To the Graduate Council:

I am submitting herewith a thesis written by Tiffany Aurora Toennisson entitled "Suburban Ant Community Structure with Emphasis on *Tapinoma sessile* and *T. sessile* Colony Movement in the Laboratory." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Entomology and Plant Pathology.

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Suburban Ant Community Structure with Emphasis on *Tapinoma sessile* and *T. sessile* Colony Movement in the Laboratory

A Thesis
Presented for the
Master of Science
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Tiffany Aurora Toennisson
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Abstract

Urbanization causes profound changes in the organization of arthropod communities. Ants, in particular, are good study subjects for community ecology and modification of habitat by humans has been shown to impact their community richness and composition. Of particular interest is how human-modified habitat affects the populations of pest ants such as the odorous house ant, *Tapinoma sessile* (Say). To better understand the relationship between urban habitat and ant community structure, ant communities in urban and suburban yards in the Knoxville, TN area were sampled via pitfall trapping and baiting, and several habitat characteristics were measured. Forty-six ant species were collected from twenty-five yards. Close proximity to human structures had the strongest relationship with both species richness and *T. sessile* abundance, with the former decreasing near structures while the latter increased. Of habitat characteristics quantified, percentage canopy cover was the most strongly related to ant species richness. These two variables had a polynomial relationship with highest richness at intermediate levels of canopy cover. Additionally, species richness had a significant, but negative, relationship with leaf litter presence. Leaf litter and the presence of logs, boards, or landscaping timbers positively related to *T. sessile* abundance.

As *T. sessile* colonies are known to move frequently, possible triggers of colony movement were examined in the laboratory including: shade, moisture, and proximity of food. *Tapinoma sessile* colonies initially moved to shaded nest tubes regardless of moisture content, but eventually moved brood and workers to moist nest tubes over a several week period. Colonies moved workers and brood to near-food nest tubes regardless of foraging distance to food. Queens moved to near-food nest tubes over 1 m distances, but not 6 m distances, during the 49 day study. Increases in moisture or food near houses may account for the dramatic rises in *T. sessile* abundance near these structures.

Dedication

I dedicate this thesis to Robbie, my husband. His support, sanity, and excellent fathering skills were valuable beyond compare for my completion of this project.

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Literature Review

"…the odorous house ants are prying little busybodies, eternally poking their antennae into everything." M. R. Smith, 1928

Tapinoma sessile Biology

Odorous house ants, *Tapinoma sessile* (Say), are common North American dolichoderine ants. *T. sessile* has one of the widest distributions of any ant species in North America dwelling from coast to coast and from Canada to Mexico (Fisher and Cover 2007). As the common name implies, these ants frequently invade human structures and have been listed as the second worst pest ant in the country (Hedges 2002). The average *T. sessile* worker is approximately 3mm long, while queens are slightly larger at around 4mm long. Colonies range in size from a few hundred to 500,000 workers (Buczkowski and Bennett 2006). Odorous house ant colonies are sometimes monogynous (Paulson and Akre 1991), but are commonly polygynous, especially in urban environments (Buczkowski and Bennett 2008), containing up to several hundred queens (Smith 1928). After several years of colony growth, winged reproductive ants, or alates, are produced. Male alates emerge first, followed by females, and mating is thought to occur within and outside of the nest (Smith 1928).

Like all dolichoderine ants, odorous house ants possess a slit-like anal pore from which they spray defensive compounds. For the genus *Tapinoma*, the seventh abdominal segmented is reflexed so that the pore is located ventrally (Fisher and Cover 2007). The chief constituent of *T. sessile's* defensive spray is butyric acid (Thompson 1990) which gives them their characteristic odor often described as "rotten coconut" (Smith 1928, Thompson 1990, Barbani 2003), although the author thinks the odor is more similar to a “rotten tangerine”. The genus *Tapinoma* can be distinguished from other dolichoderinae by the reduced size and strong leaning of the petiolar node and four gastral segments visible from above (Fisher and Cover 2007), and *T. sessile* can be distinguished from the few other *Tapinoma* reported in the United States by its uniform dark color (Smith 1928).

Feeding preference studies have found that odorous house ants consistently prefer carbohydrates, sucrose especially, and proteins over lipid-rich foods (Barbani 2003). Outdoors, odorous house ants are know to forage heavily on the honeydew exudates of ‘homopteran’ species and nectar. Similarly, inside human structures, odorous house ants are frequently attracted to sweet foods such as honey and jams. In addition to foraging for carbohydrates, odorous house ants scavenge dead insects to provide protein for their brood (Smith 1928). Odorous house ants rarely forage in temperatures below 10°C. However, in warmer months, greater foraging occurs during cooler times of the day (Barbani 2003).

Odorous house ants have the ability to nest within and under a wide variety of frequently impermanent, pre-fabricated objects. Their nests are shallowly excavated and commonly located under rocks, in and under logs, in leaf litter and mulch, and under a wide variety of human generated debris and structures (Buczkowski and Bennett 2006). Some more unusual nest sites include colonies dwelling under a Slip-and-Slide, inside the tube of a hula-hoop, and in a second-grader’s sugar-cube model of a pueblo adobe (T.A.T., *pers. obs.*; R. L. Toennisson, *per. comm.*).

Urban Ecology

Along with springtails and mites, ants are some of the most abundant soil-dwelling arthropods found in urban areas (McIntyre 2000), a pattern that reflects the general abundance of these soil dwelling taxa world wide (Hölldobler and Wilson 1990). This abundance makes ants ideal study subjects for community ecology (Hölldobler and Wilson 1990), especially in the growing field of urban ecology (Yamaguchi 2004).

Urbanization has been documented to cause shifts in the composition of arthropod communities for a variety of reasons including: pollution limiting the number of pollution-sensitive species, the urban "heat island" effect allowing certain species to live further north than their rural range, and human modification of vegetation causing changes in resource availability and succession. Different studies have shown both increases and decreases in arthropod species richness with increasing urbanization depending on the taxa and urban area involved (McIntyre 2000).

Of special importance to soil dwelling insects, human structures, roads, and landscaping efforts can cause dramatic changes in soil physical properties such as density, temperature, and pH. Soil nutrient cycling is also affected. Impervious surfaces and hardwood mulches decrease nitrogen availability in soils, while irrigation and fertilization increase the rate of nitrogen cycling and nitrogen availability, respectively (Byrne 2007). In arid urban environments, irrigation of ornamental plantings can dramatically increase the richness and abundance of certain species of arthropods while decreasing the number of desert specialists (Cook and Faeth

2006). Excess water run-off from urban environments possibly contributes to the invasiveness of *Linepithema humile* (Mayr) in arid areas of California (Holway and Suarez 2006). The increase in temperature associated with heat retention by urban pavement and structures has caused shifts in heat tolerance between urban and rural leaf-cutter ants (Angilletta Jr. et al. 2007).

Several studies on the effects of increasing urbanization on ant communities have found decreases in ant species richness due to urbanization. A survey of urban parks in Tokyo, Japan revealed that older parks closer to the city center had fewer species than comparable, younger parks in the city's suburbs. Although, the paucity of the collection methods in this study leaves the results somewhat questionable (Yamaguchi 2004). A much more robust study in California showed similar decreases in ant diversity in small scrub-habitat fragments surrounded by urban development than larger areas of intact scrub. For this study, the difference in ant diversity was possibly due to the propensity of the *Linepithema humile* to out-compete native ants in close proximity to urbanization (Suarez et al. 1998). Similarly, a survey of ants in urban and rural Canadian forests recorded fewer species from urban forests than rural ones (Thompson and McLachlan 2007).

However, other studies have found urbanization to have little effect or actually increase species richness, although community composition is still frequently affected. In contrast with the Suarez study above, surveys of ant communities in green areas in Sydney, Australia (Gibb and Hochuli 2002) and San Francisco, California (Clarke et al. 2008) both found little relationship between habitat fragment size and ant diversity. However, the former study did find proportionally more generalist ant species in smaller fragments, and the latter found fewer ant species in forests dominated by non-native plant species. A survey of ants in the Florida Keys found that the number of native species and rare native species were not affected by development or proximity to roads, and the number of non-native species increased near such development (Forys and Allen 2005). In Quebec, Canada, ant communities were found to be more diverse in urban backyards than a nearby forested nature reserve. However, community composition differed between forest, forest edge, and urban sites (Lessard and Buddle 2005). A few species of ants are extremely specialized for living in close association with humans. These so called "tramp" species commonly share traits such as polydomy, unicoloniality, and opportunistic foraging and nesting strategies (Passera 1994). Alternately, urban environments may occasionally provide native ants refuge from invasive ants. A native American fire ant, *Solenopsis geminata* (F.), was abundant in older neighborhoods of Austin, TX, but this ant had been displaced by the invasive fire ant, *S. invicta*, in nearby younger neighborhoods and surrounding rural areas (Plowes et al. 2007).

Habitat and Ant Communities

Inter-specific competition has long been touted as one of the most important force in shaping ant communities, and numerous studies show strong evidence that such competition occurs (Hölldobler and Wilson 1990). Many studies have focused on documenting dominance hierarchies in which a few species of ants dominate either behaviorally or ecologically over other ants in the community. In many of these hierarchies, there seems to be a trade off between a species ability to discover resources quickly (exploitative competition), and its ability to defend resources against more aggressive species (encounter competition) (Davidson 1998). In one such study of eastern American woodland ants, *Tapinoma sessile* was found to be relatively quick to discover baits, but the second most submissive ant in the dominance hierarchy (Fellers 1987). However, dominance hierarchies are not static, and the ability of a given species of ant to dominate a resource depends upon other biological and environmental factors such as resource density (Palmer 2003), presence of parasitoids (LeBrun 2005), and temperature (Cerdá et al. 1997). In fact, null-modeling has shown that the patterns of species distributions in many ant communities do not show evidence of being structured by competition (Ribas and Schoereder 2002).

As an alternate hypothesis to competition determining ant community structure, habitat quality or heterogeneity could contribute to structuring ant communities. Differences in habitat heterogeneity have been shown to change the composition and dynamics of ant communities. In general, predatory arthropods, including ants, increase in abundance in areas of higher complexity. Changes in the amount of detritus had the strongest effect on predatory arthropod abundance with vegetation complexity showing a weaker, but clear, effect as well (Langellotto and Denno 2004). However, in some systems, increasing habitat complexity has a negative relationship with ant species richness (Lassau and Hochuli 2004).

Reducing habitat heterogeneity changes the dynamics of foraging interactions at baits. For example, the invasive yellow crazy ant, *Anoplolepis gracilipes* (Smith), easily dominated baits over other ant species native to the island of Tokelau in a simple, planar foraging area. However, ants native to the island were able to dominate baits in a more rugose environment which they could navigate and locate food in more quickly due to their smaller size than the crazy ant (Sarty et al. 2006). The complexity of ants' environment can also indirectly alter foraging dynamics by changing their susceptibility to parasitoids. In areas with removed leaf-litter, two species of *Pheidole* decreased foraging success when their parasitoids were present, but high success, despite the parasitoids, in areas with litter (Wilkinson and Feener 2007).

Changes in microhabitat change ant communities. In Costa Rican coffee plantations, the additions of shade and leaf litter caused huge increases in the activity of forest species at baits, while reducing the activity of the frequently dominant *Solenopsis geminata* (Perfecto and Vandermeer 1996). Mediterranean ant foraging response and dominance hierarchies were different between baits placed in mowed, edge, and unmowed microhabitats in close proximity, a difference that could not be explained simply by change in temperature (Luque and Lopez 2007).

A complex habitat with variability in resource distribution allows for differential niche portioning by ants that specialize in areas with high or low resource availability. For example, acacia tree sprouts and litter-dwelling invertebrate densities are higher on areas over termite mounds probably due to increased nitrogen concentrations. Competitively dominant acacia-dwelling ant species were more likely to out compete more subordinate species in these resource-rich areas, but were less likely to dominate away from the resource increase (Palmer 2003). Similarly, some species of epiphyte-specialist ants dominate where host-plant densities are high, while other species dominate the ant-plants when host-plant densities are low (Yu et al. 2001).

Diversity of plants has strong relationships with diversity of ants. Arboreal ant species richness was positively related to tree species richness and tree density in a Brazilian savanna

(Ribas et al. 2003). Even, simply increasing the plant species richness of twigs used to create artificial nesting tubes increased the number of ant species nesting in the tubes despite the tubes' otherwise similar dimensions (Armbrecht et al. 2004).

