

Influences on the Structure of Suburban Ant (Hymenoptera: Formicidae) Communities and the Abundance of *Tapinoma sessile*

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ABSTRACT Urbanization can alter the organization of ant communities and affect populations of urban pest ants. In this study, we sampled ant communities in urban and suburban yards to understand the habitat factors that shape these communities and influence the abundance of a common pest species, *Tapinoma sessile* (Say). We used pitfall traps to sample ant communities and a combination of pitfall traps and baiting to collect *T. sessile* at 24 sites in Knoxville, TN. In total, we collected 46 ant species. Ant species richness ranged from seven to 24 species per yard. Ant species richness tended to be lowest near houses, whereas *T. sessile* abundance was highest near houses. The best predictors of ant species richness in yards were canopy cover and presence of leaf litter: ant species richness peaked at mid-levels of canopy cover and was negatively correlated with the presence of leaf litter. *Tapinoma sessile* abundance increased with presence of logs, boards, or landscaping timbers and leaf litter in yards. Our results indicate that ant communities and the abundance of particular pest species in these urban and suburban landscapes are shaped by many of the same factors that structure ant communities in less anthropogenically disturbed environments.

KEY WORDS community ecology, habitat structure, landscaping, odorous house ant, urban

Urban areas, that include both city centers and outlying suburbs, are growing; >50% of the global human population lives in urban areas, with nearly 70% projected to live in urban areas by 2050. More than 80% of the U.S. population lives in urban areas, and that proportion is expected to exceed 90% by 2050 (UN 2008). With this growth comes an increasing need to understand how urbanization affects the biodiversity occurring in urban landscapes and to develop models which can help predict habitats that enhance biodiversity and influence populations of pest species within these dynamic landscapes.

Ants are ideal subjects for studying effects of urbanization because they are abundant and respond to urban impact (Gibb and Hochuli 2002, Lessard and Buddle 2005, Sanford et al. 2009). Some ant species, especially so called “tramp ants” that are widely dispersed by human activities (Passera 1994), respond positively to anthropogenic disturbance, while other less generalized species respond negatively (Gibb and Hochuli 2002). The odorous house ant, *Tapinoma sessile* (Say), is a common North American ant in both urban and “natural” ecosystems. The pest status of *T. sessile* has been well documented since the early 20th

century (Smith 1928). However, detailed studies of its ecological interactions in urban areas have been initiated only recently (Buczowski and Bennett 2006, Buczowski 2010, Menke et al. 2010).

One consequence of urbanization can be a dramatic shift in habitat structure. Changes in habitat can affect the structure of ant communities (Gotelli and Ellison 2002, Luque and Lopez 2007); foraging behavior (Sarty et al. 2006); and interactions with other species (Wilkinson and Feener 2007). In urban areas, human made structures, anthropogenic landscape modifications, and accumulation of detritus must be considered to contribute to habitat just as more “natural” habitat attributes like vegetation structure (Lessard and Buddle 2005, Pecarevic 2007, Sanford et al. 2009). In other words, ants probably do not distinguish between nesting under a log in a forest and a piece of discarded plywood in a backyard.

To examine the relationships among anthropogenically altered habitat structure and ant communities, we surveyed ant population and diversity in yards around urban and suburban houses within Knox County in Knoxville, TN. In addition, we explored factors that influenced abundance of a common urban pest ant, *T. sessile* by addressing three questions: 1) Does ant community structure vary among houses and habitats? 2) Does *T. sessile* abundance vary among houses and habitats? 3) What components of suburban habitat structure influence ant community structure and the abundance of *T. sessile*?

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Materials and Methods

Study Location. Knoxville is a city of 174,000 people covering an area of 257.4 km² in the foothills of the southern Appalachian Mountains (City of Knoxville 2009). The region experiences a temperate climate with an average of 122-cm annual rainfall (NWS 2009). All houses used in this study were single family dwellings, most of which had traditional American suburban landscaping in the form of ornamental plantings around the foundation (at least for the front of the house) with a few other patches of garden, trees, or shrubs located in beds not directly adjacent to the structure. The remainder of surrounding yards was covered by mowed lawn.

