large	50	10	0	2	10	5	0	23	0	100	0	0	0
P16	Large	45	20	15	5	10	0	0	5	0	100	0	1	0
P17	Medium	25	15	5	0	40	10	0	5	0	100	1	1	0
P18	Large	35	10	0	0	20	5	5	20	5	100	0	1	1
P19	Large	10	0	5	0	5	0	0	80	0	100	1	1	0
P20	Large	40	15	30	0	0	0	5	10	0	100	1	1	0
P21	Large	20	0	25	0	0	8	2	20	25	100	1	1	0
P22	Large	25	5	0	0	10	5	2	50	3	100	1	1	1
P23	Large	15	10	0	0	40	25	0	10	0	100	0	1	0
P24	Large	6	2	0	1	1	1	3	85	1	100	1	1	1
P25	Medium	40	5	0	5	10	20	0	0	20	100	0	1	1
P26	Large	33.5	5	0	0.5	26	5	15	10	5	100	0	0	0
P27	Large	5	2	0	1	1	0	1	85	5	100	1	1	1
P28	Medium	45	5	0	2	24	15	5	2	2	100	1	1	1
P29	Large	5	3.5	0	1.1	20	6	3	55	6	99.6	1	1	1
P30	Large	1	0	0	0	30	0	0	68	1	100	1	1	1
P31	Small	75	15	0	0	0	2.5	2.5	2.5	2.5	100	0	0	0
P32	Large	18	11	6	0	30	0	1	30	4	100	1	1	1
P33	Large	30	15	0	0	20	4	1	20	10	100	1	1	1
P34	Large	20	20	0	0	40	0	20	0	0	100	0	0	0
P35	Medium	40	25	0	10	0	5	0	0	25	105	1	1	1
P36	Medium	60	2	10	3	10	3	5	5	2	100	1	1	1
P37	Large											1	1	1
P38	Large	5	5	0	0	35	20	5	30	0	100	1	1	1
P39	Large	10	5	0	0	60	10	5	0	10	100	0	1	0
P40	Medium	40	20	0	20	0	0	0	10	10	100	1	1	1
P41	Medium	28	0	10	0	3	12	0	40	7	100	1	1	1
P42	Large	10	20	10	0	30	0	10	20	0	100	1	1	1
P43	Small	40	0	15	5	0	0	10	30	0	100	0	0	0
P44	Medium	20	10	10	5	15	15	5	10	10	100	0	1	1
P45	Large	10	0	0	1	20	0	5	59	5	100	0	0	0
P46	Medium	40	10	0	3	5	0	0	35	7	100	1	1	0
P47	Small	80	5	10	0	0	0	0	5	0	100	1	1	1
P48	Large	20	5	0	2	69	2	0	0	2	100	0	1	0
P49	Medium	60	5	0	5	15	5	2	0	8	100	0	0	0
P50	Medium	40	10	0	5	0	15	0	25	5	100	0	0	0
P51	Large	40	20	0	0	0	5	0	20	15	100	0	1	1
P52	Large	10	0	5	2	5	1	2	75	0	100	1	1	1
P53	Large	5	1	5	2	1	5	5	75	1	100	1	1	0
P54	Medium	40	7	0	5	25	3	15	5	0	100	0	0	0
P55	Large	30	2	0	8	20	10	10	10	10	100	0	0	0
P56	Medium	20	5	0	0	55	10	2	2	6	100	0	0	0
P57	Large	25	5	0	1	30	20	15	2	2	100	0	0	0
P58	Small	50	30	5	0	5	0	5	0	5	100	0	0	0
P59	Large	25	20	0	0	45	1	4	2	3	100	1	1	1
P60	Medium	60	5	0	5	20	2	1	2	5	100	0	0	0
P61	Small	55	2	0	10	20	5	0	0	3	95	0	0	0
P62	Large	50	5	0	0	5	5	35	0	0	100	0	0	0
P63	Small	70	10	0	0	10	0	5	0	5	100	0	0	0
P64	Medium	40	40	0	0	0	5	5	0	10	100	0	0	0
P65	Small	95	5	0	0	0	0	0	0	0	100	0	0	0
P66	Medium	35	35	0	0	0	10	0	0	20	100	0	0	0
P67	Large	15	0	0	10	25	10	5	35	0	100	0	1	1
P68	Large	30	0	20	0	0	0	50	0	0	100	0	0	0

Appendix XIII Hobart properties survey data sheet – circle environmental estimates

HCC COHORT CODE	Distance to nearest patch of native vegetation	Native vegetation	Hard surfaces	Soft surfaces	Grass	Non-native vegetation	Buildings	Total
P2	0	75	5	5	10	0	5	100
P4	7.5	65	5	0	20	0	10	100
P5	43.88	5	20	25	25	0	25	100
P6	23.29	55	5	15	20	0	5	100
P7	10.4	30	10	5	40	0	15	100
P8	56.28	30	10	5	25	10	20	100
P9	19.43	15	20	5	30	5	25	100
P10	6.8	55	10	10	10	0	15	100
P11	47	20	10	5	25	10	30	100
P13	122.62	2	15	5	18	30	30	100
P14	189.26	0	15	5	15	35	30	100
P17	16.38	50	10	5	10	5	20	100
P18	11.1	35	15	25	5	0	20	100
P19	51	35	15	5	5	15	25	100
P20	104.62	10	25	5	40	10	10	100
P21	5	50	10	10	15	5	10	100
P22	4.85	50	10	5	10	5	20	100
P23	95.78	5	20	5	25	20	25	100
P24	9.11	60	15	10	0	5	10	100
P25	29.46	60	5	3	15	5	12	100
P26	17.8	15	10	5	50	15	5	100
P29	14.92	30	10	5	35	5	15	100
P32	0	85	0	5	5	0	5	100
P33	5	40	10	5	20	5	20	100
P34	615	0	20	5	15	15	45	100
P38	10.5	30	15	10	30	5	10	100
P39	78	15	15	10	35	10	15	100
P40	13.6	20	25	25	15	0	15	100
P41	8.4	50	10	5	20	5	10	100
P42	17.18	10	20	5	30	5	30	100
P43	89.87	25	10	10	25	10	30	100
P48	7.1	40	10	10	15	5	20	100
P49	223	0	25	5	15	25	30	100
P50	1341	0	20	0	15	20	45	100
P51	8.5	35	15	5	15	5	25	100
P52	6.76	80	0	10	5	0	5	100
P54	5	60	10	5	10	0	15	100
P55	297.61	0	15	5	20	10	50	100
P56	163	0	15	5	40	20	20	100
P57	261	5	10	0	30	15	40	100
P58	859	0	20	0	25	15	40	100
P59	11.26	45	10	5	15	5	20	100
P60	508.7	0	25	0	10	35	30	100
P61	265	0	45	0	5	10	40	100
P62	881.6	0	20	0	20	25	35	100
P63	280	0	25	10	15	10	40	100
P64	162.66	0	15	5	15	30	35	100
P65	1746	0	20	0	15	10	55	100
P66	1853	0	45	5	10	10	30	100
P67	6.25	40	10	5	15	5	25	100
P68	1528	0	25	0	10	15	50	100