Anthropogenic disturbance of habitats dramatically changes the composition of ant communities. For example, as disturbance increased from tropical forest, to abandoned farmland, to active cocoa plantations, ant diversity similarly decreased (Roth et al. 1994). The majority of studies on the effects of agriculture on ant diversity have shown similar decreases in species richness, with the exception of low-impact, "traditional" farming and pastoral practices (Brussaard et al. 1997). Anthropogenic disturbance can facilitate the domination of a local community by ants that are well adapted to open environments as seen for the Australian meat ant, *Iridomyrmex purpureus* (Smith) (Gibb and Hochuli 2003), the red imported fire ant, *Solenopsis invicta* (Buren) (King and Tschinkel 2008), and *Linepithema humile* (Suarez et al. 1998).

Colony Movement

Although ant colonies have historically been viewed as fairly immobile (Wheeler 1910), frequent movement of ant colonies is widespread among ants from various taxa (Smallwood and Culver 1979). In some cases, colonies completely abandon an old nest site in favor of a new one. In other instances, the colony splits to become polydomous (Debout et al. 2007). *T. sessile* colonies are have been observed to move frequently outdoors, in one instance 78% of its colonies in an eastern woodland moved within 21 days (Smallwood and Culver 1979). In urban areas colony movement may be less frequent as one study reported the average colony occupation time to be 133 days (Buczkowski and Bennett 2008).

Numerous causes of nest relocation for other ant species have been proposed and investigated. Smallwood and Culver (1979) hypothesized that escaping disease or parasite load could explain colony movement, an idea corroborated by the correlation between parasitic mite numbers and movement of the ant *Aphaenogaster araneoides* Emery (McGlynn et al. 2004). However, in other instances, the presence of the disease-causing microsporidia, *Kneallhazia solenopsae* Knell, Allen, and Hazard, had no effect on the movement of fire ants (Briano et al. 1995).

Excessive shading triggered nest relocation of the forest ant, *Aphaenogaster rudis* Enzmann, probably due to its unfavorable effect on the thermoregulation of the colony (Smallwood 1982). Shading of colonies has also triggered relocation in colonies of the Australian ant, *Iridomyrmex purpureus* (Hölldobler and Wilson 1990). The movement of the ponerine ant, *Rhytidoponera metallica* F. Smith, from small rocks to larger, more thermally stable rocks could also reflect colony movement for thermoregulatory purposes (Thomas 2002). In some instances, ants seem to move simply when presented with a nest site with more preferred architecture, as exemplified by *Temnothorax albipennis* (Curtis) (Dornhaus et al. 2004).

Changes in moisture levels could be especially important triggers for movement as several studies have shown that ants move more frequently after rainfall (Gordon 1992) due possibly to flooding or other factors such as the workability of moist soil. The expansion of *Linepethema humile* colonies shows a strong positive correlation with summer rainfall (Heller et al. 2006). *Tapinoma sessile* workers have frequently been seen transporting brood before rainstorms (Vail et al. 2003), and *T. sessile* colonies have been known to abandon compost/leaf piles when the piles dry during summer droughts (personal observation). *T. sessile* colonies are common around the mulch at the bases of irrigated bushes, an area with high moisture levels and close proximity to 'homopteran' exudates (Buczkowski and Bennett 2008). The presence of even a few drops of water on the nest entrance causes minor workers of the neotropical species *Pheidole cephalica* Smith to scurry through the nest and lay odor trails to lead others in the colony to unobstructed entrances; occasionally colony relocation occurred (Hölldobler and Wilson 1990).

Disturbance by biotic or abiotic factors also could trigger movement (Tsuji 1988). Most ants scurry to relocate brood and queens upon any type of physical disturbance to the nest, and some ants, such as *Temnothorax*, will even relocate to a new nest site upon disturbance. Invasion of the nest by raiding ants such as fire ants and army ants triggers evacuation of the raided colonies. Even within the same genus, ants show unique species specific patterns in how they organize such evacuations (reviewed in Hölldobler and Wilson 1990).

Many colonies of polydomous ants have been shown to seasonally expand to occupy more nest sites during spring and summer, but then coalesce as winter approaches. Seasonal polydomy has been documented in diverse taxa including: *Linepithema humile* (Heller et al. 2006), *Pheidole megacephal*a (F.) (Hoffmann et al. 1999), *Temnothorax longispinosus* (Roger), and *Myrmica punctiventris* Roger (Hölldobler and Wilson 1990). Recent work with odorous house ants has shown similar seasonal polydomy as the odorous house ants exponentially increase the number of nest sites occupied in the spring, hold steady in nest site number during the summer, and return to their over wintering location in the fall (Buczkowski and Bennett 2008).

Improving foraging success appears to be the motivation for some ant movement. Artificially starved army ants in the genus *Neivamyrmex* have been shown to migrate twice as often as overfed colonies (Hölldobler and Wilson 1990). The formation of polydomous colonies could allow for strategic allocation of brood and workers to better utilize foraging resources, a phenomenon known as dispersed-central place foraging (Holway and Case 2000). Another polydomous Dolichoderine species, *L. humile*, relocates workers and brood to nest sites closer to food (Holway and Case 2000), and *T. sessile* foragers have been shown to have high nest-site foraging fidelity, in support of dispersed-central place foraging theory (Buczkowski and Bennett 2006).

Chapter 1: Odorous House Ant, *Tapinoma sessile*, Colony Movement in Response to Moisture, Shade, and Food Proximity

Introduction

Nest relocation is common among ants from various taxa (Smallwood and Culver 1979, Hölldobler and Wilson 1990, Debout et al. 2007). Numerous causes of ant nest relocation have been proposed and investigated. Smallwood and Culver (1979) hypothesized that avoiding disease or parasite load could explain colony movement, an idea supported by the correlation between parasitic mite numbers and movement of the ant *Aphaenogaster araneoides* Emery (McGlynn et al. 2004). However, in other instances, the presence of the disease-causing microsporidia, *Kneallhazia solenopsae* Knell, Allen, and Hazard, had no effect on the movement of fire ants (Briano et al. 1995). Excessive shading triggered nest relocation of the forest ant, *Aphaenogaster rudis* Enzmann, probably due to its unfavorable effect on the thermoregulation of the colony (Smallwood 1982). The movement of the ponerine ant, *Rhytidoponera metallica* F. Smith, from small rocks to larger, more thermally stable rocks could also reflect colony movement for thermoregulatory purposes (Thomas 2002). In some instances, ants seem to move simply when presented with a nest site with more preferred architecture, as exemplified by *Temnothorax albipennis* (Curtis) (Dornhaus et al. 2004). Changes in moisture levels could be especially important triggers for movement as several studies have shown that ants move more frequently after rainfall (Gordon 1992, Briano et al. 1995, Heller et al. 2008) due possibly to flooding or other factors such as the workability of moist soil. Some species, including *Tapinoma sessile* (Say) and *Linepithema humile* (Mayr), are seasonally polydomous, meaning colonies expand by budding to occupy multiple nest sites in the spring and coalesce again in the fall (Holway and Case 2000, Buczkowski and Bennett 2008).

The widespread North American ant, *Tapinoma sessile,* commonly called the odorous house ant, can form large polydomous colonies in shallow, preformed nest sites such as under rocks and logs, in leaf litter, and in urban areas, under various types of human-generated debris (Smith 1928). *T. sessile* colonies have been observed to move frequently outdoors (Smallwood and Culver 1979), yet, despite their wide geographic range and long standing notoriety as a household pest (Smith 1928), only recently have investigations turned to focusing on triggers of *T. sessile's* colony movement (Buczkowski and Bennett 2008). *Tapinoma sessile* workers have frequently been seen transporting brood before rainstorms (Vail et al. 2003), and *T. sessile* colonies have been known to abandon collecting sites in compost/leaf piles when the piles dry out during summer droughts (T.A.T., *pers. obs*.). The formation of polydomous colonies could allow for strategic allocation of brood and workers to better utilize foraging resources, a phenomenon known as dispersed-central place foraging (Buczkowski and Bennett 2006). In the laboratory, odorous house ants frequently moved out of nest cells consisting of petri-dishes filled with slightly moistened castone to take up residence in shaded areas underneath the nest cells, under food dishes, and inside water tubes (personal observation). Additionally, in a study documenting seasonal polydomy in this species, new *T. sessile* colonies were common around the mulch at the bases of bushes, an area with high moisture levels and close proximity to homopteran exudates (Buczkowski and Bennett 2008). While many of the above observations provide strong anecdotal evidence for possible triggers of *T. sessile* colony movement, controlled experiments in this area are lacking. This study investigates several possible triggers for nest relocation in odorous house ants: moisture, shade, and food location.

Materials and Methods

Colony Collection and Maintenance. Colonies of *T. sessile* for these studies were collected around residences in the Knoxville, TN area. Colonies were maintained in the lab in Fluon (AGC, Philadelphia, PA) coated boxes and given tubes to nest in. Each tube consisted of a 13 mm x 100 mm glass test tube covered with red acetate secured along all edges with transparent tape. One third of the test tube was filled with water and plugged with a small cotton ball. Tubes used in experiments constructed as described above will be referred to as standard nest tubes and variations in construction will be noted (Figs. 1.1 and 1.2). The ants had constant access to water and 10% sugar water (10g sugar:100mL water) and twice weekly feedings of previously frozen dead crickets and hard-boiled chicken egg yolk. *T. sessile* colonies were maintained in the lab and throughout these studies at 27º ± 1°C (mean ± sd), 22% ± 5% relative humidity, and 14 hr light:10 hr dark cycle.

Moisture/Shade Tests. To investigate *T. sessile* colony preferences for moist or shaded nest sites, and to see if this preference changed over time, two tests were used. In the first test, the ants had the choice of a moist site or a shaded site. One test tube with acetate only (shade) and one clear tube with water capped with cotton (moisture) were placed in each of ten 21 cm x 15.5 cm x 9.5 cm plastic disposable/reusable boxes. In the second test, the ants had a choice of a moist, shaded or dry, shaded site, and one standard nest tube (moisture + shade) and one tube covered with acetate alone (shade) were placed in ten similar boxes. Tubes were secured to the bottom of the box with a small piece of putty. Boxes were randomly placed on trays at various levels of wire racks and in various orientations to minimize any area effect.

T. sessile ants collected 3 days prior to the tests were split into twenty subcolonies consisting of ~200 ants, 3 queens, and 2 cm^2 of brood. Previous observations of nest tube inhabitation indicated that this number of ants would occupy a single nest tube even if excess nesting sites were available so overcrowding would be an unlikely trigger of movement. Each subcolony was introduced in the center of each box. After 24 hours, the number of ants and brood (cm^2) in each nest tube was visually estimated using a transparent 0.5 cm square grid held over each tube. Care was taken to not touch the tube or otherwise disturb the ants within. At this time, ants were also provided a tube of sugar water and dead crickets as food at points equidistant from both nest tubes (Fig. 1.1). Thereafter, sugar water was replenished as needed and dead crickets offered twice a week. Worker number and brood area were recorded again at 6, 10, 27, 36, and 46 days after ant placement. The test was terminated after 46 days when the water levels were too low to saturate the entire cotton plug.

Data could not be taken on humidity of ant-containing nest tubes without disturbing the ants and causing them to exit the tube and, in some instances, hide in the humidity probe. However, empty nest tubes maintained a near constant humidity of 73.5% ± 2.9% for 6 weeks. The humidity remained at that level even after the water reserve in the tube appeared to be gone with only moisture remaining in the cotton balls. However, after the cotton balls began to dry, the humidity in all tubes dropped dramatically to the same humidity as the surrounding lab between 7 and 8 weeks after nest tube construction.   Although, the presence of ants likely alters humidity within the cells, these data indicate that the humidity levels within the nest tubes used in this study remained fairly constant prior to any ant presence.

The mean percentage difference in worker numbers in the two test tubes was analyzed using a Repeated Measures ANOVA (SAS 2003). The data were examined to determine differences over time and whether the mean percentage difference was equal to zero at each time of data collection (a mean differing from zero would indicate preference for a particular treatment). For this and all subsequent tests, an $\alpha \leq 0.05$ was used to reject the null hypotheses. For each ANOVA, normality and equal variance were checked using the Shapiro-Wilk and Levene *P* tests, respectively. As the raw and log transformed data for percentage differences of workers in the moisture versus shade test did not meet these assumptions the data was ranked for these analyses. All other data from these tests were suitable for analysis without transformation. The mean percentage difference in brood area estimates in the two tubes was analyzed the same as worker counts.

