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Changes in ant biodiversity across an urban gradient

Hao Brooks
University of Tennessee at Chattanooga, hkw326@mocs.utc.edu

Changes in Ant Biodiversity Across an Urban Gradient

Hao Bradley Brooks

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Department of Biology

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Dr. DeAnna E. Beasley
Assistant Professor of Biology
Thesis Director

Dr. Stylianos Chatzimanolis
Associate Professor of Biology
Department Examiner

ABSTRACT

There are two aims to this study: compare diversity across an urban gradient and across seasons. We deployed traps and identified the collected 12 ant species at nine different sites centered at Chattanooga, Tennessee, for the purpose of relating levels of urbanization to the diversity of ant species at each site. We successfully sampled in the summer (June 27, 2017) and spring (March 31, 2018), and unsuccessfully sampled in winter (Feb. 16, 2018) when we collected zero ants, likely due to cold soil temperatures. To quantify "urbanization" we divided the sites into "Urban" core verses surrounding "Suburban" area using a city development model, and by a direct measure of the percent impervious surface within a 25m radius of each collection site. We predict that as urbanization increases, ant diversity will decrease.

We found that the "Suburban" versus "Urban" sites showed a decline in species diversity for the summer sampling (averages of 4.6 and 2.2, respectively), but no difference for the Spring sampling (averages of 2.0 and 2.0). Impervious surface percentage was strongly related (r^2 = 0.63) to a decline in ant species over the combined summer and spring samplings. Our linear least-squares regression line slope indicates a decline of 0.34 species for every 10% increase in impervious surface area, with a modeled 6.4 species for pavement-free land cover and 2.9 species for 100% impervious surface. Overall, our ant samplings support this hypothesis for our measures of urbanization.

Characteristics of urbanization include impervious surface coverage, fragmentation of habitats, warmer micro-climates, and human food wastes. In general, it is believed that urbanization favors the "opportunistic" or "generalistic" ant species that can thrive on a variety of food and water sources in dense human populations. These species displace the more numerous "specialist" species, resulting in less ant diversity with increasing levels of urbanization.

INTRODUCTION

Urbanization is defined as the growth of cities in terms of outward expansion, vertical growth and population growth (Gotham, 2011). Towards the end of the 18th century, during Britain's Industrial Revolution, urbanization began to increase rapidly as more people moved to the cities for jobs. As the world population continues to increase, so too will the expansion of urban areas. Specifically, approximately 66% of the world's population is expected to live in urban areas by the year 2030 (United Nations, 2014; Figure 1).

Rapid rural-urban conversion will have both environmental and ecological consequences. One major environmental effect of cities is the urban heat island effect in which the ambient temperature within urban areas is higher than the rural areas surrounding it (Oke, 1973). In a study conducted in the country of Bahrain, it was shown that the temperature within urbanized regions was higher by 2-5°C due to urbanization activity such as construction and reduction in vegetation (Radhi et al., 2013). Similarly, the conversion of areas such as grassland and woodland into urbanized areas will have significant effects on ecosystem function. In some areas, the percent area used for residential or commercial purposes has almost doubled whereas the percent area occupied by vegetation has decreased significantly (Tang et al., 2008). Understanding the effects of ecological changes associated with urbanization will provide insight into assessing the quality and function of cities for organismal and human health.

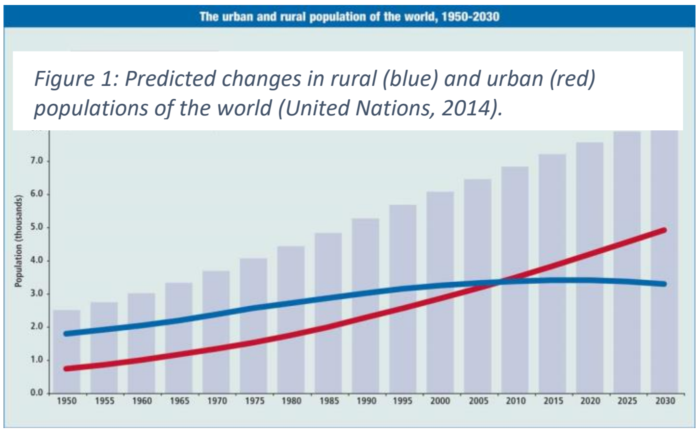

Figure 1: Predicted changes in rural (blue) and urban (red) populations of the world (United Nations, 2014).

One of the major ecological consequences of increased urbanization is the decline in native species and overall loss of biodiversity. Several studies have been conducted to study the effects cities have on biodiversity. Alberti (2005) demonstrated how fragmentation of natural and rural areas disrupts the movement of resources and organisms. With increased fragmentation, species that are isolated in an urban environment are more susceptible to extinction due to loss of resources and changes in migratory patterns. This change in landscape also changes the movement of nutrients in urbanized areas which can cause a decrease in biodiversity if species can no longer meet their nutritional needs. Additionally, Rensburg et al. (2009) analyzed biotic homogenization and abundance of species across an urban gradient in Pretoria, South Africa. When they compared the number of species across the three environments (semi-natural, suburban, and urban), they noticed a decrease in specialist species with increasing urbanization (Rensburg et al., 2009). Furthermore, they found that the invasive alien species was one of the predominant species in the urban environments. The data indicated that as urbanization increases, biotic homogenization also increased. Thus, biodiversity can serve as a tool to measure the ecological health of a specific area.

