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Oil preference in ants and arthropod diversity in urban environments

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Oil Preference in Ants and Arthropod Diversity in Urban Environments

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ABSTRACT

The success of certain ant species in urban areas is largely unknown. Available food in the environment could affect the composition of ants in urban areas due to a possible relationship between ant physiology and diet. I tested the oil preference of ants as a function of available arthropod prey in urban environments. I hypothesized that as arthropod diversity decreased, ant abundance at oil baits would decrease. Oil is an important nutrient that can affect ant body functions and activities. Ant foraging activities have been found to be affected by lipid depletion. A food source where ants can obtain oil in an urban environment is arthropod prey. However, their diversity in urban areas can be low due to high impervious surfaces and low plant diversity. Decrease in available arthropods could lead to an oil scarcity for ants, who need to fulfill their lipid requirements. To balance their nutrients ants will forage for a scarce nutrient the colony needs. In my research baits of sugar, water, and different concentrations of oil were chosen at random and deployed throughout Chattanooga, TN. The oil baits consisted of either 0.1%, 0.5%, or 1%. The habitats the baits were deployed in were neighborhoods, parks, and street medians during the months of August and September. Pitfall traps were also setup to measure available arthropod prey. A linear regression was used to view ant abundance against arthropod diversity, temperature, and soil moisture. Results showed that in most oil bait concentrations, there was a downwards trend in ant abundance as arthropod diversity increased. This demonstrates a weak relationship between oil preference of ants in regard to arthropod diversity. While my hypothesis was not supported, further research can still be done on lipids role in ant adaptability.

INTRODUCTION

The human population is growing in large numbers; however, it is accumulating in dense areas. These are known as urban areas and they are expanding along with our population. Urbanization is increasing worldwide with predictions of 66% of the world's population will live in urban areas by 2050 (United Nations, 2014).

Typically, urban areas are very developed, having a high density of human structures. These structures are known to absorb massive amounts of heat, which is released into the environment causing the heat-island effect. Another contributor to this effect is a structure's low absorption of water. These factors can lead to urban environments having a distinct microclimate due to intensified heat (Aminipouri et al., 2019). Another known contributor is the small number and size of green areas, which would normally help negate heat in their surroundings (Oliveira et al., 2011).

Ants are ideal study the effects of urbanization due to their quick ability respond to environmental change, represent different trophic levels, are ecosystem engineers, can disrupt ecological communities, are successful invaders, and have large economic impacts (Menke, 2010; Buczkowski, 2010). The huge role ants play in an environment and their ability to affect their surroundings makes it imperative to understand how they function in urban environments. While ants can quickly adapt and spread in urban environments, we have yet to find what makes certain species more successful than others. Some studies have found that the decrease in ant species diversity in urban environments and the understanding of invasive ant species is largely unknown due to the poor knowledge about their diets (Menke, 2010; Holway, 2002). If diet can affect ants' ability to adapt to urban environments, then their diet composition should be looked at. In the Integrative Ecology lab in Chattanooga, research by Guzman-Hernandez (2018) found that a high abundance of ants demonstrated a preference for oil in high traffic areas. This suggest that oil may be a limiting food resource in urbanized areas.

Oil is vital nutrient for most organisms as hormones are lipid soluble, make up cell membranes, and is a source of energy (Bayes et al., 2014). In insects, fatty acids can be used in waxes, pheromones, defensive secretions, development, and activities (Stanley-Samuelson et al., 1988). Lipids are essential in insects as they help prevent desiccation by making cuticular wax and can affect their chemical communication (Stanley-Samuelson et al., 1988). Since ants mainly communicate through chemicals, it should be important for them to have enough oil resources in their environment. Oils have been found to be used in defensive secretions in *Atta* and *Camponotus* ants (Stanley-Samuelson et al., 1988). Ants tend to monopolize limited resources that the colony needs (Kay, 2004). When an important nutrient like oil is missing from their environment, ant's foraging behavior seems to be affected. Research done by Silberman (2016) found that foraging behavior is associated with lipid depletion for some ant species. When foraging, ants are found to prefer seeds with high lipid content than those with lower lipid content (Pizo & Oliveira, 2000). This active search for high lipid sources demonstrates its importance to ants, as it affects their body functions and activities. Food sources capable of supplying their oil requirement should be looked at like arthropod prey.

However, the arthropod prey that ants may depend on to satisfy their oil requirement are affected by urbanization. Fragmented landscapes surrounded by a high density of built infrastructure are negatively associated with the abundance of most beetle taxa, Lepidoptera, and Hymenoptera (Delgado De La Flor et al., 2017; Lagucki et al., 2017). Over usage of popular plants reduce plant diversity and also affect arthropod prey. Research has found that the relationship between plant diversity and arthropod diversity is positively correlated (Bennett & Gratton, 2016). Furthermore, urban development tends to affect unique environments in the same way. This leads to biotic homogenization, where endemic species are replaced by widespread exotic species resulting in decreased diversity (McKinney & Lockwood, 1999). The changes urbanization has on arthropod availability could affect ants' attempt to fulfill their lipid requirement.