Food Proximity Tests. The food proximity tests were designed to investigate whether *T. sessile* nest site selection is influenced by the proximity of food. Each experimental apparatus consisted of a plastic storage box with 35 cm x 22 cm floor dimensions containing four standard nest cells, called hereafter the main box. Each main box was connected to two 21 cm x 15.5cm x 9.5 cm disposable/reusable containers one of which was selected at random to contain food and a standard nest cell (food box) and one of which contained only a nest cell (no-food box). In order to provide long foraging distances in a small amount of lab spaces, Slinky® toys (Poof®-Slinky®, Inc, Plymouth, MI), children’s toys made of coils of flattened wire, were connected from two hooks in the main box to each food and no-food box (Fig. 1.2). The use of a Slinky® to simulate long distance foraging was introduced previously with Pharaoh ants, *Monomorium pharaonis* (L.) (Buczkowski et al. 2005).

Ant movement in response to food was investigated over two foraging distances: 1m and 6m. Each test had ten replicates of the apparatus in Fig. 1.2 with the Slinky® cut so that the total foraging distance along the coils was 1m or 6m for each of their respective tests. Apart from the difference in foraging distance length, the tests were conducted identically.

Odorous house ants were collected the day before placement in the test apparatus from a colony nesting in pine straw. They were given test tubes of water and allowed to feed on 10% sugar water and dead crickets for 24 hours. The next day, subcolonies consisting of ~400 workers, 2-4 cm^2 brood, and queens were placed in each of the 20 main boxes. They were starved in the main box without Slinkys® connected for 3 days to promote a vigorous foraging response once food was made available.

After the three-day starvation period, dead crickets and a tube of 10% sugar water were placed in each food box, and Slinkys® were used to connect the main box to both the food and no-food boxes. The foraging activity of the ants along the Slinkys® and the presence and location of workers and brood in either of the upper boxes was recorded after 48 hours and twice a week thereafter until the termination of the test 49 days later. On the last day of the test, the nest tubes in the two upper boxes were emptied to see if queens were present and to determine brood life stages present.

The differences in workers and brood between the food and no food nest tubes were analyzed using repeated measures ANOVA as described above for the Moisture/Shade tests. To correct for non-normality of the data, ranked data was used for the repeated measures ANOVA for the 6 m test. All other similar ANOVAs were performed with the original data. To compare ant movement between the 1m and 6m distances over time, a Repeated Measures ANOVA was performed on the combined data from the 1m and 6m tests as above with both time and slinky length as main effects. In this ANOVA, the data for both worker differences and brood differences were rank transformed because of unequal variances.

Results

Moisture/Shade Tests. The distribution of workers and brood between the two nest tubes varied over time for both the moisture versus shade (workers: $F = 18.18$, df = 5, 45 $P < 0.0001$; brood: $F = 15.37$, df = 5, 45 , $P < 0.0001$) and the moisture + shade versus shade tests (workers: $F = 3.54$, df = 5, 45, $P < 0.0087$; brood: $F = 4.24$, df = 5, 43, $P < 0.0032$). For the test comparing moist, unshaded tubes (moisture) with dry, shaded tubes (shade), initially, close to 100% of the workers and brood took up residence in the shaded tubes. By Day 10 of the test, workers and brood moved into the moist tubes so that they were distributed 50/50 between the two tubes. The workers remained nearly evenly distributed between the two tubes for the remainder of the test. However, a significantly higher ($t = 3.40$, df = 54, $P < 0.0013$) proportion of the brood was moved into the moist tube by 27 days and remained higher thereafter (Fig. 1.3).

For the test comparing ant nest site choice between standard nest tubes (moisture + shade) and tubes with no moisture (shade), initially, both workers and brood were split nearly 50/50 between both tubes. Across time, there was a trend in worker movement towards tubes with moisture with the mean percentage difference between worker counts in the two tubes not equal to zero (indicating 50:50 distribution) for two data points (Day 27: $t = 4.24$, df = 45 , $p < 0.0001$; Day 36: $t = 2.00$, df = 45, $P < 0.05$). A much more robust response was seen in the movement of brood. Significantly ($t = 2.81$, df = 43 , $P < 0.0074$) higher proportions of brood were moved to tubes with moisture by Day 6 of the test and remained consistently higher in tubes with moisture throughout the duration of the test (Fig. 1.4).

Food Proximity Tests. Ants distributed themselves nearly evenly between the four nest tubes upon initial introduction to the main box. When the Slinkys® were initially attached to connect the main box to the food and no-food boxes, the workers from the main box exhibited a vigorous foraging response up both Slinkys® for all boxes in both the 1m and 6m tests. Workers moved and brood was moved into the nest tubes of all food boxes of the 1m and 6m test within the 49 days of the test (Figs. 6). By then end of the experiment, an average of 72 ± 10 ants moved into the nest tube of the food box for the 1m test, and an average of 67 ± 18 ants occupied the food boxes in the 6m test.

The differences in workers and brood for changed over the time for both the 1 m (workers: $F = 16.60$, df = 7, 61, $P < 0.0001$; brood: $F = 18.10$, df = 7, 61 , $P < 0.0001$) and 6 m (workers: $F = 5.27$, df = 7, 63, $P < 0.0001$; brood: $F = 29.81$, df = 7, 61 , $P < 0.0001$) tests. For the 1 m test, the difference in workers between food and no food tubes was significantly different from zero for all days but day two (at least $t = 2.71$, df = 61, $P = 0.0087$), and brood differences were different from zero by day 29 ($t = 3.32$, df = 61, $P < 0.0015$; Fig. 1.5) and remained different thereafter. Similarly, for the 6 m test, the difference between food and workers was significantly different for all days (at least $t = 2.14$, df = 63 $P < 0.036$), and brood differences differed from zero for all days after day 35 (at least $t = 4.67$, df = 61, $P < 0.0001$; Fig. 1.6). Comparisons of the 1m and 6m tests showed that Slinky® length significantly effected worker movement ($F = 6.51$, df = 1, 133, $P = 0.012$) with on average more workers moving to 1m near food nest tubes than to 6m near food nest tubes, but no effect of length was seen for movement of brood ($F = 0.57$, df = 1, 131 , $P < 0.45$). In no instance was there a length by time interaction (workers: $F = 1.56$, df = 7, 133 , $P = 0.16$; brood: $F = 0.63$, df = 7, 131 , $P = 0.73$).

On the last day of the test, brood in all three lifestages (egg, larvae, pupae) were found in half of the food nest tubes for both tests. The other half of the food box nest tubes contained only eggs or eggs plus larvae. In contrast with food boxes, no more than five ants were found in no-food boxes on any given day for either test (the average was less than one for all days) and no brood were ever moved to these boxes. Additionally, three queens moved into the nest tubes of two of the food boxes over the 1 m distance (two queens were found in one tube, one in another). No queen movement was observed over the 6 m distance.

Discussion

Although care must be taken when extrapolating the results of laboratory studies to the workings of life in the field, the results of these studies lend support to hypothesis based on field observations (Buczkowski and Bennett 2008) that the movement of wild *T. sessile* colonies is strongly influenced by moisture and food availability. Many nest sites occupied by *T. sessile* colonies are shallow and prone to desiccation, especially nests located in leaf litter or mulch. Odorous house ant colonies in mulch are frequently found around irrigated landscaped plantings (Bucxkowski and Bennett 2008), and colonies have been observed to move out of litter piles during prolonged dry spells (personal observation) thus moisture levels most likely play a role in colony relocation outdoors as well.

This study indicates that location of food resources is likely to be a major driver of colony movement. Over short distances, queens moved along with workers and brood into nest tubes closer to food. In previous study, a protein marker showed that *T. sessile* colonies have high nest-site fidelity in foraging behavior in concordance with dispersed central-place foraging theory (Buczkowski and Bennett 2006). Our work further supports the dispersed central-place foraging model for explaining odorous house ant polydomy as there was overwhelming evidence of partial colony movement to near-food nest sites.

Practical applications of this study exist for both further laboratory studies and for pest control. Laboratory apparatuses for testing behavioral choices of odorous house ants must be carefully designed to avoid biasing ant movement towards areas with higher food, moisture, or shade availability, and artificial nest sites for odorous house ants should be constantly moist (possibly around 70% relative humidity) and shaded. Additionally, the results of this study suggest cultural control methods for these ants. Reducing food and moisture availability in and around the structures may reduce the likelihood of ants moving near to structures.

Although *Tapinoma sessile* colonies are frequently polydomous in urban settings, these ants are more commonly monodomous in more forested settings (Paulson and Akre 1991, Buzchowski and Bennett 2008). The availability of novel food and moisture sources in close proximity to novel nest sites in anthropogenically altered habitats may spur these ants to form polydomous colonies. Investigations comparing food, moisture, and nest site availability in the field between polydomous and monodomous colonies could prove valuable in elucidating the ecology of polydomous ants.

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Appendix

Figure 1.1. A box from the Moisture / Shade Test. The tubes on either side are the nest tubes, and the central tube contains sugar water. Dead crickets on the bottom served as another food source for larvae. Boxes for the other Moisture and Disturbance Tests were arranged similarly.

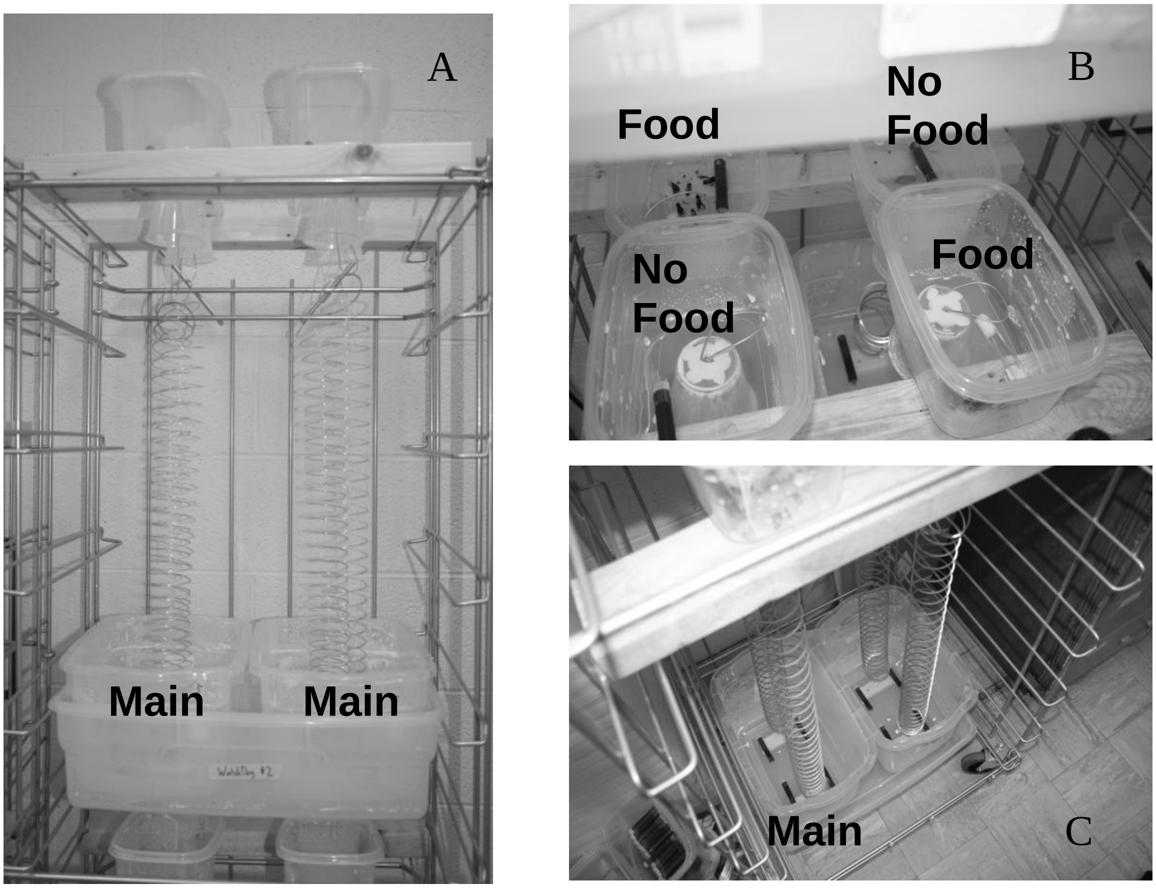

Figure 1.2. The Food Location Test Setup. A. shows a front view of two experimental apparatuses with 6m Slinkies®. Two upper boxes (B.), a ‘food’ box with dead crickets, a sugar water tube, and a standard nest tube and a ‘no food’ box with only a standard nest tube, connected to each ‘main’ box (C).