Appendix XIV Nest survey – complete correlation table

	Canopy cover	Easting	Northing	Aspect Class_1	Aspect Class_2	Aspect Class_3	Aspect Class_4	Aspect Class_5	Slope	Altitude	Height_1	Cover_1	Height_2	Cover_2	Height_3	Cover_3	Height_4	Cover_4	Height_5	Cover_5	Sandstone/Siltstone	Dolerite	Talus_Scree	Clay	drainage	Rock	Bare ground	CWD	Litter	Moss
Easting	-0.3439																													
Northing	-0.3663	-0.0773																												
Aspect Class_1	-0.0665	-0.1023	0.1906																											
Aspect Class_2	-0.1406	0.113	-0.0144	-0.2642																										
Aspect Class_3	-0.0103	-0.0343	0.1063	-0.2113	-0.4503																									
Aspect Class_4	0.1291	0.0326	-0.1933	-0.1833	-0.3907	-0.3124																								
Aspect Class_5	0.181	-0.0923	-0.0928	-0.082	-0.1748	-0.1398	-0.1213																							
Slope	0.3676	-0.1500	-0.2427	-0.0047	-0.023	0.0279	0.0128	-0.0228																						
Altitude	0.26	-0.6640	-0.1423	-0.0055	-0.1324	0.0486	0.0492	0.1076	0.1615																					
Height_1	0.4643	-0.293	-0.2008	-0.0554	-0.0686	0.1029	-0.0272	0.0731	0.2803	0.1066																				
Cover_1	0.2683	0.0693	-0.0473	-0.0621	-0.0631	-0.0363	0.0967	0.1185	-0.0242	-0.0685	-0.2129																			
Height_2	0.1925	-0.0781	-0.1031	-0.1126	-0.1162	0.1781	0.0379	-0.0138	0.1182	0.057	0.2961	-0.0673																		
Cover_2	0.3207	-0.1011	-0.081	-0.0224	-0.0416	-0.0733	0.1462	-0.0002	0.1054	0.0448	0.22	0.0016	-0.0713																	
Height_3	0.198	-0.2088	-0.0791	-0.1461	-0.1165	0.1819	0.075	-0.042	0.2181	0.1157	0.2992	-0.1265	0.4291	-0.0896																
Cover_3	-0.1453	0.049	0.049	-0.0679	-0.0791	0.0628	0.1242	-0.0876	0.0087	-0.082	0.2046	-0.2856	0.2097	-0.2023	0.5048															
Height_4	0.0715	-0.1066	-0.0177	-0.0843	-0.0591	0.0666	0.0871	-0.0463	0.1694	0.0635	0.1162	-0.1848	0.2764	-0.0329	0.4729	0.2776														
Cover_4	-0.1247	0.2317	-0.0925	-0.1284	-0.0681	0.1923	0.0056	-0.0642	0.0022	-0.1309	0.0617	-0.1322	0.3267	-0.2384	0.2467	0.316	0.2274													
Height_5	0.1168	-0.08	0.0465	-0.0474	-0.0449	0.1531	-0.0591	-0.0313	0.1451	0	0.0186	-0.1042	0.0651	0.0277	0.2645	0.1898	0.0637	0.1214												
Cover_5	-0.0976	0.0873	-0.0292	-0.098	0.0646	0.1187	-0.0926	-0.0665	-0.1069	-0.102	0.0973	-0.163	0.2547	-0.2049	0.2838	0.2284	0.2144	0.3783	0.1943											
Sandstone/Siltstone	0.4878	-0.498	-0.1081	0.086	-0.0435	-0.1403	0.1128	0.0436	0.2816	0.2198	0.3556	0.0907	0.0374	0.2165	0.1316	-0.0646	0.083	-0.2128	0.0778	-0.0814										
Dolerite	-0.6736	0.6379	0.1636	-0.0396	0.0511	0.0531	-0.044	-0.0796	-0.3268	-0.3925	-0.4226	-0.0929	-0.0763	-0.2108	-0.1677	0.0673	-0.0861	0.265	-0.0601	0.119	-0.8758									
Talus_Scree	0.1688	-0.2774	-0.1104	-0.0937	-0.0149	0.1755	-0.1386	0.0719	0.0868	0.3449	0.1322	0.004	0.0777	-0.0126	0.0716	-0.0452	0.0058	-0.0833	-0.0358	-0.0749	-0.2547	-0.2437								
Clay	-0.1476	0.2414	-0.0674	0.0128	-0.0565	-0.0274	0.1427	-0.1052	0.0268	-0.1765	-0.0617	-0.1012	-0.1472	0.1364	0.132	0.0719	0.0173	0.086	0.0713	-0.0001	-0.3176	0.2796	0.0782							
drainage	0.0464	-0.0272	-0.0263	-0.0373	-0.049	-0.0256	0.1089	0.0086	0.0521	0.1711	0.0415	0.0528	0.1911	-0.1709	-0.0192	-0.0872	0.1729	0.2112	-0.0335	0.1167	-0.133	0.0864	0.0943	-0.1827						
Rock	-0.1861	-0.2497	-0.052	-0.0408	-0.0249	0.0774	-0.0259	0.0054	0.066	0.3739	-0.0429	-0.1861	0.0595	-0.2275	-0.1016	-0.0436	-0.0566	-0.0858	-0.0523	-0.026	-0.0682	0.0258	0.0852	-0.1816	0.1436					
Bare ground	-0.2121	0.035	0.2086	0.0532	-0.1222	0.1336	-0.1068	0.1251	-0.1424	-0.0807	-0.087	-0.005	-0.1095	-0.2568	-0.1212	-0.0657	-0.079	-0.081	0.0155	-0.099	-0.0265	0.0117	0.0299	-0.0639	-0.1334	0.1429				
CWD	0.3892	-0.3374	-0.0611	0.1313	0.0225	-0.0723	-0.0491	0.0006	0.2747	0.1828	0.2918	0.0986	0.2689	0.2136	0.124	-0.0751	0.2003	-0.0713	0.046	0.0398	0.4004	-0.4087	0.0143	-0.1807	0.0967	-0.006	-0.1459			
Litter	0.6875	-0.3272	-0.2176	0.0348	-0.0299	-0.1068	0.0801	0.0803	0.2446	0.2153	0.3755	0.2693	0.1715	0.2264	0.0781	-0.2344	0.1452	-0.1767	0.0841	-0.055	0.3861	-0.4664	0.1586	-0.1229	0.2148	-0.1585	-0.2744	0.3226		
Moss	0.4496	-0.1623	-0.199	-0.0716	-0.1187	-0.0001	0.1318	0.1153	0.1684	0.086	0.1701	0.1087	0.2552	0.1631	0.2634	-0.0613	0.1807	-0.0877	-0.0326	0.0026	0.2822	-0.2924	0.0188	0.0696	-0.1046	-0.0122	-0.1703	0.1986	0.2396	
litter depth	0.6237	-0.4482	-0.2086	-0.0203	-0.1223	-0.006	0.1074	0.1075	0.2774	0.293	0.3806	0.2127	0.1775	0.2945	0.2524	0.009	0.2245	-0.1226	0.1985	-0.041	0.4694	-0.5864	0.2316	-0.0612	0.0924	-0.2064	-0.2033	0.5461	0.5861	0.2955

Appendix XV Nest survey - Non-parametric correlation test of environmental variables (Spearman ρ)

Variable	Variable	Spearman ρ	Prob>|ρ|
Altitude	Easting	-0.9423	0.0001
Dolerite	Sandstone/Siltstone	-0.762	0.0001
litter depth	Dolerite	-0.4828	0.0001
Dolerite	Canopy cover	-0.4456	0.0001
Aspect Class_3	Aspect Class_2	-0.419	0.0001
Rock	Cover_2	-0.4099	0.0001
Bare ground	Altitude	-0.3918	0.0001
Rock	Cover_1	-0.3877	0.0001
Aspect Class_4	Aspect Class_2	-0.3688	0.0001
Litter	Dolerite	-0.3677	0.0001
Talus_Scree	Easting	-0.3647	0.0001
Talus_Scree	Dolerite	-0.3537	0.0001
Rock	Easting	-0.35	0.0001
Northing	Canopy cover	-0.3482	0.0001
Dolerite	Slope	-0.345	0.0001
CWD	Dolerite	-0.339	0.0001
Talus_Scree	Sandstone/Siltstone	-0.3362	0.0001
Dolerite	Altitude	-0.3322	0.0001
Aspect Class_4	Aspect Class_3	-0.3139	0.0001
Talus_Scree	Cover_1	-0.3067	0.0001
Cover_1	Altitude	-0.3053	0.0001
Moss	Dolerite	-0.2986	0.0001
Clay	Sandstone/Siltstone	-0.2982	0.0002
Height_2	Northing	-0.2901	0.0001
Dolerite	Height_1	-0.2878	0.0001
Bare ground	Talus_Scree	-0.2781	0.0001
drainage	Clay	-0.2752	0.0007
Talus_Scree	Cover_2	-0.26	0.0002
Moss	Northing	-0.2517	0.0003
Rock	Sandstone/Siltstone	-0.2487	0.0004
Rock	Canopy cover	-0.2456	0.0007
Height_1	Altitude	-0.2432	0.0005
Rock	Height_2	-0.2405	0.0006
Aspect Class_2	Aspect Class_1	-0.2379	0.0008
litter depth	Rock	-0.2371	0.0007
Moss	Aspect Class_2	-0.234	0.001
Litter	Northing	-0.2282	0.0012
Litter	Rock	-0.2238	0.0014
litter depth	Northing	-0.2187	0.0019
Aspect Class_5	Aspect Class_2	-0.2174	0.0023
Sandstone/Siltstone	Aspect Class_3	-0.2146	0.0027
Height_2	Aspect Class_2	-0.2104	0.0032
Height_1	Northing	-0.2052	0.0036
litter depth	Bare ground	-0.2028	0.004
Aspect Class_3	Aspect Class_1	-0.2025	0.0046
Aspect Class_4	Northing	-0.2009	0.005
Bare ground	Canopy cover	-0.1902	0.0091
Height_3	Aspect Class_2	-0.1887	0.0084
Litter	Clay	-0.1874	0.0225
Aspect Class_5	Aspect Class_3	-0.1851	0.0098
Sandstone/Siltstone	Easting	-0.1828	0.0096
CWD	Clay	-0.1822	0.0267
Cover_3	Aspect Class_2	-0.1794	0.0123
Rock	Height_1	-0.1791	0.0112
Rock	Clay	-0.1783	0.0302
Aspect Class_4	Aspect Class_1	-0.1782	0.0129
Cover_2	Northing	-0.1754	0.013
Cover_4	Cover_2	-0.1707	0.0157
Talus_Scree	Cover_4	-0.1686	0.017
Aspect Class_5	Aspect Class_4	-0.1629	0.0232
Clay	Altitude	-0.1629	0.048
Talus_Scree	Height_4	-0.1609	0.0228
Cover_2	Altitude	-0.1605	0.0232
CWD	Altitude	-0.1599	0.0237
Height_4	Cover_2	-0.1594	0.0242
Slope	Northing	-0.1507	0.0332
Rock	Aspect Class_5	-0.1505	0.0362
Cover_5	Cover_2	-0.1472	0.0376
litter depth	Aspect Class_2	-0.147	0.0409
Cover_1	Aspect Class_2	-0.1442	0.0449
Height_5	Cover_2	-0.1431	0.0433
Talus_Scree	Height_2	-0.1413	0.0459
Height_5	Cover_1	-0.1407	0.0468
Cover_5	Cover_1	-0.14	0.0481
Height_4	Cover_1	-0.1382	0.0509
CWD	Northing	-0.1369	0.0532
Aspect Class_2	Canopy cover	-0.136	0.0679
Talus_Scree	Aspect Class_1	-0.1334	0.0637
Cover_5	Altitude	-0.1319	0.0627
Bare ground	Slope	-0.1314	0.0637
Height_5	Altitude	-0.1294	0.0678