We sampled ant communities at 24 houses. These houses had received no perimeter pesticide applications within the past 2 yr, and all of the occupants had agreed to refrain from both pesticide use and major landscaping changes during the course of the study. None of the houses were on lots adjacent to one another. The two closest sites were within the same neighborhood ≈ 0.3 km apart, and the two most extreme sites were nearly 40 km apart. On average, each house was $3.6 \text{ km} \pm 2 \text{ km}$ (mean \pm SD) apart from the next nearest house.

We categorized the area around each house within one of the three following "habitat locales": 'near house' was within 3 m of the house foundation, 'lawn' was grassy, mowed areas >3 m from the house, and 'distant landscaping' was ornamental landscaped, vegetable garden areas located >6 m from the house, or both. In most instances the majority of the herbaceous plants and shrubs in the "distant landscaping" areas were introduced species of ornamental or edible importance, although some of the trees in such areas were native to the southeastern United States. All houses had near and lawn habitats, and twenty of the twenty-four houses included the distant landscaping habitat.

How Does Ant Community Structure Vary Among Houses and Habitats? We sampled the ant communities at each house using pitfall traps. We randomly placed ten traps within each habitat locale at each house such that each pitfall trap was spaced at least 1 m from the nearest pitfall trap. To disturb the soil as little as possible and avoid the "dig-in effect" in which some species of ants are attracted to freshly disturbed soil (Agosti et al. 2000), we used a portable drill and rapid-spade driver bit to excavate the holes for the traps leaving minimal soil disturbance (compared with hand digging), and allowed at least 1 wk to elapse between digging the hole and placing the pitfall trap. Each pitfall trap consisted of an outer plastic vial (3 cm in diameter by 8.5 cm in length) and an inner 50-ml centrifuge tube cut to 8.5 cm tall. Traps were inserted flush with the soil surface. This double-tube trap design allowed for easy removal of trap contents and replacement of the collecting solution.

The inner tube of each pitfall trap was filled with 12 ml of a preservative solution consisting of propylene glycol with 2–3 drops of detergent per 3.8 liters to

reduce surface tension. We removed the lids from the traps on 8 July 2005 and left traps open for 72 h. Although no precipitation occurred during the three day trapping period, the ground was damp from rain the night before, and temperature ranged from 16 to 31°C (NCDC 2005). Specimens were stored in 70% ethanol and later identified to species under a dissecting microscope using a variety of taxonomic keys (Ross et al. 1971, Hölldobler and Wilson 1990, Coovert 2005, MacGown 2007). Reference specimens of each species were confirmed by an ant taxonomy expert, Lloyd R. Davis (Gainesville, FL). A reference collection of specimens is located at the University of Tennessee, Department of Entomology and Plant Pathology insect museum. Abundance of each species was quantified as the number of times at least one specimen of that species was present in a trap at each house.

For this and subsequent analysis, each pitfall trap was treated as a sampling unit. Because some traps were damaged, destroyed, or lost, we used sample-based rarefaction to estimate species richness in each habitat locale. For each habitat locale at each house, we used EstimateS (Colwell 2008) to rarify richness to seven traps per habitat locale. To investigate possible differences in species composition in each habitat locale a trap location by species presence matrix was constructed for each house. We used ANOSIM (PRIMER-E 2007) to assess whether species composition varied among habitat locales.

We used mixed models (SAS Institute 2007) to examine house and habitat effects on rarefied species richness. If distant landscaping occurred only in one corner of the yard, data from these sites were not included in the analysis because of the possibility that spatial clumping of traps may have biased data analysis. Because the three habitat locales we examined were nested within sites, to examine effects of habitat on rarefied richness, 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 analysis of variance (ANOVA) using the three habitat locales as treatments and rarefied species richness as the response variable. If ANOVA results rejected the null hypothesis of equal means ($\alpha < 0.05$), means were compared using the Tukey–Kramer honestly significant difference (HSD) test. All data used in these ANOVAs met the assumptions of normality and equal variances as confirmed by Shapiro-Wilk and Levene-P tests, respectively.