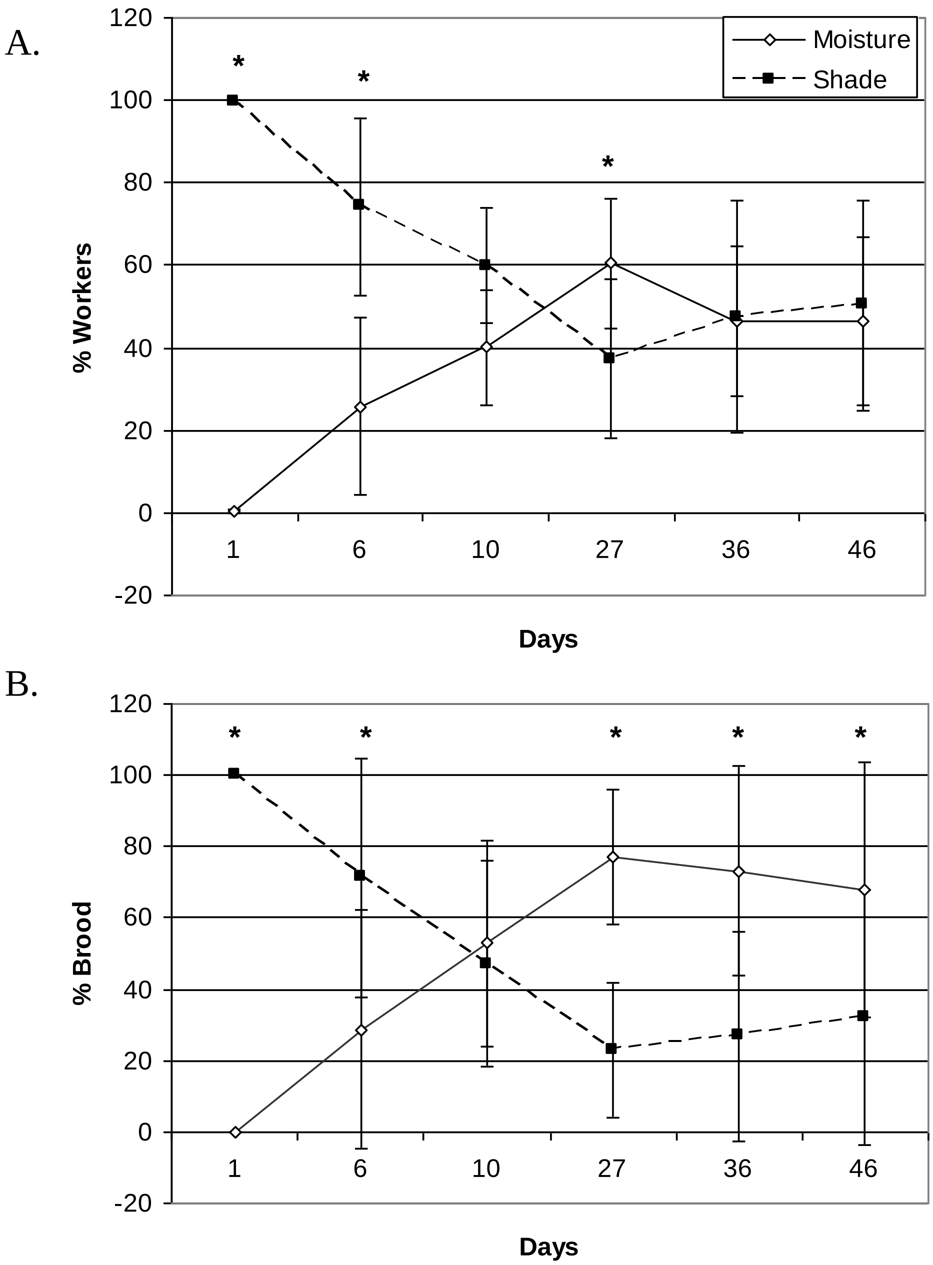

Figure 1.3. Percentage of worker number (A.) and brood area (B.) in moist nest tubes or shaded nest tubes from the Moisture/Shade Test. The * indicates that the mean percentage difference between the two tubes was significantly different ($\alpha \leq 0.05$). Error bars indicate standard deviations.

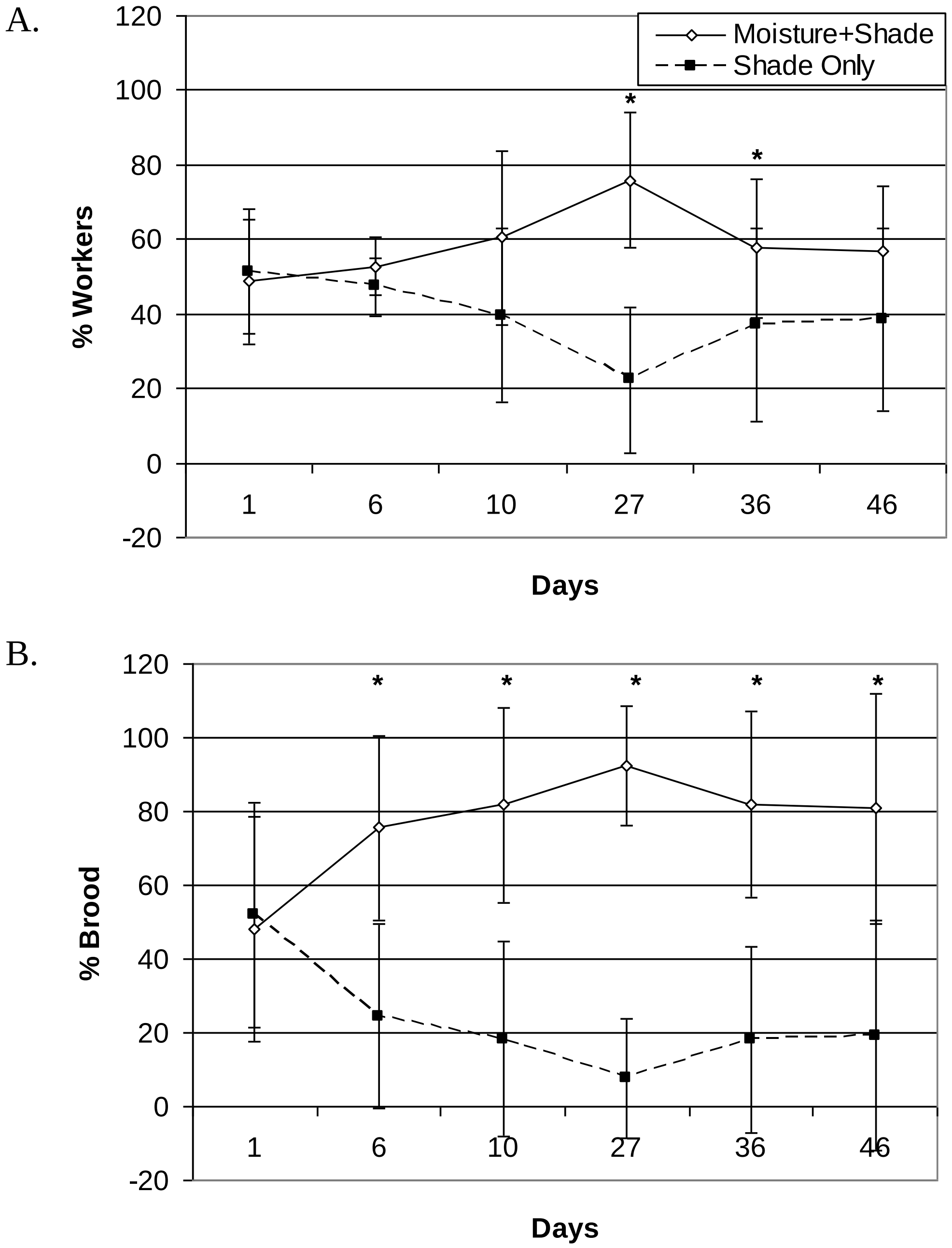

Figure 1.4. Percentage of worker number (A) and brood area (B) in moist, shaded nest tubes or shaded nest tubes from the Moisture/Shade Test. The * indicates that the mean percentage difference between the two tubes was not equal to zero on that day. Error bars indicate standard deviations.

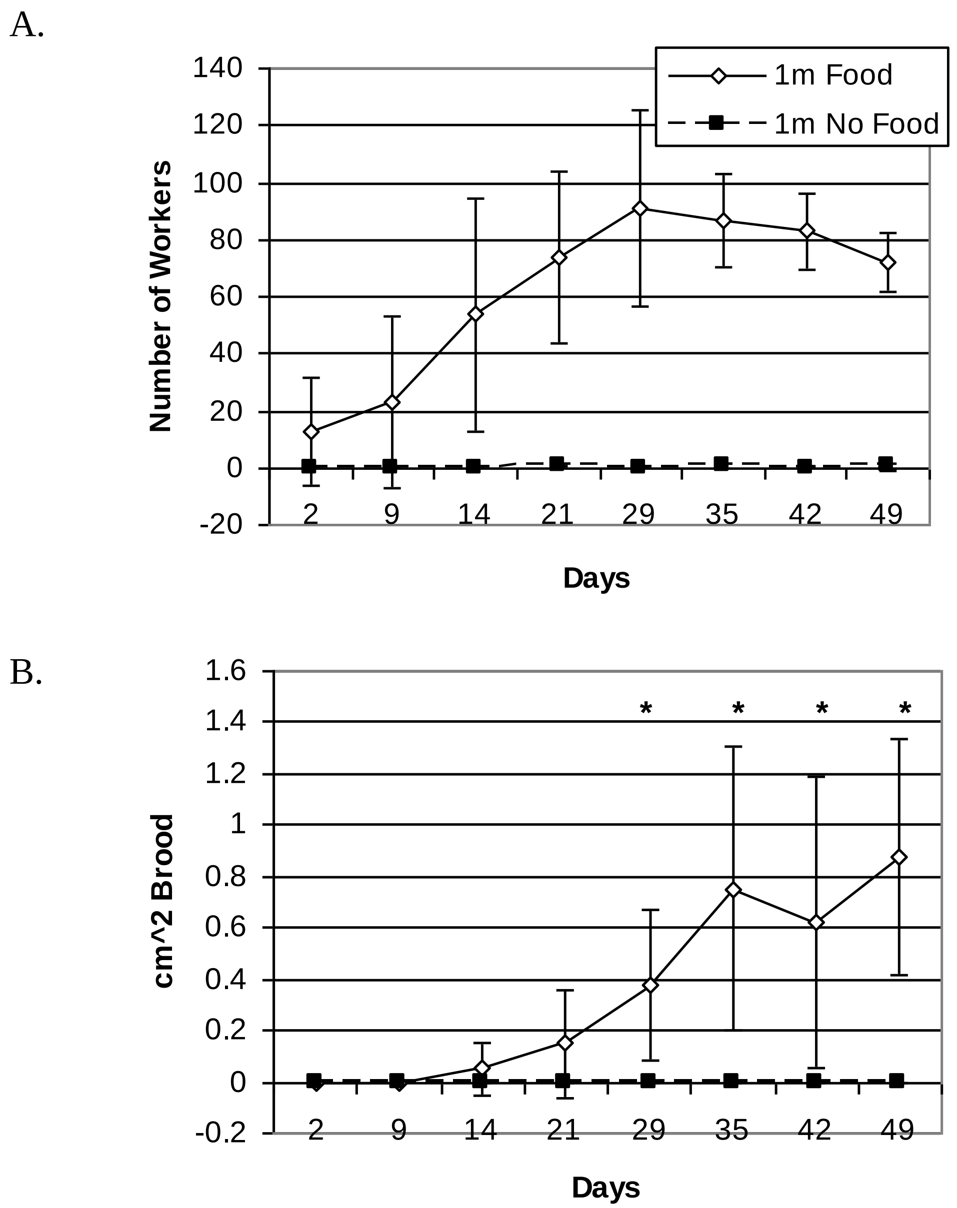

Figure 1.5. Number of workers (A.) and brood area (B.) in nest tubes in 'Food' and 'No Food' boxes at 1 m. The * in B. indicates that the mean percentage difference between the nest tubes in food and no food boxes was not equal to zero on that day. Nest tube differences were significantly different for workers for all days except day 2. Error bars indicate standard deviations.