Ants (Formicidae) provide an effective means for assessing biological diversity across an urban gradient. One of the key qualities of ants is the very large diversity of species. The estimated number of species is around 20,000 but only around 12,000 have been officially classified (Ward, 2006). Ants also occupy a wide range of terrestrial environments, including urban habitats (McIntyre, 2000). Urbanization brings about changes in resources and microclimates which may be especially severe and long lasting. Affected areas tend to become dominated by opportunistic or generalist ant species, because it is thought that generalist species can take full advantage of changing resources. In an urban environment, ants provide essential ecosystem functions such as biological pest control, seed dispersal, and soil modification (Philpott et al., 2016). Lastly, ants have several unique functions in an ecosystem. For example, ants interact with their environment and other organisms through a variety of ways including: predation, herbivory, scavenging, and mutualistic interactions (Sanders and Veen, 2011). Ants also alter nutrient levels through their colony formation in soil. Large amounts of organic matter can be found inside ant nests. Nutrients from the surface move downward and nutrients from below get carried upward (Sanders and Veen, 2011). Thus, ant activity alters decomposition rates and amount of nutrients available for other species. These traits, as well as others, make the diversity of ants a useful tool for assessing the quality of the local environment.

Chattanooga is a medium sized city in southeastern Tennessee that is currently experiencing rapid population growth. According to United States Census extrapolation from 2010, Chattanooga had an estimated population of 175,000, in 2015 making it the 4th largest city in Tennessee. Within the city limits the population density is 1,223 people per square mile (472/square kilometer). The human population of Chattanooga's Hamilton County grew at a rate of 5.2 percent from 2010 to 2015, exceeding the national average for cities of similar size. This rate makes the Chattanooga area the second-fastest growing (just behind Nashville) among Tennessee's four biggest urban areas, according to U.S. Census Bureau data. Much of the southeastern United States is experiencing rapid growth. By the year 2060, urbanization in the southeastern United States is predicted to increase by 100 percent, creating a megalopolis that extends from Raleigh, North Carolina to Atlanta, Georgia (Terando et al., 2014). Under these conditions, assessing changes in biodiversity will be important for monitoring ecological function in the rapidly changing region.

There are two aims of this study. The first is to document the change in ant diversity across a rural-urban gradient, and the second is to compare diversity across seasons. I predict that the diversity in ants will decline as urbanization increases (Figure 2), and that diversity will decrease in the winter season.

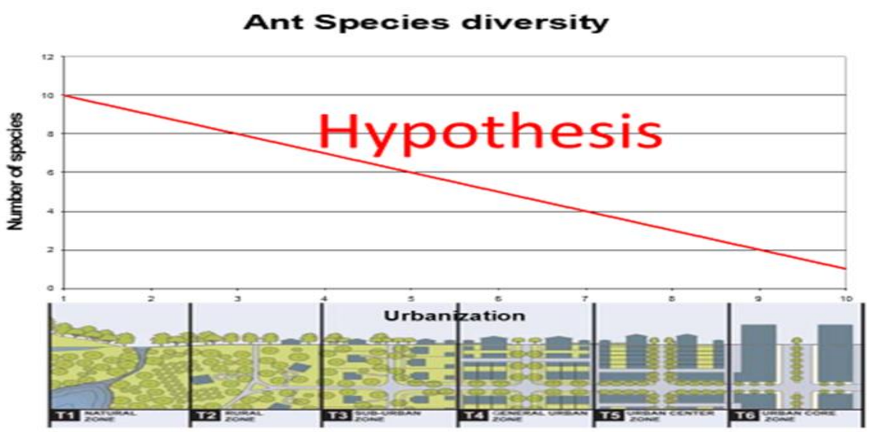

Figure 2. Hypothesis of decreasing ant diversity with increasing urbanization.

METHODS

Local urbanization can be characterized by percent impervious surface. The impervious surface area of each site was determined by measuring 25 meters in the approximate North, South, East and West directions from the GPS coordinate location. At each 1-meter interval if the surface was impervious that counted as 1%. The sum of the impervious surface, at each of the 100 single meter points, determined the total percent impervious surface. For example, if 34 of the points were impervious, the site was judged to be 34% impervious. These percentages are given in the site descriptions sections. The range of a rural-urban gradient is measured as the percent impervious value (PIMP value: 0-15% = rural; 75-100% = highly urbanized; University of Minnesota, 2011). I have divided the sites into “Park” (sites 4,5 and 8; average impervious surface 12%), “Street Median” (Sites 2, 3 and 9; average impervious surface 74%) and “Street Edge” (sites 1, 6 and 7; average impervious surface 90%), as representing levels of surrounding impervious surfaces as low, medium and high, respectively. Street edges represent the highest impervious surface and urbanization. They have a width of about 0.6-0.9 meters and a length of 2-8 meters, and are surrounded on all sides by pavement. The vegetation that grows in these habitats include grasses and small bushes. Street medians represent medium levels of diversity. They are typically found between two lanes of traffic and have a width similar to street edges but a much longer length of 7-30 meters. City parks demonstrate lower levels of urbanization and impervious surfaces. They are generally the size of a few city blocks and have roads that either cut through them, or surround them, and traffic can be moderate or heavy. The vegetation is limited and can include grasses, shrubs and bushes, and a small variety of trees.