We used the C-score of Stone and Roberts (1990) to test the null hypothesis that species co-occur randomly with respect to one another. The index quantifies the number of "checkerboard units" for each species pair, where the number of checkerboard units is $(R_i - S)(R_j - S)$, R_i is the number of occurrences (equal to the row total) for species i , R_j is the number of occurrences for species j , and S is the number of yards in which both species occur. The C-score is the average number of checkerboard units for each unique species pair. If this index is unusually large compared with a null distribution, there is less pair-

Table 1. Regression of species richness by habitat variables

Variables used in multiple regression	Variables that entered model	R ²	Root MSE	Df	Model F
FHP 150–200 cm, avg % canopy cover; stepping stones/brick/rocks; logs/boards/landscape timbers	Average % canopy cover	0.03	3.26	1, 57	1.62
Number of sites with mulch; no. of sites with leaves; logs/boards/landscape timbers	Number of sites with leaves	0.10	3.14	1, 57	6.56
Number of sites with mulch; avg % canopy cover; logs/boards/landscape timbers	Number of sites with mulch; Average % canopy cover	0.05	3.25	2, 56	1.54
% plant cover, FHP 150–200 cm; logs/boards/landscape timbers	% plant cover	0.05	3.23	1, 57	2.71
n/a	Quadratic fit of average % canopy cover	0.19	2.99	2, 56	6.77

wise species co-occurrence (segregation) than expected by chance. If the index is unusually small, there is more species co-occurrence (aggregation) than expected by chance.

We used EcoSim Version 7.0 (Gotelli and Enstsminger 2005) to compare the observed C-score to the average C-score generated from 5,000 randomly constructed assemblages. We used the most conservative null model, a fixed-fixed model, to generate randomly constructed assemblages. In this null model, row sums are fixed, so that each species occurs with the same frequency in the randomly constructed assemblages as in the observed assemblages. Column totals are also fixed, so each yard has the same number of species in the null assemblages and in the observed assemblages, as would be the case if some yards had more species than others, for whatever reason. *P* values are calculated directly by comparing the observed C-score to the histogram of C-scores from the 5,000 randomly constructed assemblages. For example, a *P* value of 0.05 indicates that the observed C-score was larger than the C-scores of 95% of the randomly constructed assemblages.

How Does *T. sessile* Abundance Vary Among Houses and Habitats? In each habitat locale at each house, we used information from the same pitfall trapping arrays described in “How Does Ant Community Structure Vary Among Houses and Habitats?” to assess *T. sessile* abundance. Abundance was defined as the number of incidences per house that at least one specimen of *T. sessile* was found at a bait and trap location either in a trap or at a bait. We randomly selected five of the pitfall trap locations for each habitat locale at each house for baiting. At each trap location, a clear plastic cup lid containing ≈5 ml of honey and ≈5 ml of tuna-in-oil was placed as bait.

Baits were checked for 2 h at 20-min intervals, and the number of *T. sessile* observed on the lid was recorded. Voucher specimens of *T. sessile* workers were taken from each trap and examined under a dissecting scope in the lab to confirm their identity. Air temperature at the beginning and end of each baiting period was measured with a hand-held digital thermometer.

Because baiting occurred only at sites of successful pitfall trapping, the combined bait and pitfall data were used to assess *T. sessile* abundance. As with the species richness data, we created mixed models to examine house and habitat effects on *T. sessile* abundance and ran an ANOVA on the residuals of a house-

effect-only linear regression to look for differences among habitat locales. All data used met the assumptions of normality and equal variances. We used linear regression to examine the relationship between *T. sessile* occurrence at baits and average temperature during collection and to examine whether there was a relationship between species richness and *T. sessile* abundance.

What Components of Suburban Habitat Structure Influence Ant Species Richness and *T. sessile* Abundance? At each pitfall trap, we recorded a variety of habitat characteristics: foliar height profile (FHP), percentage canopy cover, primary vegetation located within 1 m² around each trap, and type of ground cover within 1 m² around each trap. The foliar height profile was quantified using a 2-m-long piece of PVC (2.5 cm diameter) pipe marked in 25-cm increments that was oriented vertically from the trap lid. We tallied each time vegetation touched the pipe within each 25-cm increment (Agosti et al. 2000). Major vegetation was identified either by common name or morphospecies. We used a densiometer constructed out of a 5-cm-diameter flat mirror marked with a cross-shaped grid of 26 squares and a circular level to estimate canopy cover. Four canopy cover estimates were collected at waist height positions (≈1 m above the ground) facing each of the four cardinal directions at each trap location. These readings were averaged for the final canopy cover estimate. For ground cover, we used 1-m² quadrat centered on each trap to estimate percentages of each type of ground cover, scored as ‘vegetation’, ‘soil’, ‘mulch’, ‘leaf litter’, ‘rock/bricks/stepping stones’, ‘pavement’, or ‘logs/boards/landscape timbers’.