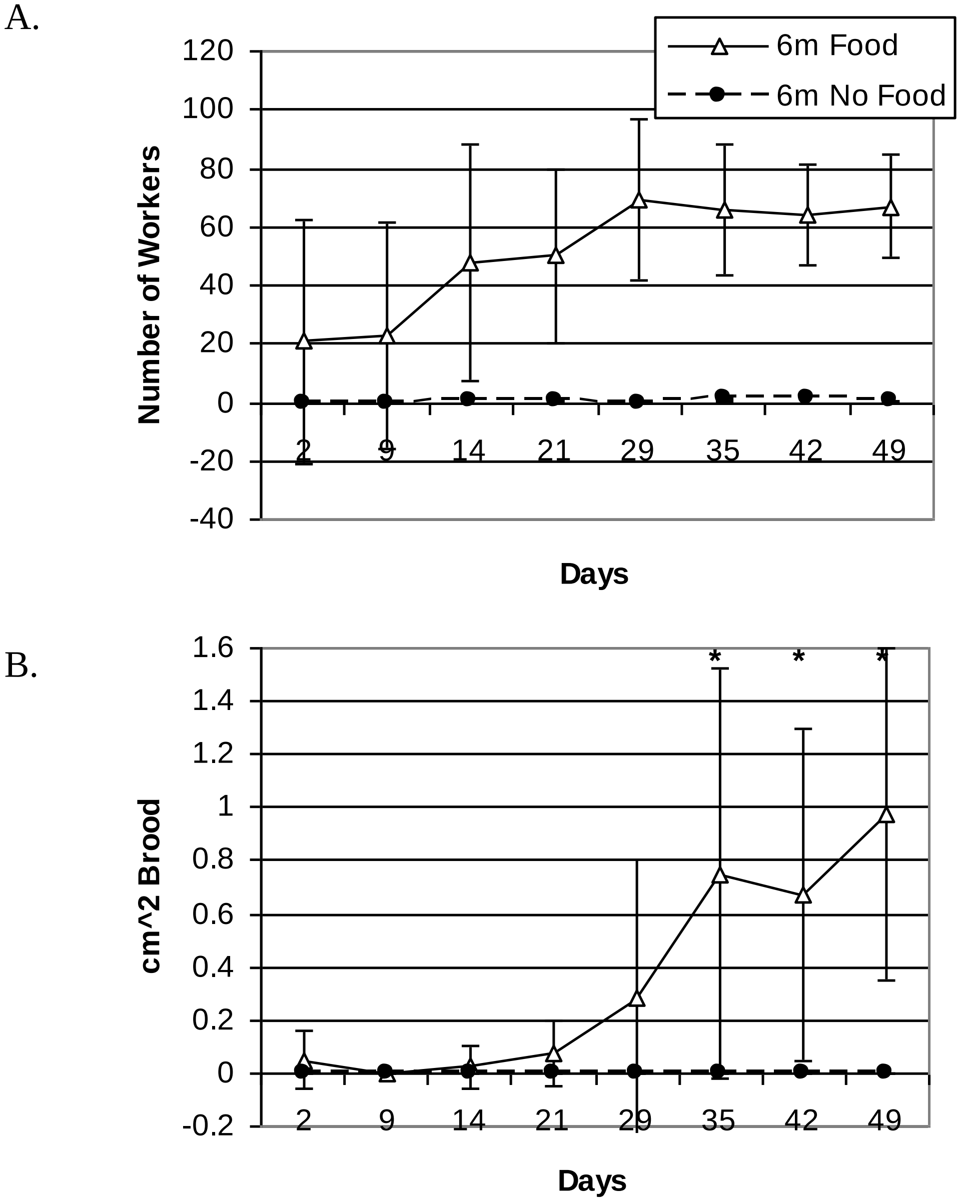

Figure 1.6. Number of workers (A.) and brood area (B.) in nest tubes in 'Food' and 'No Food' boxes at 6 m. The * in B. indicates that the mean percentage difference between the nest tubes in food and no food boxes was not equal to zero on that day. Nest tube differences were significantly different for workers for all days. Error bars indicate standard deviations.

Chapter 2: Community Structure of Southern Appalachian Suburban Ants with Emphasis on the Habits of *Tapinoma sessile*

Introduction

Urban areas, which include both city centers and outlying suburbs, are growing; more than 50% of the global human population lives in urban areas, with nearly 70% percent projected to live in urban areas by 2050. Within the United States, more than eighty percent of the population lives in urban areas which should grow to greater than ninety percent by 2050 (United Nations 2008). With this growth comes an increasing need to understand how urbanization affects the interacting communities that make up urban ecosystems. Ants are ideal subjects for studying community ecology (Hölldobler and Wilson 1990) and the effects of urbanization due to their abundance and response in species composition to urban impact (Gibb and Hochuli 2002, Lessard and Buddle 2005). Urban development alters many ecological processes that influence ground-dwelling arthropod communities including: nutrient cycling (Byrne 2007), vegetation succession (McIntyre 2000), moisture availability (McIntyre 2000, Holway and Suarez 2006), soil physiology (Byrne 2007), and temperature fluctuation (McIntyre 2000, Angilletta Jr. et al. 2007). Some ant species, especially so called “tramp ants” (Passera 1994), respond positively to anthropogenic disturbance, while others respond negatively (Gibb and Hochuli 2002). Many of these ants that benefit from disturbance are invasive species whose presence dramatically decreases populations of native ants in their introduced range (Human and Gordon 1996, Wojcik 1994). Displacements of native ants can have cascading impacts in ecosystems such as altering plant composition in areas where native ants would normally provide services seed dispersers (Gómez 2003) and decreasing populations of native ant-feeding vertebrates (Suarez et al. 2000).

Tapinoma sessile (Say), the odorous house ant, is a common North American urban ant that exhibits many characteristics of a “tramp ant” including: polygyny, flexible nesting habits, frequent nest relocation, unicoloniality, and reproduction by budding (Smith 1928, Smallwood and Culver 1979, Passera 1994). *T. sessile* shows an amazingly wide geographical and ecological distribution throughout most of the United States (Fisher and Cover 2007), and its pest status in urban areas has been well documented since the early 20th century (Smith 1928). However, only recently have detailed studies of its ecological interactions in urban areas begun to be investigated (Buczkowski and Bennett 2006). In undisturbed woodlands, *T. sessile* colonies are usually less than 100 workers, typically monogynous, and in low abundance (Buczkowski and Bennett 2008). Additionally, *T. sessile* foragers are behaviorally subordinant to most other woodland ants encountered at food sources (Fellers 1987). However, in urban areas, *T. sessile* colonies are extremely common, usually polygynous, grow to hundreds of thousands of workers, and dominate to the apparent exclusion of many other ant species (Buczkowski and Bennett 2008).

Interspecific competition has long been touted as one of the most important forces in shaping ant communities (Hölldobler and Wilson 1990). However, dominance hierarchies are not static, and the ability of a given ant species to dominate a resource depends upon other biological and environmental factors such as resource density (Palmer 2001), presence of parasitoids (LeBrun 2005), microclimate (Luque and Lopez 2007), and temperature (Cerdá et al.

1997). In fact, null-modeling has shown that patterns of species distributions in many ant communities do not show evidence of being structured by competition (Ribas and Schoereder 2002).

As an alternate hypothesis to interspecific competition determining ant community composition, habitat structure could strongly influence ant community composition. Increases in habitat heterogeneity have been shown to alter ant dominance hierarchies (Luque and Lopez 2007), improve foraging ability of native ants over invasive ants (Sarty et al. 2006), and decrease ant susceptibility to parasitoids (Wilkinson and Feener 2007). Spatial heterogeneity in resource distribution allows niche partitioning by ant species that specialize in areas with high or low resource availability (Yu et al. 2001, Palmer 2003). In urban areas, human-generated structures and artifacts must be considered as contributing habitat just as much as more “natural” habitat qualities such as vegetation structure. For example, in New York City street medians, the number of trash cans had a strong positive effect on ant richness and abundance, while the number of subway vents had a negative effect on ant abundance (Pecarevic 2007).

To better understand the relationships between anthropogenically altered habitat structure and ant communities, ants were surveyed from yards around urban and suburban houses in the Knoxville, Tennessee area during the summer of 2005. A variety of habitat characteristics in each yard were quantified and the relationships between habitat structure, species richness and composition, and *Tapinoma sessile* abundance were explored.

Materials and Methods

Pitfall Trapping. Multiple methods were used to collect ants for this study. Species richness was determined by pitfall trapping, and *T. sessile* abundance was determined using a combination of pitfall trapping and baiting. Twenty-four houses were found for the study, and participants were asked to not use insecticides in or around the house during the course of the study. The area around each house was categorized as one of the following habitat types: 'near house' was within 3 m of the house, 'lawn' was grassy, mowed areas greater than 3 m from the house, and 'distant landscaping' was ornamental landscaped and/or vegetable garden areas greater than 6 m from the house. All houses had near and lawn habitats, and twenty of the twenty-five houses had distant landscaping habitat. In three cases, traps were not put all the way around the house due to aggressive dogs in the back yard. Ten trap locations were randomly placed within each habitat type. A new trap location was generated if the final destination would have been within 1 m of a nearby trap or in the middle of impassible vegetation such as the middle of a tree trunk, poison ivy, or thick brambles.

To disturb the soil as little as possible and avoid the "dig-in effect" (Agosti et al. 2000), the holes for the pitfall traps were drilled in the ground using a 1 3/8" rapid-driver spade bit and a 12-V portable drill, and at least one week was allowed to elapse between placing the traps in the ground and collecting with them. In heavy or rocky soils, a 2.5-cm diameter auger bit was hammered into the ground and pried out, and the hole was expanded by drill if needed. Next, traps were inserted and gently pounded flush with the soil surface. Each trap consisted of an outer 3 cm i.d. x 8.5 cm plastic vial with an inner 50 mL centrifuge tube cut to be flush with the outer tube's top. The inner/outer tube system allowed for easy removal of the trap's contents without removing the outer tube from the often unyielding soil. Traps were kept lidded until actively trapping ants to prevent water and debris from filling them.

All pitfall traps were filled with 12 mL of propylene glycol/detergent mixture (2-3 drops of detergent added per 3.8 L propylene glycol to reduce surface tension) and left open for 72 hours starting on July 8, 2005. Although no precipitation occurred during the trapping period, the ground was damp from a rain the night before, and temperature ranged from 16°C to 31°C (NCDC 2005). On July 11, 2005, the specimens inside each trap were removed, rinsed with 70% ethanol, and stored in vials of 70% ethanol.

Habitat Characteristic Data. Habitat characteristic data including: foliar height profile (FHP), percentage canopy cover, major vegetation in 1 m^2 around each trap, and type of ground cover in 1 m^2 around each trap were recorded at each trap location. The FHP was taken using a 2 m long piece of 1" PVC pipe that was marked in 25 cm increments and was placed vertically on the trap lid. The number of times vegetation touched the pipe in each 25 cm increment was recorded (Agosti et al. 2000). Major vegetation was tentatively identified by common name or morphospecies. Percentage canopy cover was estimated by taking four readings at right angles to each other holding a densitometer consisting of a level attached to a 5 cm diameter flat mirror marked with a cross-shaped grid of 26 squares. For ground cover and resource availability measurements, a 1 m x 1 m PVC pipe square centered on the ground over the trap was used to estimate percentages of each type of ground cover (vegetation, soil, mulch, leaf litter, rock/bricks/stepping stones, pavement, logs/boards/landscape timbers).

Baiting. In each habitat type at each house, five locations where pitfall traps had not been lost or damaged were randomly selected for baiting. At each trap location, a clear plastic cup lid containing 1-2 teaspoons of honey and a heaping teaspoon of tuna-in-oil was placed as bait. Baits were checked for 2 hours at 20 min intervals, and the number of each ant morphospecies observed on the lid was recorded. For each new ant morphospecies found on the lid, a voucher specimen was collected with an aspirator. Collected specimens were frozen and later stored in 70% ethanol. Air temperature at the beginning and end of each baiting period was measured with a hand-held digital thermometer. In the laboratory, both bait and pitfall trap voucher specimens were identified to species under a dissecting microscope using a variety of keys (Ross et al. 1971, Hölldobler and Wilson 1990, MacGown 2007, Coovert 2005). Reference specimens of each species were confirmed by an ant taxonomy expert, Lloyd R. Davis (Gainsville, FL). A reference collection is located at the University of Tennessee, Department of Entomology and Plant Pathology insect museum, and another in T. A. Toennisson’s personal insect collection.