As a second characterization of urbanization we have grouped the six Street medians and Street edges together to represent “Suburban” because they had similar impervious surface values. For a comparison, we have grouped the remaining three park sites as “Urban”. As a third characterization of urbanization we are using the Hoyt model (Knox and McCarthy, 2005) for quantifying urbanization. The Google Earth image of the Chattanooga area is shown in Figure 3, with the Hoyt model shown in Figure 4.

Figure 3. Collection sites on a Google Earth Image of greater Chattanooga. Sites 1-4 are within 1.6 km of downtown Chattanooga are considered as the “urban sites”. Sites 5-9 are 1.6-8.0 km from downtown are considered the “suburban sites”.

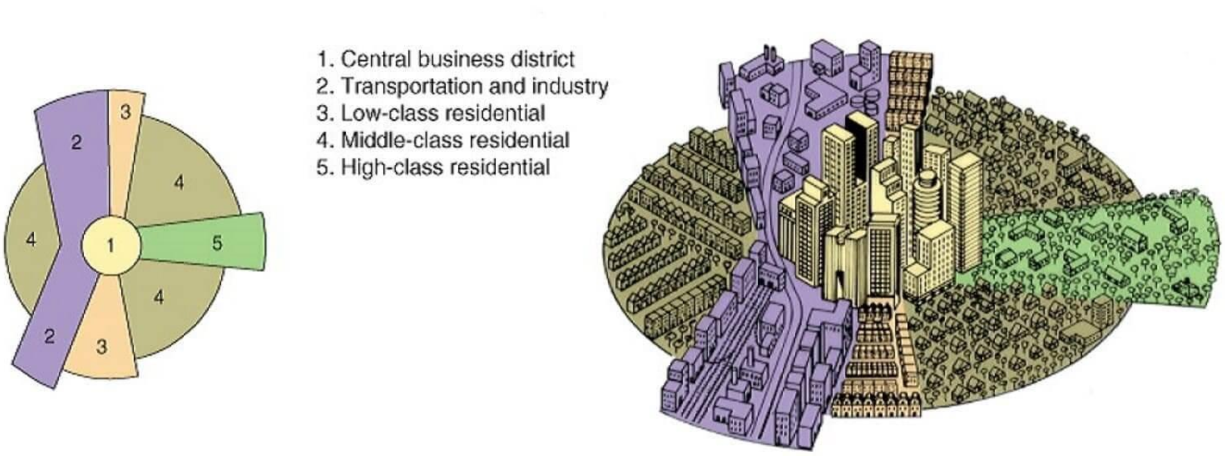

Image: https://planningtank.com/settlement-geography/hoyt-model-sector-model-land-use-1939-homer-hoyt

Figure 4. Hoyt model of urbanization structure.

According to the Hoyt model, cities founded prior to 1890 (such as Chattanooga) developed around a circular central business district of approximately 1.6 km in radius. This distance was dictated by the reasonable Horsecar trip time and distance, and the walking distances within the central commerce and central shopping zones within the central business district. Further expansion during the streetcar era (after 1890), the automobile era (starting 1920), the freeway era (~1945), the edge city era (~1973), and finally the Boomburb era (~1985) typically left the central business district intact, and led to the lower urbanization development of higher density corridors, suburbs, and edge cities (Knox and McCarthy, 2005).

For the center of our Hoyt urban core we took the point where the two major roads that run the length of the city, Market and E. Martin Luther King, intersect. Under examination of the current Google Earth image of greater Chattanooga (Figure 3), it appears from the general surface colors of the image that this Hoyt "urban" circle (Figure 4) does encompass a 1.6 km radius of the downtown center, and that multiuse "suburban" areas follow the road nodes, surrounding this 1.6 km radius "urban" area. This defines sites 1-4 as "urban" and sites 5-9 as "suburban" for the third urbanization categorization in this study.

To conduct this study, nine sampling sites were selected in the Chattanooga area. Three street edges, three street medians, and three parks were chosen to represent changes in urbanization. The sites are as follows:

Site ID	Habitat Type	% Impervious	Lat.	Long.
1VIN	street edge	94%	35.044735	-85.291841
2E23	street median	76%	35.024739	-85.299263
3WAS	street median	82%	35.031629	-85.303864
4JEF	Park	8%	35.030452	-85.300904
5MIL	Park	4%	34.999716	-85.314424
6PIL	Street edge	87%	35.038645	-85.261013
7WIL	Street edge	90%	35.048171	-85.240396
8COL	Park	25%	35.060686	-85.307887
9DAL	Street median	69%	35.073166	-85.305881

Sample collections took place on June 27, 2017 (summer; max Temp. of 28 deg. C), February 16, 2018 (winter; max Temp. of 21 deg. C and March 31, 2018 (spring; max Temp. of 21 deg. C). At the sites labeled as street edge or park, two trees were selected for collecting ants. Street median locations had 3 sampling sites each; one at each end and one in the middle. We used bait traps to collect ants. The four types of baits used were: sugar, oil, water, and cookie. These represented the essential dietary needs of ants with cookies being an all-encompassing food source. The sugar trap, which I focused on for this study, was made by dissolving 50 grams of sugar into 250 mL of water. To make the sugar, water, and oil traps, cotton balls would be soaked in a mason jar that contained the substance, and then placed on an index card with the site information. These index cards were then laid out in the open at each site. The cookie traps were made by crushing a single Pecan Sandies cookie and placing it inside a plastic container that had openings for ants. Additionally, a flag and sign were placed down at each site to inform the public. The traps were set for one hour before being recollected and placed into plastic bags. The collected ants were then humanely euthanized via freezing for 24 hours and identified by species using morphological keys. Lastly, they were stored in 95% ethanol for additional study.