Variable	Variable	Spearman ρ	Prob>|ρ|
Litter	Aspect Class_3	-0.129	0.0731
Dolerite	Cover_2	-0.1273	0.0724
Talus_Scree	Height_1	-0.127	0.0731
Talus_Scree	Cover_3	-0.1265	0.0742
Height_3	Northing	-0.1259	0.0756
CWD	Talus_Scree	-0.1256	0.0763
Aspect Class_5	Northing	-0.1242	0.0845
Dolerite	Aspect Class_5	-0.1237	0.0858
Slope	Aspect Class_5	-0.1233	0.0867
Cover_4	Cover_1	-0.1232	0.0822
Litter	Altitude	-0.122	0.0852
Height_2	Altitude	-0.1198	0.0911
Clay	Canopy cover	-0.1183	0.167
Cover_2	Aspect Class_3	-0.1182	0.1006
Dolerite	Height_2	-0.1154	0.1037
Bare ground	Aspect Class_4	-0.1138	0.1142
Litter	Bare ground	-0.1137	0.1088
litter depth	Clay	-0.1109	0.1796
drainage	Aspect Class_3	-0.1097	0.1417
Talus_Scree	Height_5	-0.1084	0.1267
Cover_3	Cover_1	-0.1083	0.1269
Talus_Scree	Cover_5	-0.1083	0.1268
Northing	Easting	-0.1082	0.1274
Height_3	Aspect Class_1	-0.1067	0.1387
Dolerite	Aspect Class_4	-0.1057	0.1423
Aspect Class_5	Aspect Class_1	-0.1051	0.1448
Rock	Aspect Class_4	-0.1026	0.1545
Sandstone/Siltstone	Cover_4	-0.1018	0.1516
Clay	Northing	-0.101	0.222
Talus_Scree	Height_3	-0.0995	0.1611
CWD	Aspect Class_3	-0.0981	0.1734
Moss	Bare ground	-0.0977	0.1689
drainage	Altitude	-0.0972	0.1869
Height_1	Aspect Class_2	-0.0967	0.18
Cover_4	Aspect Class_1	-0.0962	0.1823
Cover_4	Aspect Class_2	-0.0962	0.1822
Clay	Cover_1	-0.0957	0.2472
CWD	Rock	-0.0953	0.1794
Height_4	Aspect Class_1	-0.0947	0.1891
Cover_5	Aspect Class_1	-0.0945	0.1899
Height_5	Aspect Class_1	-0.0945	0.1898
Aspect Class_5	Easting	-0.0916	0.2038
Height_4	Aspect Class_2	-0.0916	0.2041
Sandstone/Siltstone	Northing	-0.0901	0.2045
Clay	Aspect Class_5	-0.09	0.2803
Bare ground	Cover_2	-0.0894	0.208
Litter	Talus_Scree	-0.0872	0.2197
Cover_5	Aspect Class_5	-0.0864	0.231
Height_5	Aspect Class_5	-0.0864	0.2309
Bare ground	Sandstone/Siltstone	-0.0861	0.2255
Cover_2	Aspect Class_2	-0.0857	0.2346
Bare ground	Height_2	-0.0836	0.2391
Height_4	Northing	-0.0832	0.2412
Bare ground	Height_3	-0.0829	0.2432
Cover_4	Northing	-0.0798	0.2612
Moss	Cover_4	-0.0798	0.2616
Rock	Cover_4	-0.0797	0.2622
Rock	Height_4	-0.0772	0.2772
Altitude	Canopy cover	-0.0771	0.2943
Cover_5	Northing	-0.0765	0.2817
Cover_4	Canopy cover	-0.076	0.301
Cover_4	Altitude	-0.0757	0.2868
Height_5	Northing	-0.0756	0.287
Sandstone/Siltstone	Height_4	-0.0745	0.2945
Cover_3	Aspect Class_1	-0.0724	0.3158
Aspect Class_3	Canopy cover	-0.0713	0.3404
Cover_3	Northing	-0.0701	0.3241
Litter	Aspect Class_2	-0.0701	0.3317
Clay	Height_1	-0.0691	0.404
Talus_Scree	Aspect Class_5	-0.0684	0.3433
Cover_1	Northing	-0.0654	0.3578
drainage	Aspect Class_2	-0.0653	0.3822
drainage	Northing	-0.0653	0.3758
Rock	Height_3	-0.0639	0.3687
Altitude	Northing	-0.0626	0.3788
Slope	Aspect Class_3	-0.0618	0.3917
Cover_1	Aspect Class_3	-0.0607	0.4002
Sandstone/Siltstone	Aspect Class_2	-0.06	0.406
Height_3	Cover_1	-0.0598	0.4003
Litter	Cover_4	-0.0597	0.4009
Clay	Height_2	-0.0583	0.4818
Clay	Slope	-0.0583	0.4818
Talus_Scree	Canopy cover	-0.0574	0.4354
Height_4	Aspect Class_4	-0.0567	0.4324
Height_4	Altitude	-0.0564	0.4277
Altitude	Aspect Class_2	-0.0544	0.451
Moss	Height_4	-0.0521	0.464

Variable	Variable	Spearman ρ	Prob>|ρ|
Height_4	Canopy cover	-0.0517	0.4824
Bare ground	Aspect Class_5	-0.0514	0.477
drainage	Sandstone/Siltstone	-0.0506	0.4924
Height_5	Aspect Class_4	-0.0504	0.4857
Cover_4	Aspect Class_4	-0.0496	0.4919
Cover_5	Aspect Class_4	-0.0493	0.4945
Cover_4	Slope	-0.048	0.4996
Talus_Scree	Northing	-0.0478	0.5017
Bare ground	Clay	-0.0456	0.5817
Height_2	Aspect Class_1	-0.0439	0.5431
litter depth	Aspect Class_3	-0.0437	0.5447
Moss	Rock	-0.0424	0.5506
Bare ground	Aspect Class_2	-0.0419	0.5623
Moss	Clay	-0.0419	0.6132
Cover_5	Slope	-0.0406	0.568
CWD	Aspect Class_2	-0.0402	0.5781
Height_5	Slope	-0.0367	0.6064
Rock	Cover_3	-0.0366	0.6066
Clay	Aspect Class_3	-0.0363	0.6636
litter depth	Altitude	-0.0362	0.611
Moss	Easting	-0.0349	0.624
Height_4	Slope	-0.0345	0.6278
Rock	Height_5	-0.0335	0.6372
Sandstone/Siltstone	Cover_3	-0.0331	0.6422
Rock	Cover_5	-0.0301	0.6718
Litter	Height_4	-0.0299	0.6748
litter depth	Cover_4	-0.0291	0.6823
drainage	Cover_3	-0.0288	0.696
litter depth	Talus_Scree	-0.0288	0.6857
Cover_3	Cover_2	-0.0287	0.6862
Clay	Aspect Class_2	-0.0276	0.7406
Litter	Cover_3	-0.0267	0.7075
CWD	Aspect Class_5	-0.0257	0.7219
Height_1	Aspect Class_5	-0.0243	0.7365
drainage	Dolerite	-0.0235	0.7499
Altitude	Aspect Class_4	-0.0226	0.7547
Dolerite	Aspect Class_1	-0.0226	0.7547
Cover_3	Altitude	-0.0225	0.7514
Bare ground	drainage	-0.022	0.7658
Altitude	Slope	-0.0217	0.7607
Aspect Class_1	Easting	-0.0197	0.7854
Bare ground	Cover_3	-0.0196	0.7833
Altitude	Aspect Class_1	-0.0195	0.787
drainage	Aspect Class_5	-0.0187	0.8022
Height_3	Cover_2	-0.0184	0.7957
Moss	Cover_5	-0.0172	0.8091
Moss	Height_5	-0.0165	0.8165
Clay	Cover_5	-0.0137	0.8689
Aspect Class_3	Easting	-0.0127	0.861
Height_3	Easting	-0.0112	0.8748
Rock	Aspect Class_1	-0.0111	0.878
Moss	Talus_Scree	-0.0085	0.9055
Dolerite	Cover_1	-0.0077	0.9139
Clay	Height_5	-0.0075	0.9277
Slope	Easting	-0.0019	0.9782
Cover_3	Slope	-0.0018	0.9796
litter depth	Height_4	0.0009	0.9904
Moss	Aspect Class_3	0.0012	0.987
drainage	Cover_2	0.0028	0.9697
Sandstone/Siltstone	Cover_5	0.0034	0.9622
litter depth	Aspect Class_5	0.0049	0.9457
Rock	Dolerite	0.0063	0.9295
Sandstone/Siltstone	Height_5	0.0064	0.9289
CWD	Cover_4	0.0077	0.9133
Cover_4	Aspect Class_5	0.0089	0.9017
CWD	Bare ground	0.0125	0.8606
Height_4	Aspect Class_5	0.0126	0.8614
Rock	Northing	0.0129	0.8559
Rock	drainage	0.013	0.8601
Talus_Scree	Aspect Class_2	0.0136	0.8507
Talus_Scree	Aspect Class_4	0.0136	0.8503
Bare ground	Height_1	0.0143	0.8407
Moss	Aspect Class_1	0.0177	0.8065
drainage	Aspect Class_1	0.0178	0.8121
Moss	Altitude	0.0182	0.7983
litter depth	Easting	0.02	0.7788
Cover_3	Canopy cover	0.0211	0.7746
Cover_1	Slope	0.0213	0.765
drainage	Height_3	0.0217	0.769
CWD	Height_4	0.0221	0.7565
Height_3	Aspect Class_5	0.0233	0.747
Cover_2	Aspect Class_1	0.0248	0.7314
Height_1	Aspect Class_3	0.0256	0.7228
Litter	Aspect Class_5	0.0261	0.7178
Dolerite	Height_3	0.0282	0.6914
Altitude	Aspect Class_3	0.0311	0.6673
Aspect Class_1	Canopy cover	0.0313	0.6762