Statistical Methods. *Testing for Differences in Species Richness and Composition and* T. sessile *Abundance between Habitat Types.* To correct for uneven data caused by lost or damaged pitfall trap, the species richness data for all sites were rarified to seven traps using EstimateS (Colwell 2008) and these data were used in all subsequent ant richness analyses. Since baiting occurred only at sites of successful pitfall trapping, the combined bait and pitfall data used for *T. sessile* abundance did not need such corrections for data to be even between sites. All statistical analyses were performed using JMP v 9.1 (SAS Institute 2007). To investigate possible differences in species composition in each habitat type a trap location by species presence matrix was constructed for each house. This matrix was analyzed using ANOSIM by habitat type in the program PRIMER v. 6.1.8 (PRIMER-E Ltd. 2007).

A least-squares linear regression model was created to examine both house and habitat effects on species richness using pitfall trap data and on *T. sessile* abundance using combined collection methods. If distant landscaping only occurred in one corner of the yard, data from these sites were not used due to spatial clumping of traps that may have biased data analysis. As the three habitat types examined (lawn, near house, distant landscaping) were nested within each house location, to examine effects of habitat on richness and *T. sessile* abundance, the residuals of a house-effect-only linear regression were saved to remove the effect of house location inherent to the nested data. These residuals were examined with ANOVAs using the three habitat types as treatments and species richness or *T. sessile* abundance as the response variable. If ANOVA results rejected the null hypothesis of equal means ($\alpha < 0.05$), means were compared using Tukey-Kramer HSD. All data used in these ANOVAs met the assumptions of normality and equal variances as confirmed by Shapiro-Wilk and Levene-P tests, respectively. Linear regression was also used to check if there were any correlations between *T. sessile* presence at baits and average temperature during collection. Additionally, linear regression was used to check for any relationship between species richness and *T. sessile* abundance.

Testing for Relationships Between Habitat Characteristics and Species Richness or T. sessile *Abundance.* Many of the habitat variables showed high levels of multicollinearity which confounded analyzing all variables simultaneously in a stepwise multiple regression. Instead, subsets of orthogonal variables were analyzed in four separate multiple regressions (Table 2.1 and 2.2). All multiple regressions were forward loading with a 0.25 probability to enter the model. As percentage canopy cover had a strong polynomial relationship (Table 2.1) with species richness, the square of the canopy cover values were used in all multiple regressions involving these two variables. While the residuals of species richness versus all habitat variables tested had normal distributions, residuals of *T. sessile* abundance did not. To improve normality, a log(x) + 1 transformation was applied to all *T. sessile* abundance data in these multiple regressions.

Results

Differences in Species Richness and Composition and *T. sessile* Abundance between Habitat Types. There were 46 ant species collected (Table 2.3). Nine species were collected uniquely in pitfall traps, but only *Camponotus decipiens* Emery was collected uniquely at baits. The five most common species collected were: *Solenopsis molesta*, *Pheidole tysoni*, *P. dentata*, *Tapinoma sessile*, and ants in the *Aphaenogaster rudis* complex. A combined model incorporating house (location) and habitat type indicated that both significantly explained ant species richness and *T. sessile* abundance (Table 2.4). Examination of the residuals saved from a house-only model, indicated that ant species richness in pitfall traps was similar between lawn and far landscaping habitat types with a significant drop in species richness in traps near to the house ($F = 9.65$, df = 2, 56, $P = 0.0002$; Fig. 2.1). ANOSIM results showed significant clustering of species by habitat type at 11 of the 24 houses ($\alpha < 0.05$). However, pairwise comparisons by habitat type showed the source of this clustering was highly variable with three distinct habitat-defined communities at only one house. The majority of other houses only showed differences between lawn and near house or near house and far landscaping (Table 2.5).

Twenty-one of the twenty-four houses had *T. sessile* present in either bait or pitfall traps. For combined pitfall and baiting collection methods, *T. sessile* abundance appeared to have an inverse relationship with species richness with *T. sessile* abundance greatest near the house but lower in both lawn and far landscaping habitats ($F = 9.24$, df = 2, 55, $P = 0.0003$; Fig. 2.1). However, there was only a weak correlation between ant species richness and *T. sessile* abundance ($R^2 = 0.07$, MSE = 3.33, model $P = 0.056$). There was no relationship between *T. sessile* abundance at baits and temperature ($R^2 = 0.0079$, MSE = 1.48, model $P = 0.47$) indicating that the range of baiting temperatures was not a biasing factor.

Relationships between Habitat Characteristics and Species Richness or *T. sessile* Abundance. For species richness, percentage canopy cover frequently entered the model generated by multiple regressions. However, a quadratic polynomial curve was much better at relating canopy cover to ant species richness than a linear model (Table 2.1). Percentage leaf litter had a small, but significant, negative relationship with ant species richness. *T. sessile* abundance was best explained by a model incorporating the number of bait/trap sites with leaf litter within 1 m^2 and the number of bait/trap sites with logs, boards, or landscape timbers present within 1 m^2 (Table 2.2).

Discussion

Ant species richness significantly decreased in close proximity to human structures. However, despite visually striking differences in the structure of vegetation and types of ground covering between lawn and landscaped areas away from the structure, ant species richness varied little between these areas. Lack of difference in species richness between lawn and far landscaping indicates that, despite popular touting of gardens as better than lawns in promoting species richness (Hadden 2008), small patches of gardens within a mowed yard do not lead to an increase in within-garden ant diversity. However, ant species composition differed between far and lawn for four of the twenty-four houses. The limited sample size of houses without distant landscaping in this study prevented the use of robust enough tests necessary to determine whether there were differences in ant richness between yards with and without gardens. As such, the difference between yards with and without gardens and investigations with larger landscaped areas remains to be explored.

Relationships between canopy cover and leaf litter with ant species richness indicate that the presence of trees may be of greater importance than low growing plants for ant diversity in suburban settings. The negative relationship with leaf litter may simply result from sampling bias and indicates a need for litter sampling in future studies. However, other studies have found similar decreases in ant diversity in urban forests and areas with increased leaf litter (Lassau and Hochuli 2004, Clarke et al. 2008, Gibb and Hochuli 2002, Thompson and McLachlan 2007, Lessard and Buddle 2005).

Of all habitat characteristics measured, percentage canopy cover best explained variation in ant species richness. Low species richness occurred in sparse and near total canopy cover, while greater species richness occurred at intermediate canopy cover. Several possible interacting mechanisms could account for this relationship. First, trees may increase resource availability, especially of honeydew-excreting ‘homopterans’ which many ant species tend as a carbohydrate source. Trees may also moderate ground temperatures, reducing the competitive ability of ants that compete more successfully at high temperatures, such as *Monomorium minimum* (Baroni-Urbani and Kannowski 1974), to dominate an area. However, dense shade has been documented to promote colony movement away from such sites (Smallwood 1982) probably for purposes of improved colony thermoregulation. In a study of urban ants in New York City street medians, numbers of trees greater than 2 m tall showed similar trends, with species richness and abundance highest at intermediate tree densities (Pecarevic 2007).

Inversely with species richness, *T. sessile* abundance increased within a few meters of the structure. Buskowski and Bennett (2008) observed similar increases in *T. sessile* numbers near human structures and hypothesized that this increase was due to structures reducing temperature fluctuations, providing protection from predators, and allowing access to human food. Additionally, as *T. sessile* colonies were found frequently in irrigated mulch (Buczkowski and Bennett 2008), and *T. sessile* colonies will relocate workers and brood from dry locations to moist locations (Chapter 2), increases in moisture availability near structures may contribute to the success of *T. sessile*.

Logs, boards, and landscape timbers as well as sites with leaves were the best habitat characteristics for explaining *T. sessile* abundance, both with positive correlations (although only explaining about 10 % of the variation). As these ground covering are both known nesting materials for *T. sessile*, their positive relationships with *T. sessile* abundance could be due to increasing the number of suitable nest sites. Surprisingly, other observed nest sites, such as mulch and rocks, were not correlated with *T. sessile* abundance. In follow-up communications with all homeowners only one house was reported to use cedar mulch which is known to be repellent to *T. sessile* (Meissner and Silverman 2001). However, the type and age of other mulches may alter their attractiveness to odorous house ants. *T. sessile* colonies may show preference for logs and landscape timbers as nest sites over rocks during dry summer times because wood absorbs moisture readily thus may present a larger reservoir of moisture than non-porous surfaces. Although mulch also absorbs water readily, it is more prone to desiccation than a solid piece of wood due to its large surface area. Unless mulch is irrigated frequently, it may provide a less attractive nest site. In concurrence with other studies, vegetation cover, density, and canopy cover were unrelated with *T. sessile* abundance (Buczkowski and Bennett 2008, Thompson and McLachlan 2007). However, it is possible despite the general lack of a relationship between woody plant presence and *T. sessile* abundance that particular species of plants used in landscaping are more attractive to *T. sessile* colonies due to nectar or ‘homopteran’ availability. For example, *T. sessile* workers were frequently seen on rhododendron flowers (presumably foraging on nectar) in spring and trailing up maple trees in the summer (presumably in search of ‘homopterans’) (T.A.T., *pers. obs.*).

This study lays the ground work for possible future controlled experiments to test for *T. sessile* nesting substrate preferences and to test mechanisms by which structures could increase *T. sessile* abundance. *T. sessile* preference to other hardwood mulches and pine straw over cedar mulch has been well documented (Meissner and Silverman 2001). However, comparisons of the attractiveness of other nesting substrates have yet to be reported. If landscape timbers or leaves can be shown to be preferred nest site locations, reduction of these ground covers around the house may lead to lower *T. sessile* populations. Additionally, investigations into other mechanisms by which structures facilitate *T. sessile* population growth e.g. by effecting moisture, nest sites, food access, temperature moderation, etc. may reveal new cultural control methods for *T. sessile*.

This study illustrates the importance of incorporating proximity to human structures into ecological investigations in urban areas.   Composition of ant communities and populations of certain pest species can dramatically change over only a few tens of meters away from the structure. However, more “natural” habitat characteristics such as vegetation structure and ground cover appear to have a limited impact on ant communities in urban yards, at least on the within-yard local scale.

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Appendix

Table 2.1. Regression of Species Richness by Habitat Variables.

Variables used in multiple regression	**Variables that entered model**	**R^2**	**Root MSE**	**Df**	**Model *F***	**Prob > *F***
FHP 150-200 cm, average % canopy cover; stepping stones/brick/rocks; logs/boards/landscape timbers	Average % canopy cover	0.03	3.26	1, 57	1.62	0.20
Number of sites with mulch; number of sites with leaves; logs/boards/landscape timbers	**Number of sites with leaves**	**0.10**	**3.14**	**1, 57**	**6.56**	**0.01**
Number of sites with mulch; average % canopy cover; logs/boards/landscape timbers	Number of sites with mulch; Average % canopy cover	0.05	3.25	2, 56	1.54	0.22
% plant cover, FHP 150-200 cm; logs/boards/landscape timbers	% plant cover	0.05	3.23	1, 57	2.71	0.11
n/a	**Polynomial (quadratic) fit of Average % canopy cover**	**0.19**	**2.99**	**2, 56**	**6.77**	**0.0023**

Table 2.2. Regression of *Tapinoma sessile* Abundance by Habitat Variables.

Variables used in multiple regression	**Variables that entered model**	**R^2**	**Root MSE**	**Df**	**Model *F***	**Prob > *F***
FHP 150-200 cm, average % canopy cover; stepping stones/brick/rocks; logs/boards/landscape timbers	logs/boards/ landscape timbers	0.08	0.35	1, 54	4.74	0.03
Number of sites with mulch; number of sites with leaves; logs/boards/landscape timbers	**logs/boards/ landscape timbers; number of sites with leaves**	**0.12**	**0.34**	**2, 53**	**3.64**	**0.03**
Number of sites with mulch; average % canopy cover; logs/boards/landscape timbers	Logs/boards /landscape timbers	0.08	0.35	1, 54	4.74	0.03
% plant cover, FHP 150-200 cm; logs/boards/landscape timbers	Logs/boards/ landscape timbers	0.08	0.35	1, 54	4.74	0.03

Table 2.3. Species Found in Pitfall Traps from All Houses. Abundance is the number of incidences at least one specimen of a species was found in a trap.