Data was analyzed using the T-TEST function in Microsoft Excel. We ran t-tests comparing urban versus suburban areas (determined by the Hoyt Model) for the summer and again for the spring. Additionally, when comparing urban vs suburban based on impervious surface values, the street edges and medians were similar, and so they were combined to perform a t-test between parks versus street sites. Finally, we analyzed the species numbers with % impervious area again separated by summer, spring and summer+spring (Total). We then used the linear regression functions (SLOPE, INTERCEPT, CORREL, and RSQ) in Microsoft Excel. The RSQ function returns the square of the Pearson product moment correlation coefficient through data points as the number of species (y's) and the impervious surface percentages (x's). The r-squared value can be interpreted as the proportion of the variance in species number attributable to the variance in percent impervious surface.

RESULTS

Overall, we found 12 different species of ants. The species found include:

Scientific Name	Common Name
Solenopsis invicta (*Solenopsis* Sp2)	Red Imported Fire Ant (RIFA)
Monomorium minimum	Little Black Ant
Solenopsis tennesseensis (*Solenopsis* Sp1)	Thief Ant
Pheidole megacephala	Big Headed Ant
Lasius niger	Garden Ant
Brachymyrmex sp.	Rover Ant
Crematogaster sp.	Acrobat Ant
Tapinoma sessile	House Ant
Camponotus sp.	Carpenter Ant
Nylanderia fulva	Crazy Ant
Forelius sp.	High Noon Ant
Tetramorium	Pavement Ant

Table 1. Ant species identified in the summer sampling with the total number of individuals collected, and the sites these species were found.

Ant Genus	Abundance	1VIN (SE)	2E23 (SM)	3WAS (SM)	4JEF (P)	5MIL (P)	6PIL (SE)	7WIL (SE)	8COL (P)	9DAL (SM)
Solenopsis sp1	527		X				X			X
Monomorium	501	X	X		X	X	X	X	X	X
Solenopsis sp2	408				X	X		X	X	
Tetramorium	336									X
Pheidole	77				X	X	X	X		
Lasius	65				X			X	X	X
Brachymyrmex	16		X				X		X	
Crematogaster	11			X						
Tapinoma	5								X	
Camponotus	1					X				
Nylanderia	1							X		
Forelius	0									
Totals	1948	1	3	1	4	4	4	5	5	4

SE= Street Edge SM= Street Median P= Park

Zero ants were collected during winter 2017

Table 2. Ant species identified in the spring sampling with the total number of individuals collected, and the sites these species were found.

Ant Genus	Abundance	1VIN (SE)	2E23 (SM)	3WAS (SM)	4JEF (P)	5MIL (P)	6PIL (SE)	7WIL (SE)	8COL (P)	9DAL (SM)
Solenopsis sp1	55		X		X					X
Monomorium	45		X		X	X	X	X	X	
Solenopsis sp2	9			X				X		
Tetramorium	0									
Pheidole	3	X								
Lasius	0									
Brachymyrmex	0									
Crematogaster	0									
Tapinoma	0									
Camponotus	0									
Nylanderia	6		X			X				X
Forelius	67				X	X			X	
Totals	185	1	3	1	3	3	1	2	2	2

SE= Street Edge SM= Street Median P= Park

Table 3. Ant species identified in the Total (summer and spring) samplings with the total number of individuals collected, and the sites these species were found.

Ant Genus	Abundance	1VIN (SE)	2E23 (SM)	3WAS (SM)	4JEF (P)	5MIL (P)	6PIL (SE)	7WIL (SE)	8COL (P)	9DAL (SM)
Solenopsis sp1	582		X		X		X			X
Monomorium	546	X	X		X	X	X	X	X	X
Solenopsis sp2	417			X	X	X		X	X	
Tetramorium	336									X
Pheidole	80	X			X	X	X	X		
Lasius	65				X			X	X	X
Brachymyrmex	16		X				X		X	
Crematogaster	11			X						
Tapinoma	5								X	
Camponotus	1					X				
Nylanderia	7		X			X		X		X
Forelius	67				X	X			X	
Totals	2133	2	4	2	6	6	4	5	6	4

SE= Street Edge SM= Street Median P= Park

We collected 1948 ants on June 27th, zero ants were collected on Feb 16th, and 185 ants were collected on March 31. Although the high daytime temperature on February 16th were ~21C, the ground was likely too cold for ant foraging. Our most common ant was *Solenopsis* sp1 (Thief) with 582 individuals collected, followed by *Monomorium* (546 individual ants), then *Solenopsis* sp2 (Fire; 417 individual ants), and *Tetramorium* at 336 individuals. All other eight species collected had an abundance of <100 individual ants (Table 3). It should be noted that "Total" refers to the combination of the summer and spring data.

For the Total sampling the urban sites, as measured by the Hoyt Model had, on average, fewer ant species (2.1) compared to the suburban sites (3.3 species, Figure 7). For the summer the T-test (2 tails, nonequal variances) value was 0.046 which indicates a strong difference between the urban and suburban sites (Figure 5). For the same comparison using the spring data, the T-test value was 1.0 (Figure 6). This means that during the spring sampling, the urban sites had an equal diversity to the suburban sites. This was due to the suburban sites having significantly lower species numbers in spring, compared to the summer.