Variable	Variable	Spearman ρ	Prob>|ρ|
Height_3	Altitude	0.032	0.653
Bare ground	Height_4	0.0337	0.6355
Aspect Class_4	Easting	0.0346	0.6316
Height_2	Aspect Class_5	0.038	0.5988
Cover_3	Aspect Class_5	0.0384	0.5951
CWD	Aspect Class_4	0.039	0.5895
Sandstone/Siltstone	Height_3	0.0404	0.5697
Slope	Aspect Class_1	0.0417	0.5642
Cover_5	Canopy cover	0.0427	0.5614
Height_3	Slope	0.0466	0.5121
Height_5	Canopy cover	0.0482	0.5128
Aspect Class_2	Northing	0.0488	0.4988
Bare ground	Cover_4	0.0491	0.4898
Cover_3	Easting	0.0491	0.4901
Aspect Class_2	Easting	0.0493	0.4945
Dolerite	Aspect Class_2	0.0506	0.4832
Litter	Height_3	0.0519	0.4651
Clay	Talus_Scree	0.0536	0.5179
Rock	Aspect Class_3	0.0555	0.4424
Slope	Aspect Class_2	0.0556	0.441
Bare ground	Cover_5	0.0561	0.4301
Slope	Aspect Class_4	0.0565	0.4341
Height_1	Aspect Class_4	0.0566	0.4331
Height_5	Aspect Class_2	0.0572	0.4282
Height_1	Aspect Class_1	0.0583	0.4194
Cover_5	Aspect Class_2	0.0598	0.4074
Bare ground	Height_5	0.06	0.3986
Cover_1	Aspect Class_1	0.0615	0.3946
Litter	Cover_5	0.0624	0.3801
Sandstone/Siltstone	Altitude	0.0626	0.3789
litter depth	Cover_5	0.0652	0.3592
Litter	Height_5	0.0658	0.3547
Clay	Aspect Class_1	0.068	0.415
Dolerite	Height_5	0.0682	0.3372
Clay	Aspect Class_4	0.0692	0.4066
litter depth	Height_5	0.0696	0.3274
Bare ground	Cover_1	0.0697	0.3265
Aspect Class_5	Canopy cover	0.07	0.349
Dolerite	Cover_5	0.0711	0.3168
Clay	Height_4	0.0727	0.38
Cover_2	Slope	0.0767	0.2803
Cover_2	Aspect Class_5	0.0779	0.2803
Clay	Cover_4	0.0817	0.3233
drainage	Cover_4	0.0843	0.2528
Clay	Cover_3	0.0858	0.2998
drainage	Height_4	0.0858	0.2442
Cover_1	Aspect Class_4	0.0859	0.2336
Bare ground	Aspect Class_3	0.0862	0.2323
Bare ground	Rock	0.093	0.1904
Height_2	Aspect Class_3	0.0942	0.1913
Altitude	Aspect Class_5	0.096	0.1829
Sandstone/Siltstone	Aspect Class_4	0.0963	0.1814
Clay	Height_3	0.0982	0.2348
litter depth	Aspect Class_1	0.0998	0.1662
Easting	Canopy cover	0.0999	0.1739
Cover_3	Aspect Class_4	0.1006	0.1626
Aspect Class_3	Northing	0.1031	0.1526
Cover_5	Aspect Class_3	0.1031	0.1527
Clay	Cover_2	0.105	0.2042
Height_5	Aspect Class_3	0.1068	0.1382
Talus_Scree	Aspect Class_3	0.1088	0.1311
Litter	Aspect Class_4	0.1105	0.1251
Moss	Cover_3	0.1112	0.1171
Height_3	Canopy cover	0.1117	0.128
Height_4	Easting	0.1129	0.1115
drainage	Height_5	0.1131	0.1242
CWD	Cover_3	0.1142	0.1074
Sandstone/Siltstone	Aspect Class_1	0.1143	0.1126
Height_3	Aspect Class_4	0.1169	0.1045
drainage	Cover_5	0.1171	0.1114
Dolerite	Cover_3	0.1198	0.091
Litter	Aspect Class_1	0.1211	0.0926
Dolerite	Northing	0.1223	0.0844
Cover_3	Aspect Class_3	0.1228	0.0879
Cover_4	Height_1	0.1231	0.0823
litter depth	Cover_3	0.1263	0.0746
Litter	Easting	0.1293	0.068
CWD	Cover_5	0.131	0.0645
CWD	Height_5	0.1313	0.0638
Height_5	Easting	0.1321	0.0622
Height_4	Height_1	0.1333	0.0599
Moss	Aspect Class_5	0.1336	0.0633
Cover_5	Easting	0.1356	0.0555
Rock	Aspect Class_2	0.1356	0.0593
Cover_1	Height_1	0.1371	0.0528
litter depth	Aspect Class_4	0.1375	0.056
Cover_4	Easting	0.1382	0.051

Variable	Variable	Spearman ρ	Prob>|ρ|
Dolerite	Aspect Class_3	0.1398	0.0518
Bare ground	Aspect Class_1	0.1418	0.0485
Cover_1	Aspect Class_5	0.1431	0.0466
CWD	Easting	0.1445	0.0412
Cover_2	Easting	0.1446	0.0411
drainage	Talus_Scree	0.1449	0.0484
Moss	drainage	0.1449	0.0484
Height_2	Aspect Class_4	0.1458	0.0425
Height_3	Aspect Class_3	0.1509	0.0358
Cover_2	Aspect Class_4	0.1525	0.0338
CWD	Height_3	0.1532	0.0303
Rock	Slope	0.1581	0.0254
drainage	Cover_1	0.1608	0.0284
Aspect Class_4	Canopy cover	0.1611	0.0303
Moss	Aspect Class_4	0.1611	0.0249
Height_2	Easting	0.1614	0.0224
Aspect Class_1	Northing	0.1628	0.0233
Height_5	Height_1	0.1645	0.0199
Cover_5	Height_1	0.165	0.0195
drainage	Easting	0.1659	0.0236
Sandstone/Siltstone	Aspect Class_5	0.1707	0.0173
CWD	Aspect Class_1	0.1753	0.0145
Moss	Height_3	0.1783	0.0115
Dolerite	Height_4	0.1846	0.0089
Height_2	Cover_1	0.1858	0.0084
drainage	Aspect Class_4	0.1908	0.0101
litter depth	Height_3	0.1995	0.0046
Talus_Scree	Slope	0.2011	0.0043
Height_4	Aspect Class_3	0.2082	0.0036
Sandstone/Siltstone	Slope	0.2082	0.0031
Cover_4	Aspect Class_3	0.2099	0.0033
drainage	Height_1	0.2114	0.0038
Sandstone/Siltstone	Height_2	0.2141	0.0023
Dolerite	Cover_4	0.217	0.002
Sandstone/Siltstone	Cover_1	0.2201	0.0017
Bare ground	Northing	0.2416	0.0006
Clay	Easting	0.2455	0.0026
Height_1	Easting	0.2467	0.0004
Moss	Cover_1	0.2484	0.0004
Cover_5	Cover_3	0.2571	0.0002
Height_5	Cover_3	0.258	0.0002
Moss	Slope	0.2586	0.0002
drainage	Height_2	0.2622	0.0003
Height_2	Slope	0.2633	0.0002
CWD	Cover_1	0.2644	0.0002
CWD	drainage	0.2671	0.0002
Cover_2	Cover_1	0.2679	0.0001
Clay	Dolerite	0.2723	0.0008
Bare ground	Dolerite	0.2767	0.0001
Height_5	Height_2	0.2841	0.0001
drainage	Slope	0.2844	0.0001
Cover_5	Height_2	0.2862	0.0001
litter depth	drainage	0.2897	0.0001
Cover_3	Height_1	0.2928	0.0001
CWD	Cover_2	0.2947	0.0001
Cover_1	Easting	0.3022	0.0001
Moss	Sandstone/Siltstone	0.3065	0.0001
Cover_4	Height_2	0.3073	0.0001
Sandstone/Siltstone	Cover_2	0.3082	0.0001
Height_3	Height_1	0.3083	0.0001
drainage	Canopy cover	0.3171	0.0001
Height_4	Height_2	0.3205	0.0001
Cover_5	Height_3	0.3254	0.0001
Height_5	Height_3	0.3268	0.0001
litter depth	Cover_1	0.3377	0.0001
Rock	Talus_Scree	0.35	0.0001
Bare ground	Easting	0.3605	0.0001
Height_1	Slope	0.3709	0.0001
Cover_2	Height_1	0.3737	0.0001
Cover_3	Height_2	0.375	0.0001
Litter	drainage	0.3762	0.0001
Cover_2	Height_2	0.3766	0.0001
Sandstone/Siltstone	Height_1	0.3777	0.0001
Cover_1	Canopy cover	0.3855	0.0001
Litter	Cover_1	0.3872	0.0001
Talus_Scree	Altitude	0.3927	0.0001
CWD	Slope	0.393	0.0001
Rock	Altitude	0.3968	0.0001
Litter	Cover_2	0.3969	0.0001
Litter	Slope	0.4012	0.0001
Moss	Cover_2	0.4036	0.0001
litter depth	Cover_2	0.4212	0.0001
CWD	Sandstone/Siltstone	0.4283	0.0001
Litter	Sandstone/Siltstone	0.4305	0.0001
Dolerite	Easting	0.4324	0.0001
litter depth	Slope	0.4354	0.0001
Slope	Canopy cover	0.4492	0.0001