Species	Near House Abundance	Lawn Abundance	Far Landscaping Abundance	Total Abundance
Aphaenogaster fulva Roger	3	1	1	5
Aphaenogaster rudis Enzmann cmplx	11	4	19	34
Aphaenogaster tennesseensis Mayr	0	1	2	3
Aphaenogaster treatae Forel	0	2	0	2
Brachymyrmex depilis Emery	1	4	1	6
Camponotus americanus Mayr	0	3	3	6
Camponotus castaneus (Latreille)	4	7	5	16
Camponotus chromaiodes Bolton	3	5	5	13
Camponotus mississippiensis Smith	0	0	1	1
Camponotus pennsylvanicus (DeGeer)	2	1	1	4
Camponotus subbarbatus Emery	0	0	1	1
Crematogaster cerasi (Fitch)	2	2	1	5
Crematogaster lineolata (Say)	4	4	16	24
Crematogaster missuriensis Emery	0	5	1	6
Crematogaster pilosa Emery	4	1	5	10
Forelius sp.	3	1	3	7
Formica dolosa Buren	0	2	0	2
Formica pallidefulva Latreille	13	22	15	50
Formica subsericea Say	6	11	12	29
Hypoponera opacior (Forel)	16	22	14	52
Lasius alienus (Fvrster)	9	22	15	46
Lasius neoniger Emery	6	16	15	37
Monomorium minimum (Buckley)	11	48	24	83

Table 2.3. Continued.

Species	Near House Abundance	Lawn Abundance	Far Landscaping Abundance	Total Abundance
Myrmica americana Weber	0	1	2	3
Myrmica pinetorum Wheeler	8	17	8	33
Myrmica punctiventris Roger	0	3	5	8
Myrmecina americana Emery	1	3	5	9
Paratrechina faisonensis (Forel)	12	12	16	40
Paratrechina vividula (Nylander)	10	15	7	32
Pheidole bicarinata Mayr	17	30	23	70
Pheidole dentata Mayr	37	58	38	133
Pheidole pilifera (Roger)	0	1	2	3
Pheidole tysoni Forel	38	81	44	163
Ponera pennsylvanica Buckley	2	0	0	2
Prenolepis imparis (Say)	1	0	0	1
Pyramica dietrichi (Smith)	0	0	1	1
Pyramica membranifera (Emery)	0	0	1	1
Pyramica ohioensis (Kennedy & Schramm)	1	1	1	3
Pyramica sp.	0	0	1	1
Solenopsis molesta (Say)	42	93	62	197
Strumigenys louisianae Roger	1	0	0	1
Tapinoma sessile	67	38	23	128
Temnothorax curvispinosus (Mayr)	1	0	0	1
Temnothorax pergandei (Emery)	0	3	1	4
Tetramorium caespitum (L.)	18	10	7	35

Table 2.4. Regression Models for Habitat and House Effects on Species Richness and *Tapinoma* Abundance.

Variables	**Model Effects**	**R^2**	**Root MSE**	**Df**	**Model *F***	**Model *p***
House and **habitat** effects on **species richness**	Whole model (house + habitat)	0.68	2.42	24, 34	3.01	0.0016
	House effect	-	-	22	2.74	0.0039
	Habitat effect	-	-	2	6.28	0.0047
House and **habitat** effects on ***T. sessile*** **abundance**	Whole model (house + habitat)	0.76	1.70	21, 34	5.21	<0.0001
	House effect	-	-	19	4.87	<0.0001
	Habitat effect	-	-	2	7.73	0.0017

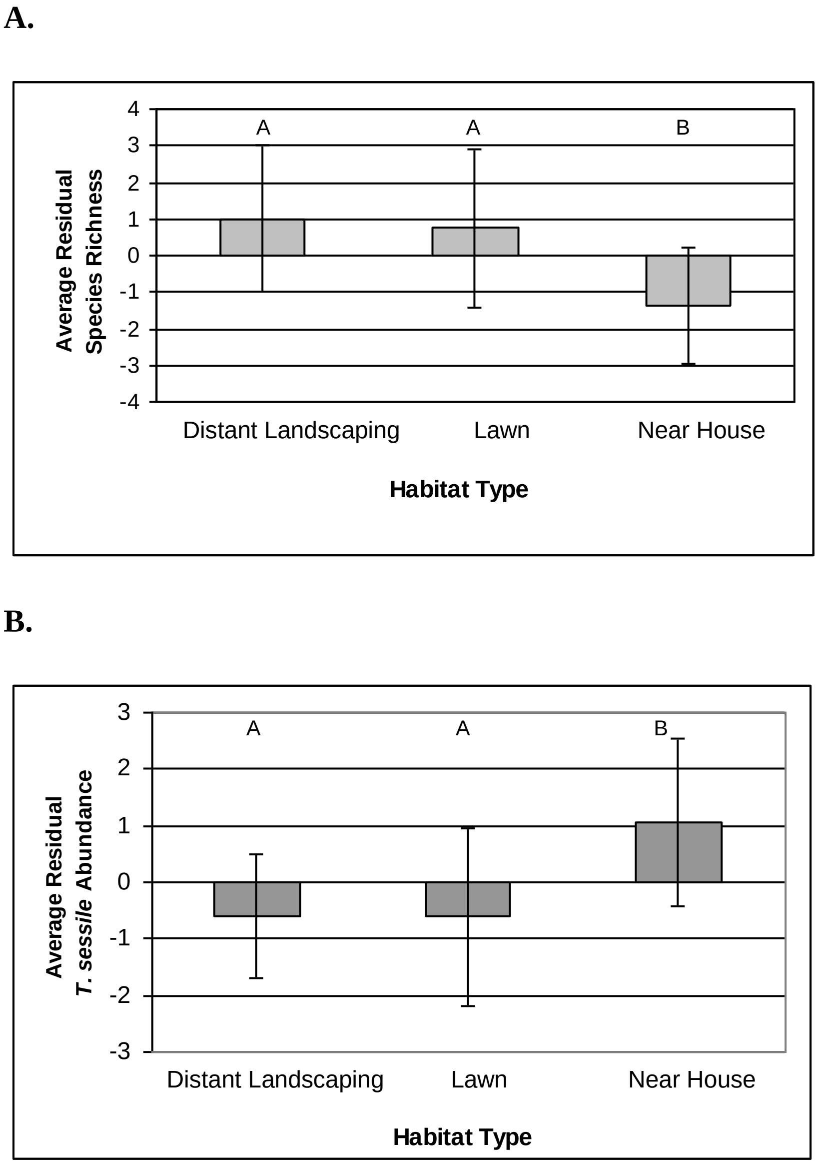

Figure 2.1. The Relationship between Habitat Type and Species Richness (A.) and *Tapinoma sessile* Abundance (B.). Error bars represent one standard deviation. Habitat types with different letter designations have significantly different means ($\alpha < 0.05$).

Table 2.5. Number of Houses that Showed Pairwise Differences in Species Composition by Habitat Type. Some of the eleven houses had multiple pairwise differences. Three of these houses had no far landscaping so only lawn and near house comparisons could be made.

Habitat types compared	Total houses with differences in species composition between these two habitat types
Lawn vs. near house	7
Lawn vs. distant landscaping	4
Near house vs. distant landscaping	4

Conclusions and Future Directions

As with any scientific endeavor, the conclusions of one study lead to the questions of another. Moist nest tubes are obviously more attractive to *T. sessile* colonies over time, but what humidity levels are optimal for colony growth and survival? *Tapinoma sessile* colonies relocate to near food nest sites over at least 6 m distances, but how do even longer foraging distances to food affect *T. sessile* colony movement? What about the effects of temperature, nest architecture, colony size and age on *T. sessile* colony movement? How do all these factors effect *T. sessile* movement in the landscape?

In the suburban yards, the richness of ant communities and the abundance of odorous house ants show dramatic changes within 3 m of human structures. Could nest site, food, or moisture availability near structures explain these differences? Canopy cover best explained species richness. How does human selection and planting of trees alter ant diversity in urban areas? Logs, boards, and landscape timbers along with leaf litter showed a relationship with *T. sessile* abundance. Are these preferred nesting sites for *T. sessile*? Do reduction of preferred nest sites, food resources, and moisture sources lead to lower pest problems with *T. sessile*? Are such methods practical for the average homeowner? More questions abound.

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Appendix A

Purpose

The purpose of this final appendix is to include data from portions of my lab and field work that are not of publication quality, but contain information that may be of use or interest to others.

Disturbance Test

The disturbance test was designed to investigate if physical disturbance of a *Tapinoma sessile* nest site would affect nest relocation. As with the moisture/shade tests, two standard nest tubes were placed in each of twenty 21 cm x 15.5 cm x 9.5 cm plastic disposable/reusable boxes (Fig. 1) and held in place with a small piece of poster putty adhered to the bottom of each tube. Odorous house ants were collected a month prior to the test and maintained as described above. From this large polygynous nest, subcolonies consisting of ~125 ants, 2 queens, and 0.5 cm^2 of brood were isolated and placed into the center of each test box. Similar to the moisture/shade tests, boxes were placed in trays at various levels of a wire rack and in various orientations to minimize any area effect.

After 48 hours, the distribution of workers and brood between the two nest tubes in each box was recorded. Ten boxes were selected at random as undisturbed control boxes. These boxes received sugar water as needed and crickets twice a week, but were not disturbed in any other way. In the remaining ten boxes, one of the two nest tubes was tapped over the center of the box until >95% of the workers and queens (if any) had fallen out of the tube into the box. The ants were allowed to redistribute themselves between the two nest tubes, and this distribution was recorded the next day. Ants in the disturbed boxes were fed the same as the undisturbed ants. The disturbance regimen was repeated in the same disturbed boxes at 5, 7, and 12 days after ant introduction.

A Repeated Measures ANOVA was used to compare the mean percentage differences in worker number and brood area between the two tubes in disturbed versus undisturbed boxes over time. The percent difference between workers was log transformed to meet the assumptions of ANOVA, but the brood percent difference met the assumptions untransformed.

The disturbance treatment showed no effect on worker or brood distribution (workers: $F = 0.02$, df = 1, $p > 0.89$; brood: $F = 2.16$, df = 1 , $p > 0.16$; Fig. 5). Similarly, the distribution of workers between the two tubes did not vary over time ($F = 0.62$, df = 5 , $p > 0.68$), nor did the brood ($F = 1.23$, df = 5 , $p > 0.30$). Disturbance, at least on the scale of our experiment, does not seem to be a major instigator of colony movement. Workers repeatedly re-colonized disturbed tubes with similar frequency throughout the study.

Edge Habitat and Bait Data

During the course of my field work I also sampled ants from unmanaged or infrequently managed habitat on the edge of several of the house properties I surveyed. Ten trap locations were designated and collected from using pitfall traps and baiting in the manner described in Chapter 2. However, only half of the houses had edge habitat available for sampling and there was wide variability in the type of habitat, ranging from scrubby early successional growth dominated by privet and brambles, to young forest, to mature hardwood stands. Due to this variability and poor replication these data were not included in analyses in Chapter 2. Table 2C below gives a complete list of all species collected in pitfall traps during this study and their relative abundances. Only three species: *Pyramica bunki*, *Pyramica ornata*, and *Paratrichina sp.* were found uniquely in these habitats. In addition to these data, *Camponotus decipiens* was found in baits at one house. This was the only species found uniquely at a bait.

Table A.1. Species Found in Pitfall Traps from All Houses Including Edge Habitat. Abundance is the number of incidences at least one specimen of a species was found in a trap.