The park sites, which represent the least amount of urbanization, had significantly more species in both the Summer and Spring (4.3 and 2.7, respectively) compared to the street edges and median sites combined (3.0 and 1.7, respectively; Figure 8). The T-test (2 tails, nonequal variances) values support this, as the T value was 0.125 for the summer, which signifies a significant difference between the Park versus the sum of Street medians plus edges. For the spring the T-test value was 0.080 which means there was an even stronger difference between the Park and Street sites. When we analyzed the data from the Spring and Summer combined

(Total) , the T-test value was 0.071 which shows that, overall, the park sites were more diverse than street medians and edges combined (Figure 8).

For ant abundance, comparing the Urban sites (1-4) to the Suburban sites (5-9), the Summer sampling averaged 30 ants per traps at the Urban sites, and 17.5 ants per trap at the Suburban sites (Figure 9). This indicated to us that ants are quite ubiquitous across the urban gradient. Comparing abundance among the summer sites exclusively, the highest ants per trap (32.5) were the Street edge sites, followed by the Street median sites (24) and the Park sites (11; Figure 10). It is possible that the street edge habitat is the most confining, making the traps more locatable to the ants.

Comparing the diversity of ant species to the measured impervious surface percentage at each site (Figure 11), each sampling (summer, spring) showed a decline in species number with increasing impervious surface area. Again, the r-squared value can be interpreted as the proportion of the variance in y attributable to the variance in x. For the Total (summer+spring data) the linear least-squares regression had a correlation coefficient of r= -0.79 and an r^2 = 0.63. This indicates a strong relationship between diversity and percent impervious surface. The Total data set also had a slope of -0.034 indicating a decrease of 0.34 species for each 10% increase in impervious surface cover. The equation of the trend line is:

 # Species = -0.034 (% impervious surface) + 6.45

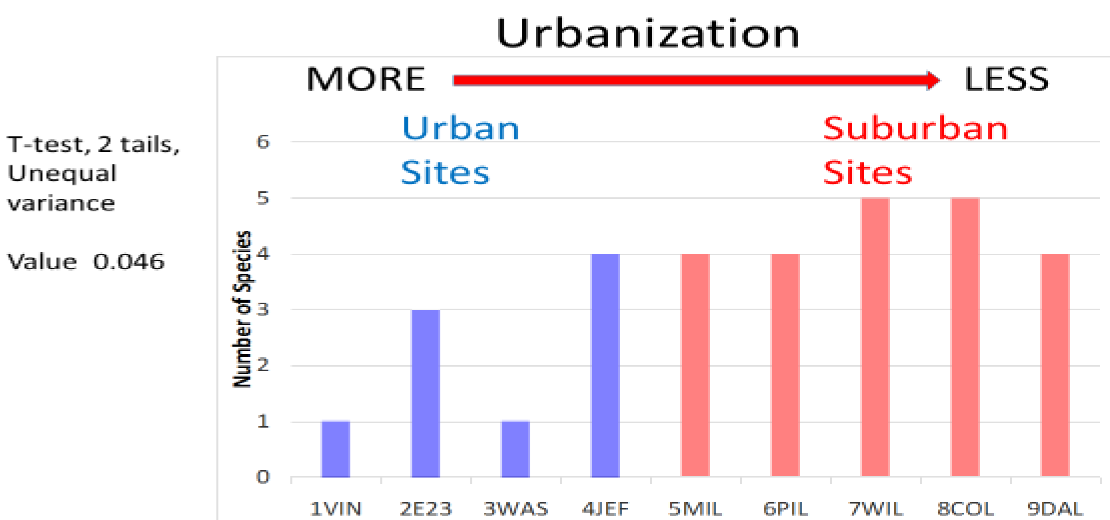

Figure 5. Number of ant species each site defined as Urban and Suburban in summer. The summer sampling showed a strong difference in number of species between the Urban sites (1-4) and the Suburban sites (5-9; T-test value 0.046).