Variable	Variable	Spearman ρ	Prob>|ρ|
Height_3	Height_2	0.4494	0.0001
Moss	Height_1	0.4543	0.0001
Moss	CWD	0.459	0.0001
Cover_4	Cover_3	0.4692	0.0001
Height_4	Cover_3	0.4726	0.0001
Moss	Litter	0.4826	0.0001
Sandstone/Siltstone	Canopy cover	0.4892	0.0001
Litter	Height_2	0.4928	0.0001
Moss	Height_2	0.4935	0.0001
CWD	Height_2	0.4977	0.0001
Cover_2	Canopy cover	0.4996	0.0001
Cover_4	Height_3	0.506	0.0001
litter depth	Sandstone/Siltstone	0.506	0.0001
Height_5	Cover_4	0.5226	0.0001
Cover_5	Cover_4	0.5233	0.0001
litter depth	Height_2	0.5236	0.0001
Height_4	Height_3	0.5251	0.0001
Height_5	Height_4	0.5394	0.0001
Cover_5	Height_4	0.5396	0.0001
litter depth	Moss	0.5584	0.0001
Height_2	Canopy cover	0.5689	0.0001
Moss	Canopy cover	0.5868	0.0001
Height_2	Height_1	0.5886	0.0001
Litter	CWD	0.6414	0.0001
Litter	Height_1	0.6551	0.0001
Height_1	Canopy cover	0.6756	0.0001
CWD	Canopy cover	0.6783	0.0001
CWD	Height_1	0.6805	0.0001
litter depth	Height_1	0.7167	0.0001
litter depth	CWD	0.741	0.0001
litter depth	Litter	0.801	0.0001
litter depth	Canopy cover	0.8029	0.0001
Litter	Canopy cover	0.8116	0.0001
Cover_3	Height_3	0.9097	0.0001
Cover_4	Height_4	0.9878	0.0001
Cover_5	Height_5	0.9991	0.0001

Appendix XVI Non- parametric correlation test (Spearman ρ) of first nest and control variables

Covariates		Spearman ρ	Prob>|ρ|
Nearest tree	Canopy cover	-0.1501	0.4459
Rock	Canopy cover	-0.0320	0.8718
Rock	Nearest tree	0.2060	0.2930
Bare ground	Canopy cover	-0.2423	0.2141
Bare ground	Nearest tree	0.1155	0.5583
Bare ground	Rock	0.0326	0.8691
CWD	Canopy cover	0.0925	0.6397
CWD	Nearest tree	-0.3091	0.1095
CWD	Rock	-0.2698	0.1651
CWD	Bare ground	-0.3364	0.0800
Litter cover	Canopy cover	0.1376	0.4851
Litter cover	Nearest tree	0.0149	0.9400
Litter cover	Rock	-0.0651	0.7419
Litter cover	Bare ground	-0.1386	0.4818
Litter cover	CWD	0.2656	0.1720
Moss	Canopy cover	-0.1521	0.4397
Moss	Nearest tree	0.0236	0.9050
Moss	Rock	-0.2553	0.1898
Moss	Bare ground	0.2242	0.2514
Moss	CWD	-0.0814	0.6805
Moss	Litter cover	0.3001	0.1207
Litter depth	Canopy cover	-0.0576	0.7709
Litter depth	Nearest tree	-0.1689	0.3901
Litter depth	Rock	-0.0772	0.6961
Litter depth	Bare ground	-0.0308	0.8762
Litter depth	CWD	0.3264	0.0900
Litter depth	Litter cover	**0.6847**	**0.0001**
Litter depth	Moss	0.4766	0.0103

Appendix XVII Non-parametric correlation test (Spearman ρ) of participant's estimates

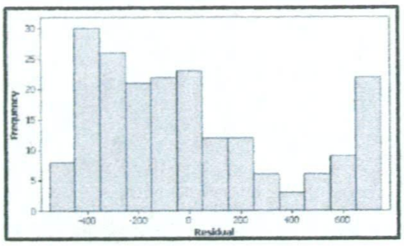
Covariates		Spearman ρ	Prob>|ρ|
Buildings	Property size	**-0.6703**	**0.0000**
Concrete	Property size	-0.1173	0.3443
Concrete	Buildings	0.3235	**0.0076**
Bitumen	Property size	-0.0372	0.7649
Bitumen	Buildings	-0.0674	0.5881
Bitumen	Concrete	-0.2186	0.0756
Paving	Property size	-0.2140	0.0821
Paving	Buildings	0.1748	0.1572
Paving	Concrete	-0.2132	0.0832
Paving	Bitumen	-0.0642	0.6056
Lawn	Property size	0.2892	**0.0176**
Lawn	Buildings	-0.3343	**0.0057**
Lawn	Concrete	-0.0164	0.8953
Lawn	Bitumen	-0.3587	**0.0029**
Lawn	Paving	-0.0373	0.7646
Trees	Property size	0.0201	0.8716
Trees	Buildings	-0.0468	0.7070
Trees	Concrete	-0.0461	0.7111
Trees	Bitumen	-0.1765	0.1531
Trees	Paving	0.0040	0.9743
Trees	Lawn	0.1841	0.1358
Veg patch	Property size	0.2429	0.0477
Veg patch	Buildings	-0.1317	0.2881
Veg patch	Concrete	-0.0744	0.5495
Veg patch	Bitumen	0.0076	0.9516
Veg patch	Paving	-0.0652	0.6001
Veg patch	Lawn	0.1648	0.1827
Veg patch	Trees	-0.1425	0.2501
Native bush	Property size	0.4441	**0.0002**
Native bush	Buildings	**-0.5808**	**0.0000**
Native bush	Concrete	-0.3573	**0.0030**
Native bush	Bitumen	0.1592	0.1980
Native bush	Paving	-0.0413	0.7397
Native bush	Lawn	-0.1571	0.2043
Native bush	Trees	-0.1208	0.3301
Native bush	Veg patch	-0.0179	0.8858
Flower garden	Property size	-0.1411	0.2548
Flower garden	Buildings	0.0810	0.5149
Flower garden	Concrete	0.2164	0.0786
Flower garden	Bitumen	-0.2578	**0.0352**
Flower garden	Paving	0.1358	0.2732
Flower garden	Lawn	-0.1067	0.3903
Flower garden	Trees	0.2488	**0.0424**
Flower garden	Veg patch	-0.2751	**0.0242**
Flower garden	Native bush	-0.1536	0.2146

Appendix XVIII Non-parametric correlation test (Spearman ρ) of the circle environmental variables and distance to native vegetation