Many of the habitat variables were co-linear. Therefore, subsets of orthogonal variables were analyzed in four separate multiple regressions (Tables 1 and 2). All multiple regressions were forward loading with a 0.25 probability required to enter the model. As percentage canopy cover had a strong polynomial relationship (Table 1) with species richness, we also used the square of the canopy cover values 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 of the *T. sessile* abundance residuals, a log(x) + 1 transformation was applied to all *T. sessile* abundance data in these multiple regressions.

Table 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
FHP 150–200 cm, avg % canopy cover; stepping stones/brick/rocks; logs/boards/landscape timbers	Logs/boards/landscape timbers	0.08	0.35	1, 54	4.74
Number of sites with mulch; no. of sites with leaves; logs/boards/landscape timbers	Logs/boards/landscape timbers; no. of sites with leaves	0.12	0.34	2, 53	3.64
Number of sites with mulch; avg % canopy cover; logs/boards/landscape timbers	Logs/boards/landscape timbers	0.08	0.35	1, 54	4.74
% plant cover, FHP 150–200 cm; logs/boards/landscape timbers	Logs/boards/landscape timbers	0.08	0.35	1, 54	4.74

Results

How Does Ant Community Structure Vary Among Houses and Habitats? Forty-five ant species were collected from pitfall traps (Table 3). The number of species per yard ranged between 7 and 24 species averaging 15 species per yard. The five most common species collected were: *Solenopsis molesta* (Say), *Pheidole tysoni* Forel, *P. dentata* Mayr, *T. sessile*, and ants

in the *Aphaenogaster rudis* complex, which is a group of several species that are largely indistinguishable in the field. A combined model incorporating house (location) and “habitat locale” indicated that both accounted for significant variation in rarefied ant species richness and *T. sessile* abundance (Table 4). Examination of the residuals saved from a house-only model, indicated that rarefied ant species richness in pitfall traps was similar between lawn and distant landscap-

Table 3. Abundance of ant species found in pitfall traps from all houses

Species	Near house	Lawn	Distant landscaping	Total
<i>Aphaenogaster fulva</i> Roger	3	1	1	5
<i>Aphaenogaster rudis</i> Enzmann complex	11	4	19	34
<i>Aphaenogaster tennesseensis</i> Mayr	0	1	2	3
<i>Aphaenogaster treatae</i> Forel	0	2	0	2
<i>Brachymyrmex depilis</i> Emery	1	4	1	6
<i>Camponotus americanus</i> Mayr	0	3	3	6
<i>Camponotus castaneus</i> (Latreille)	4	7	5	16
<i>Camponotus chromaiodes</i> Bolton	3	5	5	13
<i>Camponotus mississippiensis</i> Smith	0	0	1	1
<i>Camponotus pennsylvanicus</i> (DeGeer)	2	1	1	4
<i>Camponotus subbarbatus</i> Emery	0	0	1	1
<i>Crematogaster cerasi</i> (Fitch)	2	2	1	5
<i>Crematogaster lineolata</i> (Say)	4	4	16	24
<i>Crematogaster missouriensis</i> Emery	0	5	1	6
<i>Crematogaster pilosa</i> Emery	4	1	5	10
<i>Forelius</i> sp.	3	1	3	7
<i>Formica dolosa</i> Buren	0	2	0	2
<i>Formica pallidefulva</i> Latreille	13	22	15	50
<i>Formica subsericea</i> Say	6	11	12	29
<i>Hypoponera opacior</i> (Forel)	16	22	14	52
<i>Lasius alienus</i> (Foerster)	9	22	15	46
<i>Lasius neoniger</i> Emery	6	16	15	37
<i>Monomorium minimum</i> (Buckley)	11	48	24	83
<i>Myrmica americana</i> Weber	0	1	2	3
<i>Myrmica pinetorum</i> Wheeler	8	17	8	33
<i>Myrmica punctiventris</i> Roger	0	3	5	8
<i>Myrmecina americana</i> Emery	1	3	5	9
<i>Nylanderia faisonensis</i> (Forel)	12	12	16	40
<i>Nylanderia vividula</i> (Nylander)	10	15	7	32
<i>Pheidole bicarinata</i> Mayr	17	30	23	70
<i>Pheidole dentata</i> Mayr	37	58	38	133
<i>Pheidole pilifera</i> (Roger)	0	1	2	3
<i>Pheidole tysoni</i> Forel	38	81	44	163
<i>Ponera pennsylvanica</i> Buckley	2	0	0	2
<i>Prenolepis imparis</i> (Say)	1	0	0	1
<i>Pyramica dietrichi</i> (Smith)	0	0	1	1
<i>Pyramica membranifera</i> (Emery)	0	0	1	1
<i>Pyramica ohioensis</i> (Kennedy & Schramm)	1	1	1	3
<i>Pyramica</i> sp.	0	0	1	1
<i>Solenopsis molesta</i> (Say)	42	93	62	197
<i>Strumigenys louisianae</i> Roger	1	0	0	1
<i>Tapinoma sessile</i> (Say)	67	38	23	128
<i>Temnothorax curvispinosus</i> (Mayr)	1	0	0	1
<i>Temnothorax pergandei</i> (Emery)	0	3	1	4
<i>Tetramorium caespitum</i> (L.)	18	10	7	35