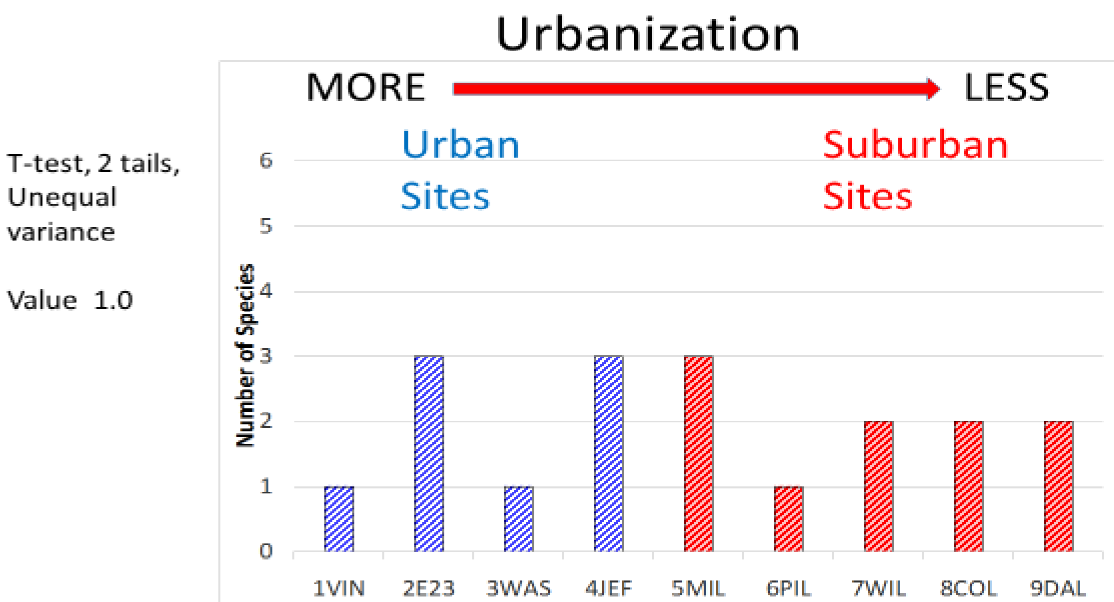

Figure 6. Number of ant species each site defined as Urban and Suburban in spring. The spring sampling showed no significant difference in number of species between the Urban sites (1-4) and the Suburban sites (5-9; T-test value 1.0).

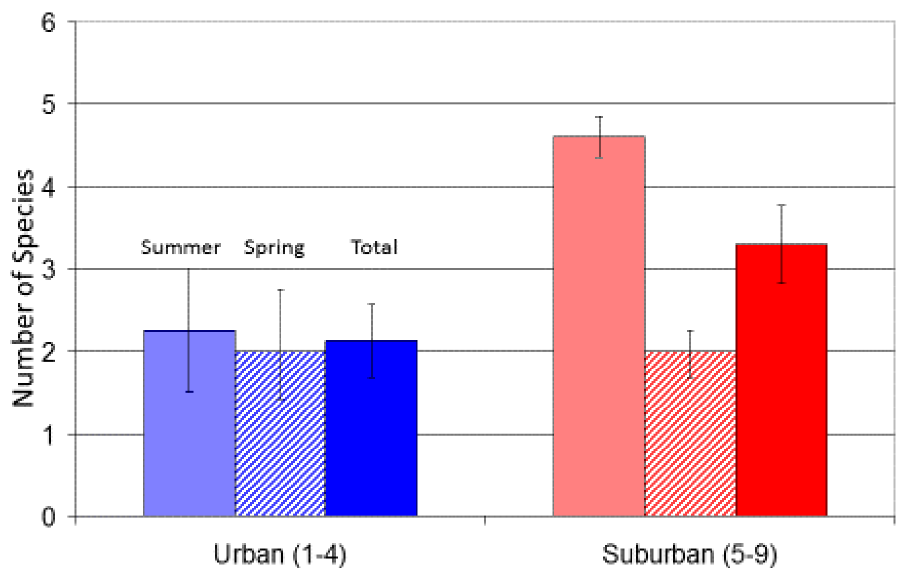

Figure 7. Average number of ant species identified with standard error bars for the summer, spring and Total. For the Total, the urban sites (1-4) averaged 2.1 ant species, while the suburban sites (5-9) averaged 3.3 species.

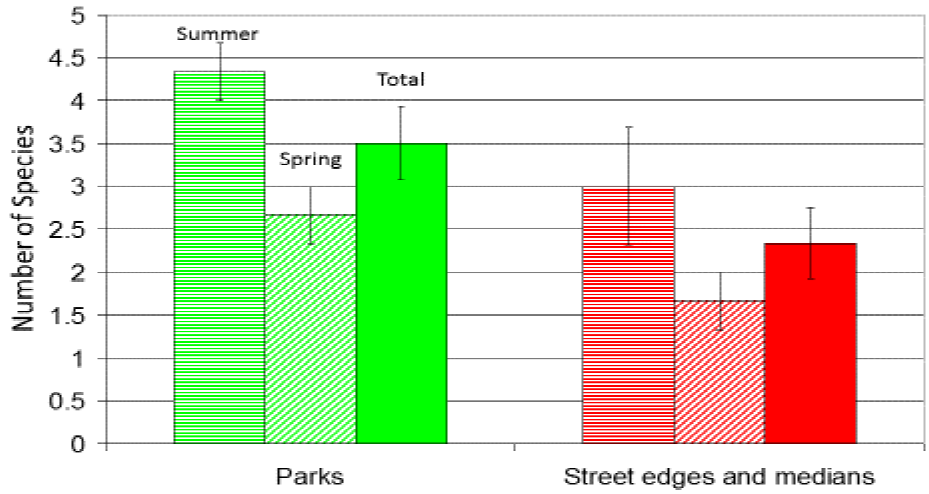

Figure 8. Average number of ant species identified with standard error bars for the summer, spring and Total. For the Total, the Park sites (4,5 and 8) averaged 3.5 ant species, while the Street Edge and Medians sites (1,2,3,6,7 and 9) averaged 2.3 species.