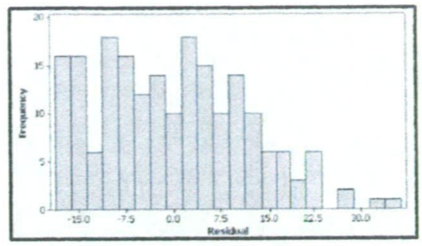
Covariates		Spearman ρ	Prob>|ρ|
Native vegetation	Distance to native vegetation	**-0.8960**	**0.0000**
Hard surfaces	Distance to native vegetation	**0.7045**	**0.0000**
Hard surfaces	Native vegetation	**-0.8094**	**0.0000**
Soft surfaces	Distance to native vegetation	-0.4403	**0.0012**
Soft surfaces	Native vegetation	0.3592	**0.0096**
Soft surfaces	Hard surfaces	-0.1684	0.2376
Grass	Distance to native vegetation	0.1625	0.2547
Grass	Native vegetation	-0.2586	0.0669
Grass	Hard surfaces	0.0060	0.9669
Grass	Soft surfaces	-0.0243	0.8655
Non-native vegetation	Distance to native vegetation	**0.7810**	**0.0000**
Non-native vegetation	Native vegetation	**-0.7870**	**0.0000**
Non-native vegetation	Hard surfaces	**0.5244**	**0.0001**
Non-native vegetation	Soft surfaces	-0.4789	**0.0004**
Non-native vegetation	Grass	0.1715	0.2288
Buildings	Distance to native vegetation	**0.7711**	**0.0000**
Buildings	Native vegetation	**-0.8100**	**0.0000**
Buildings	Hard surfaces	**0.6299**	**0.0000**
Buildings	Soft surfaces	-0.4551	**0.0008**
Buildings	Grass	-0.0246	0.8639
Buildings	Non-native vegetation	**0.6527**	**0.0000**