Table 4. Regression models for habitat and house effects on species richness and *Tapinoma* abundance

Variables	Model effects	R ²	Root MSE	Df	Model F
House and habitat effects on species richness	Whole model (house + habitat)	0.68	2.42	24, 34	3.01
	House effect	-	-	22	2.74
	Habitat effect	-	-	2	6.28
House and habitat effects on <i>T. sessile</i> abundance	Whole model (house + habitat)	0.76	1.70	21, 34	5.21
	House effect	-	-	19	4.87
	Habitat effect	-	-	2	7.73

ing habitat locales with species richness lower in near house traps ($F = 9.65$, $df = 2, 56$, $P = 0.0002$; Fig. 1). Community composition varied among habitat locales at 11 of the 24 houses ($\alpha < 0.05$). However, pairwise comparisons by habitat locale showed the source of this clustering was highly variable with only one house having three distinct habitat-defined communities. Some of the eleven houses had multiple pairwise differences. Three of these houses provided no distant landscaping locale so only lawn and near house comparisons could be made. A majority of other houses only showed differences between lawn and near house or near house and distant landscaping (Table 5).

How Does *T. sessile* Abundance Vary Among Houses and Habitats? A combined model incorporating house (location) and habitat locale indicated that both parameters significantly explained ant species richness and *T. sessile* abundance (Table 4). Twenty-one of the 24 houses had *T. sessile* present either at baits or in pitfall traps. For combined pitfall and baiting collection methods, *T. sessile* abundance appeared to be inversely related with species richness. *Tapinoma sessile* was most abundant near the house but less abundant in both lawn and far landscaping habitats ($F = 9.24$, $df = 2, 55$, $P = 0.0003$; Fig. 2). However, ant species richness and *T. sessile* abundance were weakly correlated ($R^2 = 0.07$, $MSE = 3.33$, model $P = 0.056$). Also, *T. sessile* abundance at baits had no relationship with the ambient air temperature ($R^2 = 0.0079$, $MSE = 1.48$, model $P = 0.47$) indicating that the range of baiting temperatures on different collection days did not bias trap catch.

What Components of Suburban Habitat Structure Influence Ant Species Richness and *T. sessile* Abundance? For species richness, percentage canopy cover frequently entered the model generated by multiple

regressions. However, the relationship between canopy cover and ant species richness was more readily explained using a quadratic polynomial than a linear model (Table 1). Percentage leaf litter had a small, but significant, negative relationship with ant species richness. *Tapinoma sessile* abundance was best explained by a model that incorporated both the number of bait/trap sites with leaf litter present within 1 m² and the number of bait and trap sites that also had either logs, boards, or landscape timbers present within 1 m² of the bait/trap position (Table 2).

Discussion

Numerous studies have sought to identify the factors that account for variation in ant species richness, but mostly in areas free of human disturbance (Dunn et al. 2009). Few studies, however, have taken the same approach and applied it to urban ecosystems. Here, we found that ant species richness depended on proximity to human structures: ant species richness was nearly always lower near houses than far from houses. Despite sometimes 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 distant landscaping locales indicates that 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 distant landscaping and lawn locales for four of the 24 houses. The limited sample size of houses that did not include distant landscaping in this study did not allow for testing for differences in ant richness between yards with and without gardens.