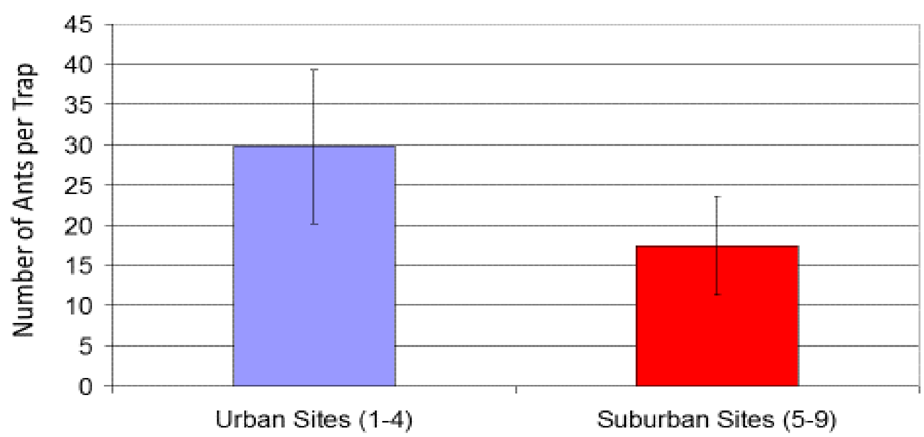

Figure 9. Summer average number of individual ants per trap with standard error bars. The traps at the urban sites (1-4) averaged 30 individual ants, while the suburban sites averaged 17.5 individuals.

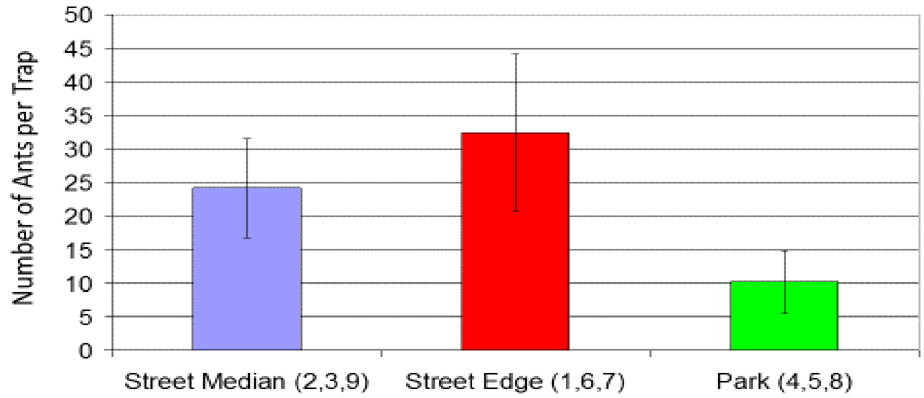

Figure 10. Average number of individual ants per trap with standard error bars. The Street Median traps averaged 24 individual ants, while the Street Edge and Park traps averaged 32.5 and 11 individuals, respectively.

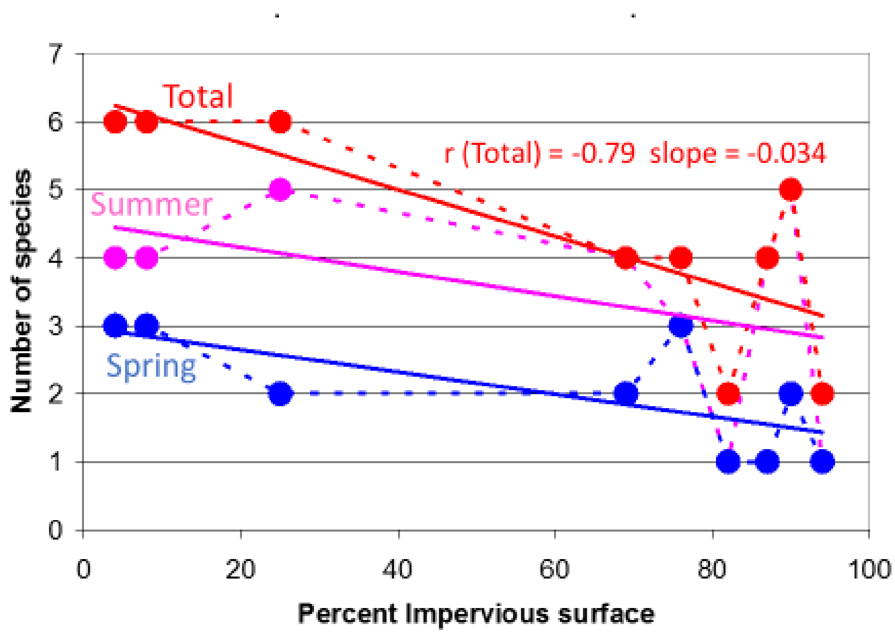

Figure 11. Number of ant species verses percent impervious surface cover. For all three datasets (summer, spring and Total) the linear regression line shows a decrease in ant species with increasing impervious surface cover. For the Total, species number decreased by 0.34 species for each 10% increase in impervious surface area (based on the linear regression line). For the total, the correlation coefficient, r, was -0.79 showing a significant anticorrelation between number of species and percent impervious surface cover. The r^2 is 0.63 (significant). This r-squared value can be interpreted as the proportion of the variance in species number attributable to the variance in percent impervious surface.

DISCUSSION

Overall, we found twelve different species of ants across the three types of habitats. The park habitat type was the most diverse with nine species, the street edge habitat has seven different species, and the street median was the least diverse with only five species. *Solenopsis* Sp1 (thief) was the most abundant followed closely by *Monomorium* sp. and *Solenopsis* sp2 (fire). All three species are considered highly invasive and are known to displace native species. Additionally, it should be noted that the species of ants that are considered invasive were the only species found in the street median habitats.