Species name	Abundance	Species name	Abundance
Aphaenogaster fulva Roger	7	*Myrmica pinetorum* Wheeler	35
Aphaenogaster rudis Enzmann cmplx	91	*Myrmica punctiventris* Roger	14
Aphaenogaster tennesseensis Mayr	3	*Myrmecina americana* Emery	14
Aphaenogaster treatae Forel	2	*Paratrechina faisonensis* (Forel)	63
Brachymyrmex depilis Emery	6	*Paratrechina sp.*	1
Camponotus americanus Mayr	11	*Paratrechina vividula* (Nylander)	33
Camponotus castaneus (Latreille)	20	*Pheidole bicarinata* Mayr	71
Camponotus chromaiodes Bolton	19	*Pheidole dentata Mayr*	134
Camponotus mississippiensis Smith	1	*Pheidole pilifera* (Roger)	3
Camponotus pennsylvanicus (DeGeer)	4	*Pheidole tysoni* Forel	164
Camponotus subbarbatus Emery	1	*Ponera pennsylvanica* Buckley	3
Crematogaster cerasi (Fitch)	5	*Prenolepis imparis* (Say)	2
Crematogaster lineolata (Say)	26	*Pyramica bunki* (Brown)	1
Crematogaster missuriensis Emery	6	*Pyramica dietrichi* (Smith)	1
Crematogaster pilosa Emery	10	*Pyramica membranifera* (Emery)	1
Forelius sp.	7	*Pyramica ohioensis* (Kennedy & Schramm)	5
Formica dolosa Buren	2	*Pyramica ornata* (Mayr)	1
Formica pallidefulva Latreille	52	*Pyramica sp.*	1
Formica subsericea Say	41	*Solenopsis molesta* (Say)	212
Hypoponera opacior (Forel)	52	*Strumigenys louisianae* Roger	1
Lasius alienus (Fvrster)	50	*Tapinoma sessile*	129
Lasius neoniger Emery	37	*Temnothorax curvispinosus* (Mayr)	2
Monomorium minimum (Buckley)	83	*Temnothorax pergandei* (Emery)	5
Myrmica americana Weber	3	*Tetramorium caespitum* (L.)	35

Pitfall Ant Data

The following data are a series of site by species matrixes of ants collected in pitfall traps from urban and suburban yards in the Knoxville, TN area. Traps were left out to collect ants from July 8, 2005 to July 11, 2005. The sites are each of the twenty-four yards sampled for the project in Chapter 2. A “1” indicates that at least one of the given species was found at that site. The final table gives the latitude and longitude of each yard sampled. The coordinates of each site are rounded to the third decimal place to protect the privacy of the homeowners in the study. If more precise coordinates or addresses are needed for future studies, please contact the author.

Table A.2. Pitfall Ant Species Matrix for Sites 1-12.

Species	**Site Number**											
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
Aphaenogaster fulva	0	0	0	0	0	0	0	0	0	0	0	0
Aphaenogaster rudis cmplx	0	1	0	0	1	0	1	0	0	1	1	0
Aphaenogaster tennesseensis	0	0	0	0	1	0	0	0	0	1	1	0
Aphaenogaster treatae	0	0	0	0	1	0	0	0	0	0	0	0
Brachymyrmex depilis	0	0	1	0	0	0	0	0	1	0	0	1
Camponotus americanus	0	1	0	0	1	0	0	0	0	0	0	0
Camponotus castaneus	0	0	0	0	1	0	0	1	1	1	0	1
Camponotus chromaiodes	0	0	0	0	1	0	0	0	0	1	1	0
Camponotus pennsylvanicus	0	0	0	1	0	0	0	0	0	0	0	0
Camponotus subbarbatus	0	0	0	0	0	0	0	0	0	0	1	0
Crematogaster cerasi	0	0	0	0	1	0	0	0	0	0	0	1
Camponotus mississippiensis	1	0	0	0	0	0	0	0	0	0	0	0
Crematogaster pilosa	0	0	0	0	1	0	1	0	0	0	0	0
Crematogaster missuriensis	0	1	0	0	1	0	0	0	0	1	0	1
Crematogaster lineolata	0	1	0	0	0	0	0	1	0	0	1	0
Forelius sp.	0	0	0	0	0	0	0	0	1	0	0	1
Formica dolosa	0	0	0	0	1	0	0	0	0	0	0	0
Formica pallidefulva	0	1	1	1	1	0	1	1	1	1	0	1
Formica subsericea	1	1	0	0	0	0	1	0	1	1	1	1
Hypoponera opacior	1	1	1	0	1	1	1	1	1	1	1	0
Lasius alienus	1	0	1	1	1	0	1	1	0	0	1	1
Lasius neoniger	0	1	0	1	1	1	1	0	1	1	0	0
Monomorium minimum	1	1	1	1	1	1	1	1	1	1	1	1

Table A.2. Continued.

Species	Site Number											
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Site 10	Site 11	Site 12
Myrmica pinetorum	0	0	0	1	1	0	1	0	0	1	0	0
Myrmica punctiventris	0	0	0	0	0	0	0	1	0	0	1	0
Myrmecina americana	0	1	0	0	1	0	1	0	0	0	0	1
Paratrechina faisonensis	0	1	1	1	1	1	1	1	1	1	1	0
Paratrechina sp.	0	0	0	0	0	0	0	0	0	0	0	0
Paratrechina vividula	1	1	1	1	0	0	0	0	1	1	1	1
Temnothorax pergandei	0	0	0	1	0	0	0	0	1	0	0	0
Pheidole bicarinata	0	1	0	1	1	1	1	1	1	1	1	1
Pheidole dentata	1	1	1	1	1	1	1	1	1	1	1	1
Pheidole pilifera	0	0	0	0	1	1	0	0	0	0	0	0
Pheidole tysoni	1	1	1	1	1	1	1	1	1	1	1	1
Ponera pennsylvanica	0	1	0	0	0	0	0	0	0	0	0	0
Prenolepis imparis	0	0	0	0	0	0	0	0	0	0	0	0
Pyramica bunki	0	0	0	0	0	0	0	0	0	0	0	0
Pyramica dietrichi	0	0	0	0	0	0	0	0	0	0	0	0
Pyramica membranifera	0	0	0	0	0	0	0	0	0	1	0	0
Pyramica ohioensis	0	0	0	0	0	0	0	1	0	0	0	0
Pyramica ornata	0	0	0	0	0	0	0	0	0	0	0	0
Pyramica sp.	0	0	0	0	0	0	0	0	0	0	0	0
Solenopsis molesta	1	1	1	1	1	1	1	1	1	1	1	1
Strumigenys louisianae	0	0	0	0	0	0	0	1	0	0	0	0
Tapinoma sessile	1	1	1	0	1	1	1	1	1	1	0	0
Temnothorax curvispinosus	0	0	0	0	0	0	0	0	0	0	0	0
Tetramorium caespitum	0	0	1	1	0	1	0	1	1	0	0	1

Table A.3. Pitfall Ant Species Matrix for Sites 13-24.

Species	**Site Number**											
	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24
Aphaenogaster fulva	0	1	0	1	0	0	1	0	0	0	0	0
Aphaenogaster rudis cmplx	1	1	1	1	0	0	0	0	0	1	1	0
Aphaenogaster tennesseensis	0	0	0	0	0	0	0	0	0	0	0	0
Aphaenogaster treatae	0	0	0	0	0	0	0	0	0	0	0	0
Brachymyrmex depilis	0	0	0	0	0	1	0	0	0	0	0	0
Camponotus americanus	0	0	0	1	0	1	0	0	1	0	0	0
Camponotus castaneus	1	0	0	0	0	0	1	1	1	0	1	0
Camponotus chromaiodes	0	1	0	0	0	1	0	1	0	1	0	1
Camponotus pennsylvanicus	0	0	1	1	0	0	0	1	0	0	0	0
Camponotus subbarbatus	0	0	0	0	0	0	0	0	0	0	0	0
Crematogaster cerasi	0	0	0	1	1	0	0	0	0	0	0	0
Camponotus mississippiensis	0	0	0	0	0	0	0	0	0	0	0	0
Crematogaster pilosa	0	1	1	0	0	0	0	0	0	0	0	1
Crematogaster missuriensis	1	0	0	0	0	0	0	0	0	0	0	0
Crematogaster lineolata	0	1	0	1	0	0	0	0	0	0	0	0
Forelius sp.	0	1	0	0	0	0	0	0	0	0	1	0
Formica dolosa	0	1	0	0	0	0	0	0	0	0	0	0
Formica pallidefulva	1	1	1	1	0	0	1	1	1	0	1	1
Formica subsericea	1	0	1	0	0	1	0	1	0	0	0	0
Hypoponera opacior	0	0	0	1	1	0	1	0	1	0	1	1
Lasius alienus	1	0	1	0	0	1	0	1	0	0	1	1
Lasius neoniger	1	1	0	0	0	0	1	0	1	0	1	1
Monomorium minimum	1	1	0	0	1	0	1	1	1	1	1	1

Table A.3. Continued.

Species	Site Number											
	Site 13	Site 14	Site 15	Site 16	Site 17	Site 18	Site 19	Site 20	Site 21	Site 22	Site 23	Site 24
Myrmica americana	0	0	0	0	0	0	0	0	0	0	0	0
Myrmica pinetorum	1	0	1	0	0	0	0	1	0	0	1	1
Myrmica punctiventris	0	0	1	0	0	0	0	0	1	0	0	0
Myrmecina americana	0	1	0	0	0	0	0	1	1	0	0	1
Paratrechina faisonensis	1	1	1	0	0	0	1	1	0	0	1	1
Paratrechina sp.	0	0	0	0	0	0	0	0	0	0	0	0
Paratrechina vividula	1	0	0	0	1	0	1	0	1	0	1	1
Temnothorax pergandei	0	1	0	0	0	0	0	0	0	0	0	0
Pheidole bicarinata	0	1	1	1	1	0	1	1	1	1	1	1
Pheidole dentata	1	1	0	1	1	0	1	1	1	1	1	1
Pheidole pilifera	0	0	0	0	0	0	0	0	0	0	0	0
Pheidole tysoni	1	1	1	1	0	1	1	1	1	1	1	1
Ponera pennsylvanica	1	0	0	0	0	0	0	0	0	0	0	0
Prenolepis imparis	1	0	0	0	0	0	0	0	0	0	0	0
Pyramica bunki	0	0	0	0	0	0	0	0	0	0	0	0
Pyramica dietrichi	0	1	0	0	0	0	0	0	0	0	0	0
Pyramica membranifera	0	0	0	0	0	0	0	0	0	0	0	0
Pyramica ohioensis	0	0	0	0	0	0	0	0	0	0	1	0
Pyramica ornata	0	0	0	0	0	0	0	0	0	0	0	0
Pyramica sp.	1	0	0	0	0	0	0	0	0	0	0	0
Solenopsis molesta	1	1	1	1	1	1	1	1	1	0	1	1
Strumigenys louisianae	0	0	0	0	0	0	0	0	0	0	0	0
Tapinoma sessile	1	0	1	0	0	1	1	1	1	1	1	1
Temnothorax curvispinosus	0	0	0	0	0	0	1	0	0	0	0	0
Tetramorium caespitum	1	1	1	0	1	1	1	0	0	0	0	0

Table A.4. Locations of Pitfall Trap Sites. All coordinates have been rounded to the third decimal place.

Site	Latitude, Longitude
Site 1	35.894°, -83.980°
Site 2	35.901°, -84.192°
Site 3	35.936°, -84.032°
Site 4	36.018°, -83.882°
Site 5	36.205°, -84.051°
Site 6	36.176°, -83.882°
Site 7	35.879°, -84.173°
Site 8	35.896°, -84.168°
Site 9	36.028°, -83.946°
Site 10	35.892°, -84.040°
Site 11	35.885°, -84.114°
Site 12	36.003°, -83.939°
Site 13	35.953°, -83.992°
Site 14	36.161°, -83.851°
Site 15	35.970°, -83.881°
Site 16	36.203°, -84.069°
Site 17	35.888°, -83.883°
Site 18	35.950°, -83.883°
Site 19	36.101°, -83.954°
Site 20	35.930°, -83.967°
Site 21	35.938°, -83.997°
Site 22	35.893°, -83.982°
Site 23	36.198°, -84.072°
Site 24	35.878°, -84.059°

Vita

Aurora Toennisson is a mother, biologist, and enthusiastic gardener. She received her undergraduate degree in biology, concentrating in ecology and evolutionary biology, from the University of Tennessee. Although originally a media arts major, she switched to biology after having worked as a summer student research assistant for an agricultural entomologist. Suddenly, she realized that there was a fascinating, but alien, world of insects teeming with life all around her. Driven by her desire to learn more about such intriguing creatures, she worked as a student assistant for two more entomology labs with focuses in apiculture and urban entomology, and volunteered in another lab to sort insects for the All-Taxa Biological Inventory of the Great Smoky Mountains National Park. She began her formal studies in entomology in 2005 and started her quest to understand what made ants tick. Shortly thereafter, she and her husband were surprised by the impending arrival of their first child. Aurora's experience sampling ants in yards during the first trimester of her pregnancy is not something she would like to repeat. Upon the arrival of her son, Aurora made the sanity-preserving decision to continue pursuing her degree on a part-time basis, which is why, in case you wondered, that this thesis took so long to come to fruition. She would not have traded a moment of her time with her wonderful baby to get done sooner. In the future, she hopes to be employed as a research technician or a technician and interpreter at a biological museum or botanical garden. If she has the opportunity to pursue further research, she would love a chance to get involved with pollination biology and agroecology. Her favorite ant is *Pyramica ornata*.