Appendix XIX Nest survey - histograms of residuals

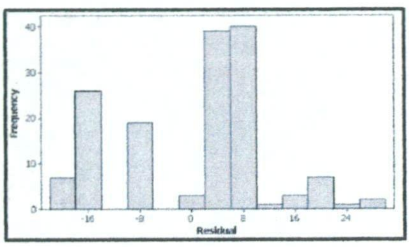
Altitude



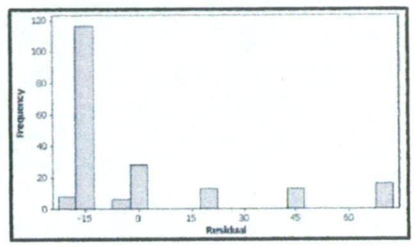
Slope



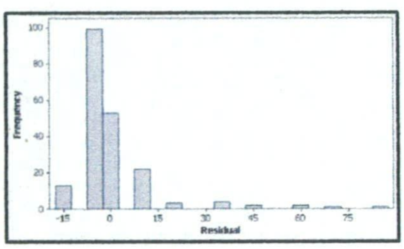
Soil clay content



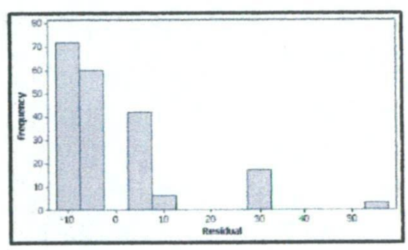
Rock cover



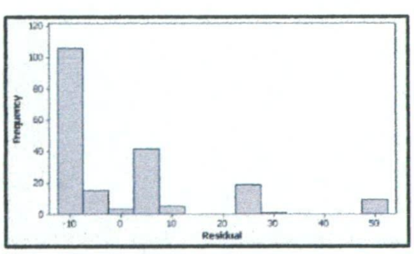
Bare ground cover



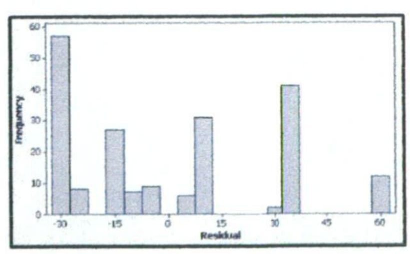
CWD cover



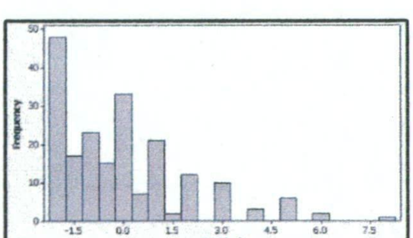
Moss cover



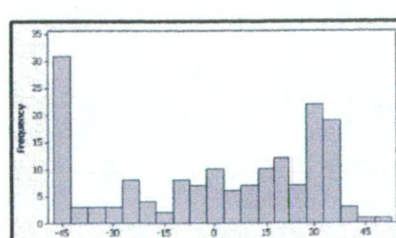
Litter cover



Litter depth

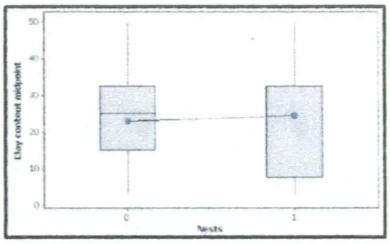


Canopy cover

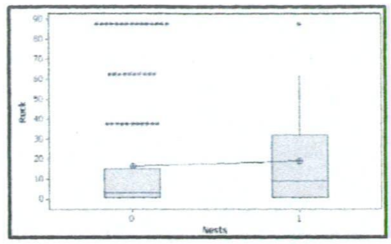


Appendix XX Nest survey - boxplots

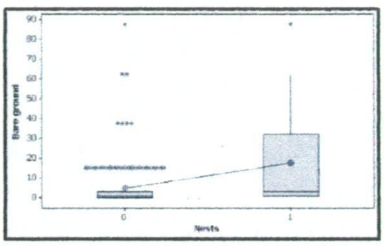
Clay content



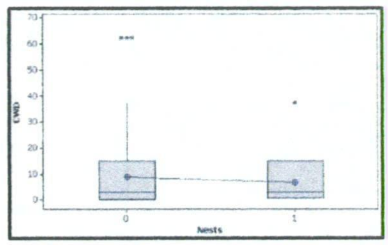
Rock cover



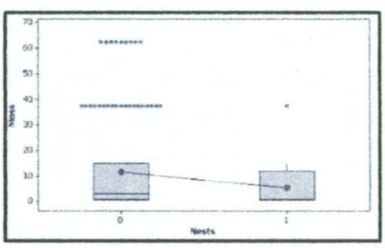
Bare ground cover



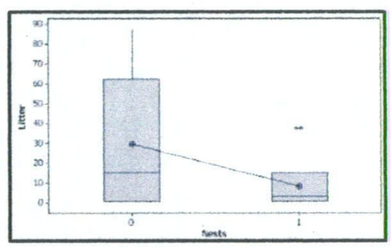
Coarse woody debris cover



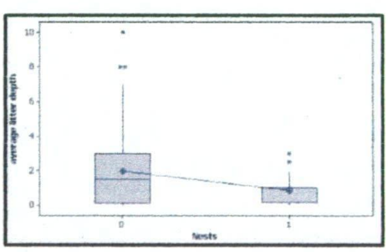
Moss cover



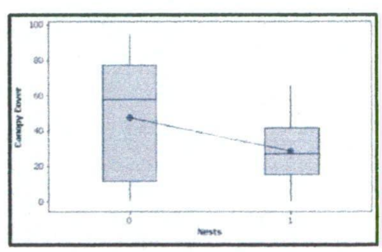
Litter cover



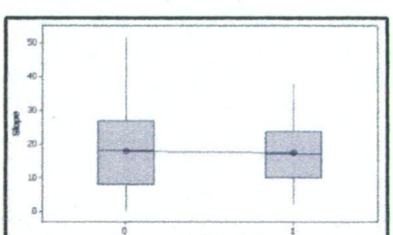
Litter depth



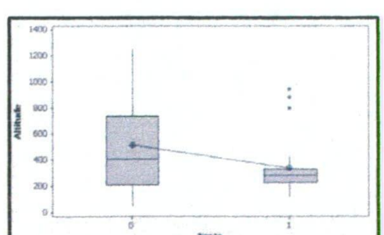
Canopy cover



Slope

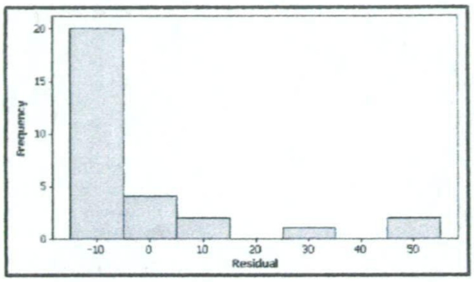


Altitude

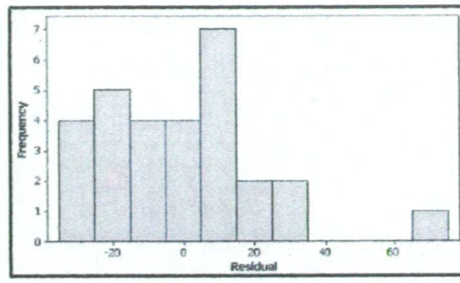


Appendix XXI Nest survey - first nest and control - histograms of residuals

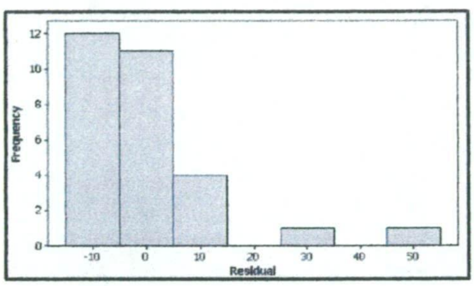
Rock cover



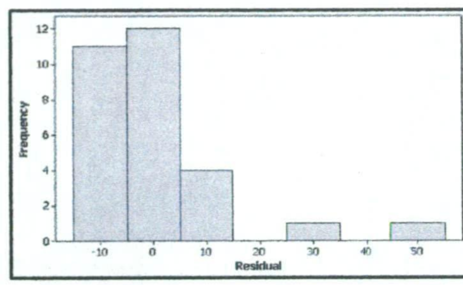
Bare ground cover



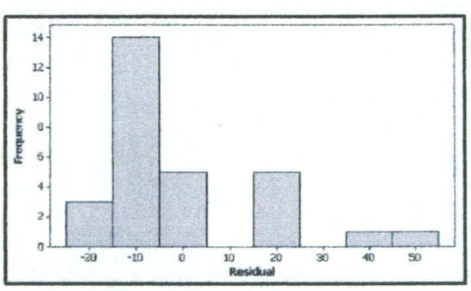
Coarse woody debris cover



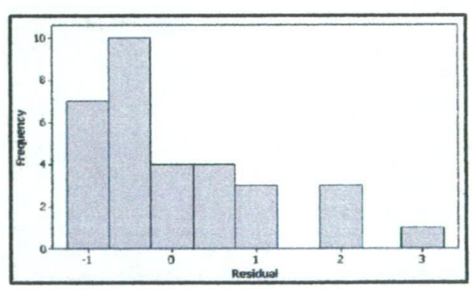
Moss cover



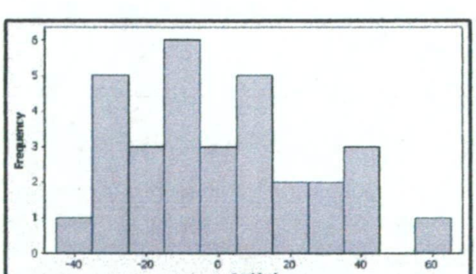
Litter cover



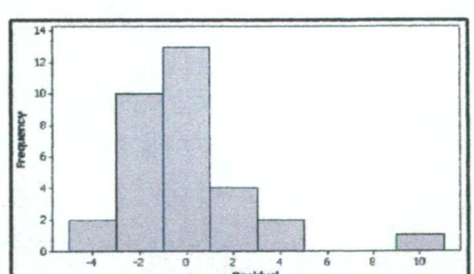
Litter depth



Canopy cover

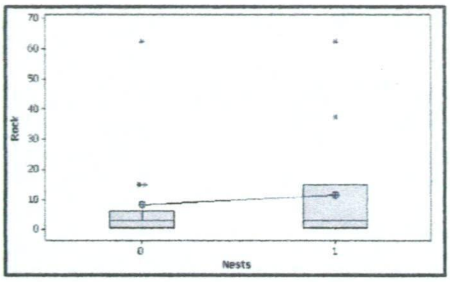


Nearest tree

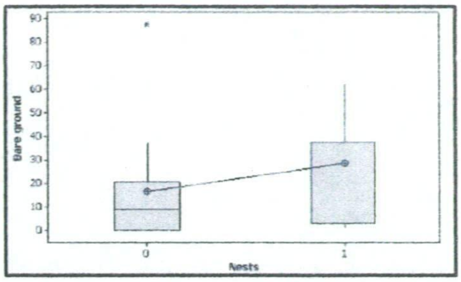


Appendix XXII Nest survey - first nest and control - boxplots

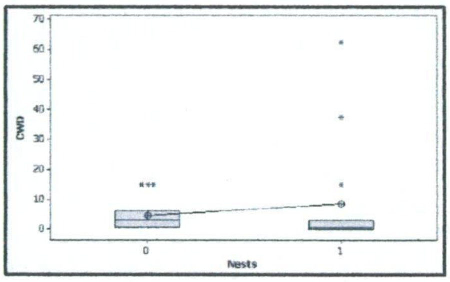
Rock cover



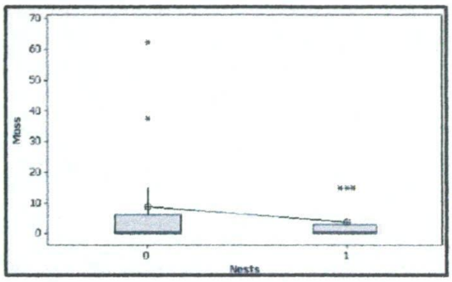
Bare ground cover



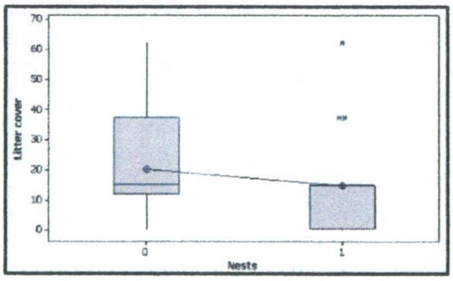
Coarse woody debris cover



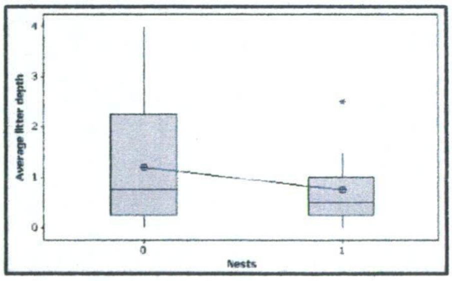
Moss cover



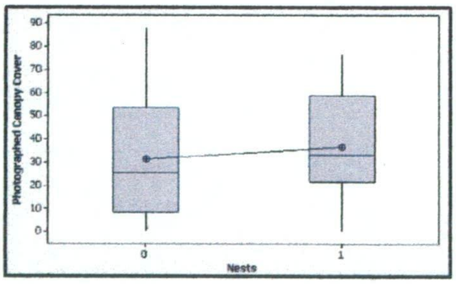
Litter cover



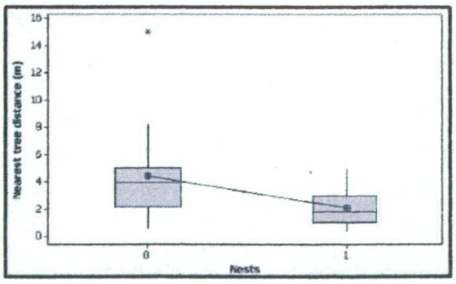
Litter depth



Canopy cover

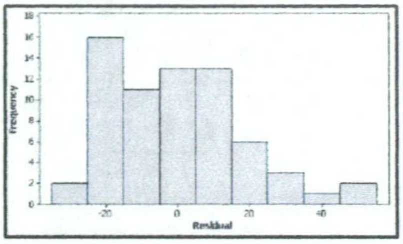


Nearest tree

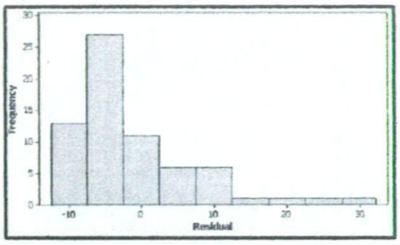


Appendix XXIII Properties survey - participants' estimates - histograms of residuals