Considering the wealth of ant species that commonly dwell in forested leaf litter in the surrounding mountains of the Knoxville area, the negative relationship of ant species richness with increasing

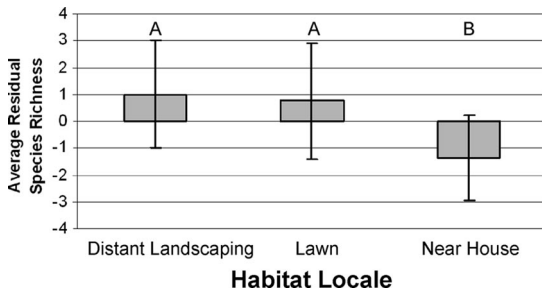


Fig. 1. Relationship between habitat locale and species richness. Error bars represent one standard deviation. Habitat locale means with the same letter are not significantly different ($\alpha < 0.05$).

Table 5. Number of houses that showed pairwise differences in species composition by habitat locale

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

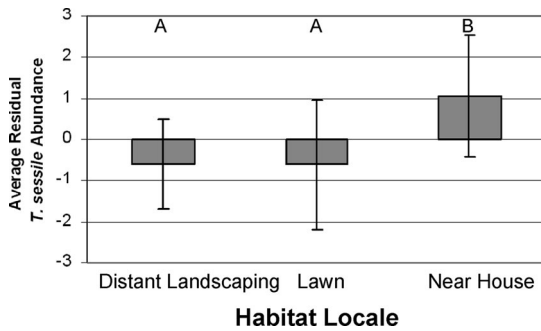


Fig. 2. Relationship between habitat locale and *T. sessile* abundance. Error bars represent one standard deviation. Habitat locale means with the same letter are not significantly different ($\alpha < 0.05$).

amounts of leaf litter is surprising. This result may simply be because of sampling bias if the pitfall traps were less effective in areas with high litter content, thus indicating 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 (Gibb and Hochuli 2002, Lassau and Hochuli 2004, Lessard and Buddle 2005, Thompson and McLachlan 2007, Clarke et al. 2008). Most of the leaf litter at our study sites was characterized as fallen leaves persisting beneath non-native shrubs that had been planted as either part of managed landscaping efforts or as abundant privet and Asian honeysuckle plants, which had colonized yard edges. This litter may be lacking in either the physical or biological characteristics of native forest plant litter to the detriment of forest litter ants. In addition, *T. sessile* levels were higher in areas with leaves, indicating that they may be displacing other litter ants, which could also account for some of the lowered diversity.

Of all habitat characteristics measured, percentage canopy cover best explained variation in ant species richness. This result supports prior studies that indicate the presence of trees may be an important influence of ant species richness in urban areas (Pecarevic 2007, Yasuda and Fomito 2009). Low species richness occurred in sparse and near total canopy cover, whereas 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 hemipterans which many ant species tend to use 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* (Buckley) (Baroni-Urbani and Kownowski 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 >2 m tall showed similar trends, with species

richness and abundance highest at intermediate tree densities (Pecarevic 2007).

Only one non-native ant, *Tetramorium caespitum* (L.), was found, and in relatively low abundance to many native species. This lack of non-native, invasive ants may seem surprising given the propensity of many invasive species of ants to thrive in human disturbed environments (Buczowski 2010). However, at the time of this study, imported fire ants (*Solenopsis* spp.) were just beginning to reach the Knoxville area and weren't considered established until 2006 (APHIS 2006). Sampling a few years later after the spread of imported fire ants into the area may show very different trends. Argentine ants, *Linepithema humile* (Mayr), which thrive in urban areas in the western United States, were not collected in this study. Although it is possible that these ants were simply not well sampled by pitfall trapping, *L. humile* was not collected over the past 8 yr when 195 urban structures were sampled with honey before insecticidal treatments in the Knoxville area (K. M. Vail, unpublished data), and no *L. humile* were observed on baits in this study. *L. humile* is present in Knoxville, but it appears to have a patchy distribution (K.M.V., personal observations). These observations are concurrent with the general trend of *L. humile* colonies to be smaller and more dispersed in the southeastern United States than the western United States (Buczowski et al. 2004). In addition, *T. sessile* shares many life history traits with *L. humile* (polydomy, polygyny, dwelling in prefabricated crevices, thriving in disturbed habitats) and may simply outcompete *L. humile* in a similar urban niche, although evidence supports *L. humile* as the successful competitor of *T. sessile* (Buczowski and Bennett 2007). Perhaps, *T. sessile* maintained a competitive edge by outnumbering *L. humile* upon its introduction into the area. The relatively low occurrence of *T. caespitum* also was surprising, which stands in contrast to other work in the eastern United States (Uno et al. 2010). This low occurrence may be the result of latitudinal differences in *T. caespitum* distribution or a reflection of the sampling method. Because there was only one date of pitfall trapping, this study offers only a "snapshot" of the urban ant diversity in the Knoxville area. Further, trapping and baiting at other times of the year would provide a more complete picture of the ant diversity and abundance of invasive species.