Our initial hypothesis was that the number of ant species would decline with increasing impervious surface cover as a characteristic of urbanization. The linear regression does show a significant decline in both the spring and summer collections (Fig. 11). Interestingly, the Total dataset had the most significant decline. The correlation coefficient was r= -0.79 which indicates a strong relationship between urbanization and diversity. The line of linear least-squares regression for the Total has a slope of -0.034 indicating a decrease of 0.34 species for each 10% increase in impervious surface cover. Therefore, our results support the hypothesis with respect to percent impervious surface.

One of our quantifications of urbanization, the Hoyt model (Figure 4), divides the sites into Urban and Suburban based on the 1.6 km radius center. For the summer sampling, the Urban ant diversity was lower with an average of 2.2 compared to the Suburban sites with an average of 4.6. The T-test value was 0.046. However, for the spring sampling the averages were 2.0 and 2.0, indicating no difference in diversity (T-test value 1.0). This could be due to the much lower numbers of total ants collected in the spring (185) compared to the summer (1,948). The summer results support our hypothesis with respect to the Hoyt model of urbanization, while the spring results are inconclusive. Our other quantification divided the sites into Urban and Suburban based on the impervious surface data. For the Total sampling (summer and spring), the number of species at the three Park (Suburban) sites averaged 3.5 compared to 2.3 at the six street medians and edges sites combined (Urban). This observed decline in ant species between the Urban and Suburban environments also supports our hypothesis.

In a temporal study of urbanization, Buczkowski and Richmond (2012) determined that the number of ant species declined during the urbanization construction period. Compared to the undisturbed forest plots, building construction reduced the number of ant species by ~83%, recovery was slow with only 35% of the original number of ant species one year after the completing of the building process. They noted a permanent loss of most of the ant species observed prior to construction. It is thought that urbanization promotes generalist or opportunistic ant species that can thrive on a variety of food and water sources (Philpott et al., 2016). Most ants are generalists, but some are strictly predatory, others are scavengers, others eat flower nectar, honeydew secreted by aphids, or seeds. Urbanization is going to favor ants that can adapt to conditions such as: warmer temperatures, fragmented habitats, increased human-associated food waste, drier climate and lots of pavement.

One possible explanation for the prevalence of invasive species may have to do with their physiology. Fire ants, *Solenopsis molesta,* are an aggressive species that originate from the tropics of South America (Creighton, 1950). Due to the urban heat island effect, the warmer climate of urbanized areas may replicate tropical climates, making them more suitable for fire ants and allowing them to drive out native species. Additionally, a study done by Slowik et al. (1996) found that ants are attracted to the bare, electrically active, conductive material of a circuit. When they contact the circuit, their death causes a release of pheromones and chemicals which are the true aggregation cues. As urbanization increases, so too does the amount of bare conductive materials and thus, an increase in an invasive species of fire ant. This poses a problem not only to the native species of ants and other arthropods but also to humans as they are known to bite people in numbers, which can be dangerous if they are allergic.

Pavement ants, *Tetramorium caespitum*, are able to construct their nests under pavement. This gives them a selective advantage in urban environment where pavement is rapidly replacing soil. With an established pavement ant colony using what little soil there is underneath the pavement, native species may have nowhere left to burrow. Of concern, however, are the few individuals of *Nylanderia* (Crazy) ant collected. Crazy ants are not generally attracted to typical pest baits, arrived very recently in Tennessee (no earlier than 2010), have an extremely high reproductive rate, and can rapidly displace other ant species, including the *Solenopsis* sp1 (Fire) ant.

Additionally, recent downtown changes include the demolition of warehouses, old retail and light industry space for the construction of multi-family housing and shopping areas. A tree planting effort targeted at the downtown, “Take Root”, began in 2008 when the downtown canopy cover was estimated at 7 percent. As of 2012 the estimated downtown canopy cover was 15%. In total “Take Root” has planted about 1,500 trees, including reintroducing American Elms which were wiped out by the fungal Dutch elm disease in the 1900’s (February 9th, 2012 by Steve Hardy, Times Free Press). In addition to providing leaf cover, food and a habit for ant species, trees can provide shading and micro-climates for some ant species. An increase in trees should favor the *Crematogaster* (Acrobat) ant which, among our 12 collected species, is the sole species that often nests and feeds in trees.

Short-term ecology studies of this type have many shortcomings and challenges. Future studies involving this type of experiment should address the following. First, sample across wider range of urban habitats, such as inside road cloverleaf). Second, future studies should collect samples multiple times over an extended period of time. For this study, only 3 days of the year were chosen to collect ants. To get a better sense of what species of ants are in an urban environment, it would help to sample more throughout the year. Additionally, environmental measures, for example soil temperature and moisture, should also be taken into account. For a more in-depth analysis, it may also be useful to monitor trends of invasive species among other rapidly urbanizing cities. One important factor to consider is if roads or structures obstruct the movements of the ants towards the traps. In this experiment, it may have also been possible that the Tennessee River played a role in the distribution of ant species across Chattanooga’s urban gradient. The river may serve as a natural barrier to the spread of certain of ant species.

Chattanooga is just one of many cities in the southeastern United States undergoing rapid growth. In addition, the transition from city to forest is very prominent in the Chattanooga area. The data collected from this study will help enhance our understanding of the effects of urbanization by presenting a glimpse at how the biodiversity of a species, in this case ants, can change as the levels of urbanization change. Using that information, comparisons can be made to other urban environments to further study the effects of urbanization. Studying the changes in biodiversity will become important for monitoring the ecological functions of locations similar to Chattanooga that are experiencing rapid urbanization.

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