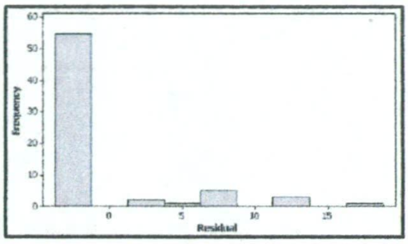
Building cover



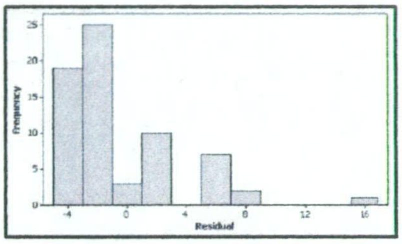
Concrete cover



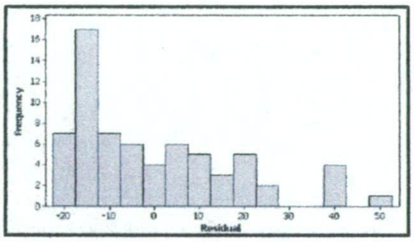
Bitumen cover



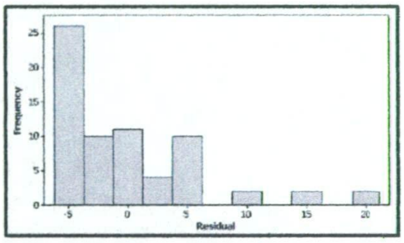
Paving cover



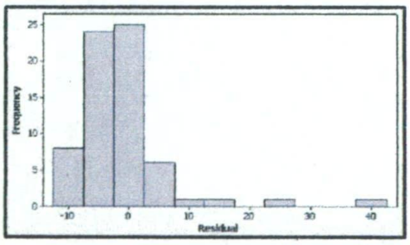
Lawn/grass cover



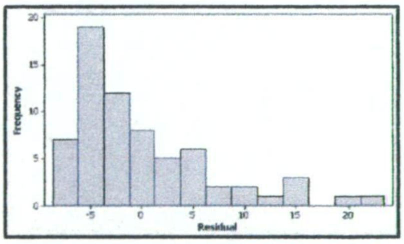
Flower garden cover



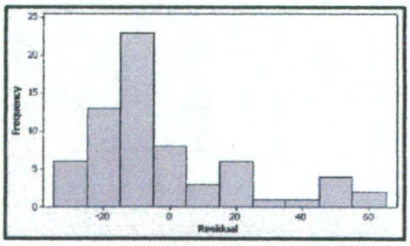
Vegetable patch cover



Non-native tree cover

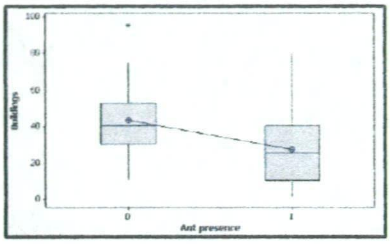


Native vegetation cover

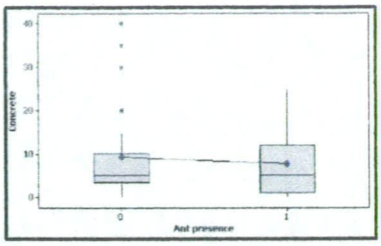


Appendix XXIV Properties survey - participants' estimates - boxplots

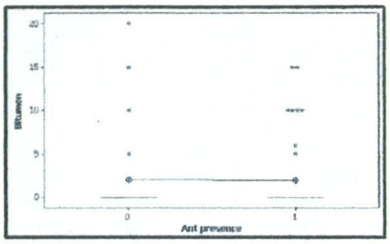
Building cover



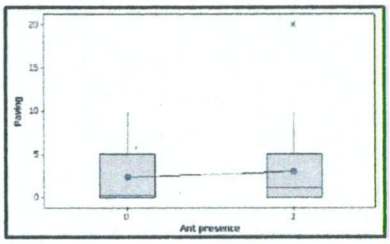
Concrete cover



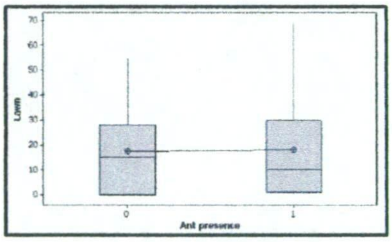
Bitumen cover



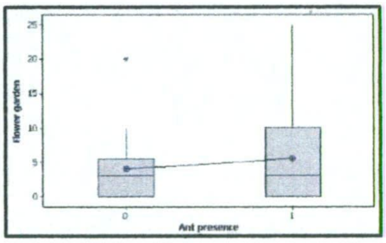
Paving cover



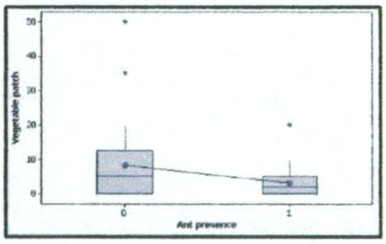
Lawn/grass cover



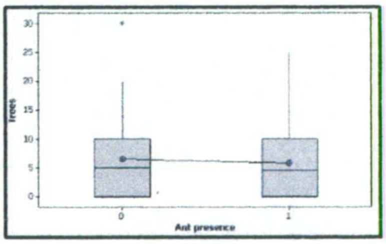
Flower garden cover



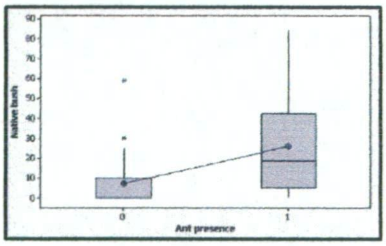
Vegetable patch cover



Non-native tree cover

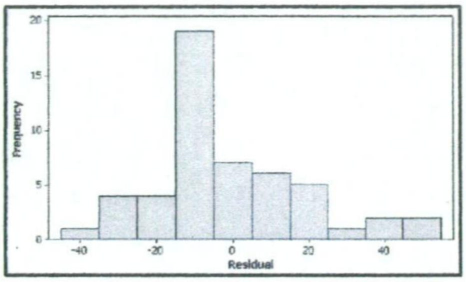


Native vegetation cover

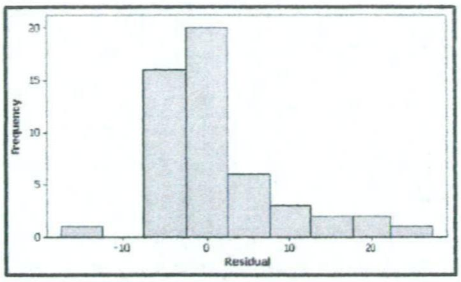


Appendix XXV Properties survey - circle estimates - histograms of residuals

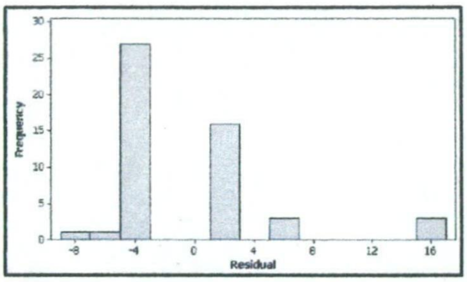
Native vegetation cover



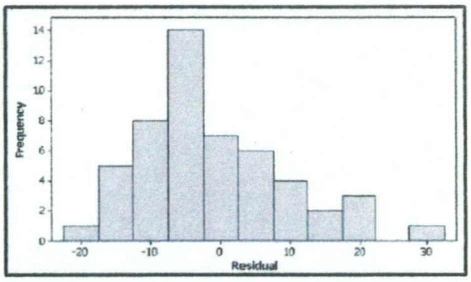
Non-native vegetation cover



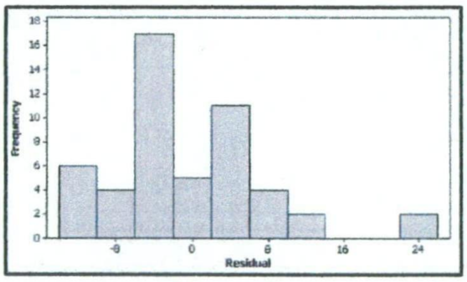
Soft surface cover



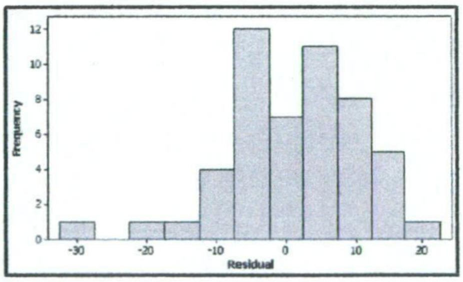
Grass



Hard surface cover

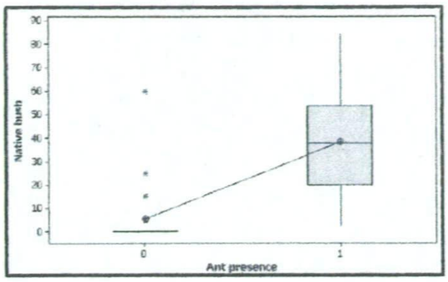


Building cover

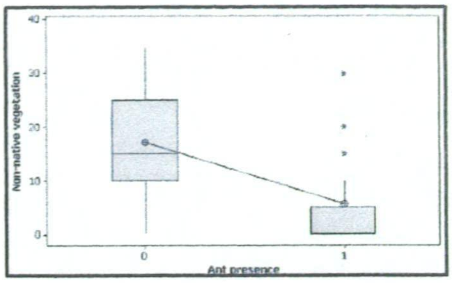


Appendix XXVI Properties survey - circle estimates - boxplots

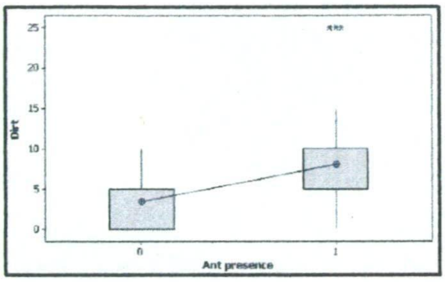
Native vegetation cover



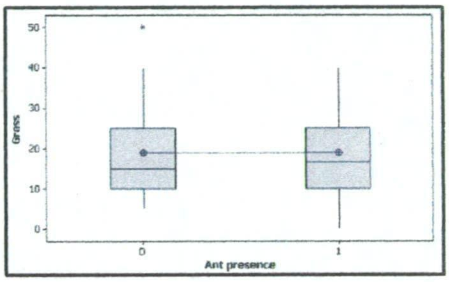
Non-native vegetation cover



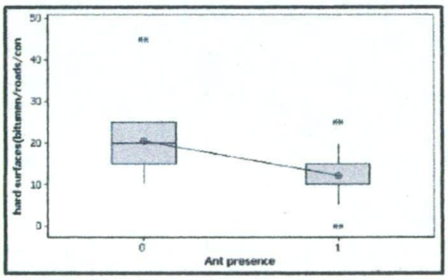
Soft surface cover



Grass cover



Hard surface cover



Building cover