The abundance of *T. sessile* increased with proximity to human structures, in contrast with ant species richness more generally. Buczowski and Bennett (2008) observed similar increases in *T. sessile* numbers near human structures and hypothesized that this increase was because of structures reducing temperature fluctuations, providing protection from predators, and allowing access to human food. In addition, as *T. sessile* colonies were found frequently in irrigated mulch (Buczowski and Bennett 2008), and *T. sessile* colonies will relocate workers and brood from dry locations to moist locations (Toennissen 2009), increases in moisture availability near structures may contribute to increasing abundance of *T. sessile* in

urban areas. It is perplexing though, that other nonpest species do not apparently associate with these structures, given that there are so many apparent benefits. This suggests one of two possibilities. Firstly, perhaps *T. sessile* displaces other ant species from these areas close to human structures. Buczkowski (2010) suggests that *T. sessile* may negatively affect other native ant abundance and diversity in urban environments. *T. sessile* coexisted with more ant species in natural environments compared with an invaded urban one. In urban environments, *T. sessile* exhibited the invasive ant characteristics of large colony size, polygyny and polydomy, whereas in natural environments, *T. sessile* colonies were small-sized, monogynous and monodamous. Or secondly, there may be a tradeoff such that along with benefits of proximity to houses, there is a cost levied by increased disturbance regimes, and only *T. sessile* can tolerate the disturbance.

Areas with “logs, boards, and landscape timbers” and “sites with leaves” were habitat characteristics that best explained abundance of *T. sessile*, each having positive correlations (although only explaining $\approx 10\%$ of the variation). As these ground coverings are both known nesting materials for *T. sessile*, their positive relationships with *T. sessile* abundance could be because of an increase in the number of suitable nest sites. Surprisingly, other observed potential nest sites, such as mulch and rocks, were not correlated with *T. sessile* abundance. In follow-up communications with all homeowners, only one house used cedar mulch, which is repellent to *T. sessile* (Meissner and Silverman 2001). However, type, depth and age of other mulches may alter their attractiveness to odorous house ants. *Tapinoma sessile* colonies may prefer logs and landscape timbers as nest sites versus rocks during dry summer times because wood absorbs moisture readily and may provide a larger reservoir of moisture than nonporous surfaces. Although mulch absorbs water readily, it is more prone to desiccation than a solid piece of wood because it has less surface area. Unless mulch is irrigated, it may provide a less attractive nest site. In agreement with other studies, we found that vegetation cover, density, and canopy cover were unrelated with *T. sessile* abundance (Thompson and McLachlan 2007, Buczkowski and Bennett 2008). Still, certain species of plants may be particularly attractive to *T. sessile* despite the general lack of relationship between woody plant presence and *T. sessile* abundance. For example, *T. sessile* workers were frequently seen on rhododendron flowers in spring, where they may be foraging for nectar, and trailing up maple trees in the summer (possibly in search of honeydew excreting hemipterans) (T.A.T., personal observations).

This study lays the ground work for controlled experiments to test for *T. sessile* nesting substrate preferences and to test mechanisms by which structures could increase *T. sessile* abundance. *Tapinoma sessile* preference to other hardwood mulches and pine straw over cedar mulch has been 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

demonstrated as preferred nest site locations, reduction of these ground covers around the house may reduce *T. sessile* populations. In addition, investigations into other mechanisms by which structures facilitate *T. sessile* population growth (e.g., by affecting moisture, nest sites, food access, temperature moderation, etc.), may reveal new cultural control options for managing *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 at the within-yard scale.

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