Since ant's foraging decision is based on the colony's nutritional needs, they will search for nutrients that are difficult to acquire (Kay, 2004). Meaning that when a vital nutrient like oil is limited, they should specifically forage for it. Yet, it is not known what role oil plays in ants' adaptability, especially in urban environments. The goal of this research was to test ant oil preference as a function of available arthropod prey diversity. When arthropod abundance is low, caused by the effects of urbanization, I expected it to affect the ants' oil preference. My hypothesis is that when arthropod abundance is high, there should be a lower abundance of ants in the oil baits as there is enough oil resource in their environment. This would imply that as arthropod prey abundance declines, ants' preference towards oil would increase due to its scarcity. Depending on the shortage of oil in the environment, I expect higher ant numbers in oil baits with higher oil concentration as they would satisfy their oil needs better.

METHODS

While research on urban environments is relatively new, it is important to continue its research on various cities. The city of Chattanooga has currently an area of 144.6 square miles and a population estimate of 179,139 in 2017, according to the U.S. Census Bureau. It is considered the 2nd fastest growing city in Tennessee. Chattanooga is expected to surpass Knoxville as the largest city in Tennessee. Because Chattanooga is known for its natural surroundings, it is important to study the effects additional urban development will have on the city.

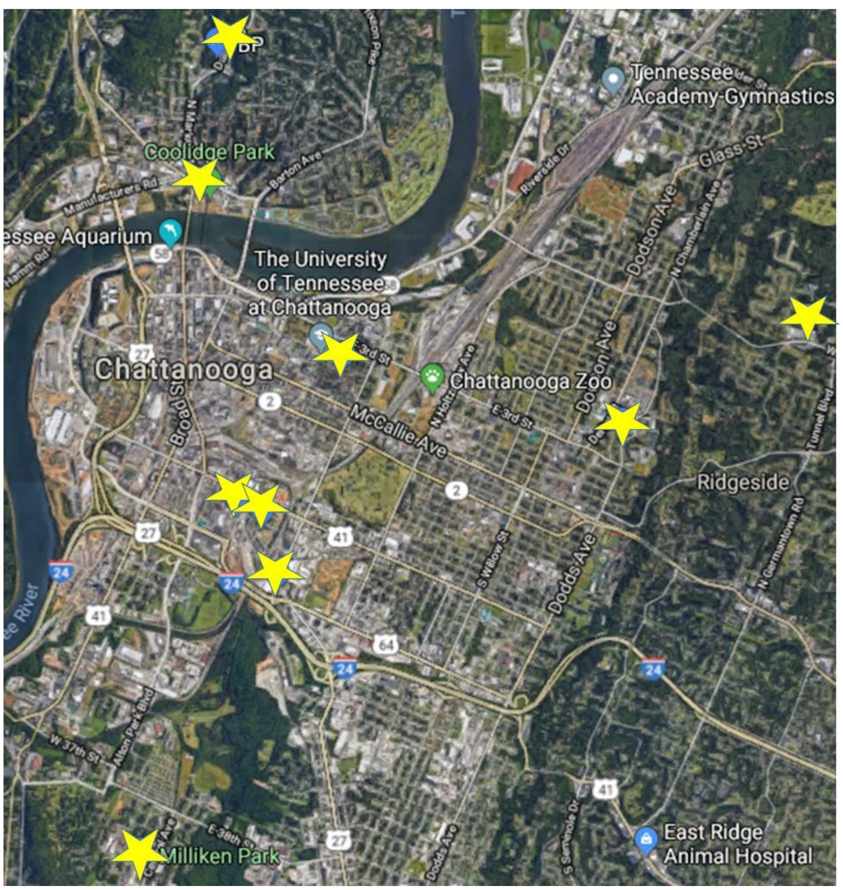
Nine sites located throughout downtown Chattanooga were sampled, which were previously used by the Integrative Ecology lab to study ant diversity and diet preference. The sites consisted of neighborhoods, parks, and street medians. These habitats vary in the amount of impervious surface as documented by Brooks (2018). Considering how ant activity can fluctuate through seasons, sampling occurred during late summer and fall. In order to see any potential variability during each month, the last week of the month of August and September was chosen.

To test for the ants' oil preference, different types of baits were used. The baits consisted of 1.5 mL Eppendorf tubes filled halfway with either saturated cotton or oil gelatin. The cotton baits were of either a 20% sucrose solution or deionized water. The sugar baits were used to demonstrate levels of ant activity, while water baits acted as the control. Gelatin was used to make the different oil concentrations as a suitable solvent. Gelatin baits were made of different concentrations of either 0.1%, 0.5%, or 1% olive oil. The different concentrations would help demonstrate how oil deprived the ants are at each site. The higher the oil concentration they seek out, the more deprived of oil they are. The process of making these baits involved following the unflavored gelatin packet instructions. To achieve the different concentrations, the required water was removed and replaced with olive oil. Once the solution of deionized water and olive oil was heated, one packet of bloomed gelatin was added to the mixture. To make sure the hot mixture was homogenized when settled, the mixture was stirred occasionally until cool.

Fifteen baits were deployed in one hundred and fifty meter transects, being left for an hour at each site. About 95% of the baits deployed were successfully retrieved. Six baits were discarded as their label was either illegible or the tube was damaged. In open areas like parks, a random direction was taken by using a random number generator and a compass. The numbers represented which cardinal directional to take. A random bait was selected and placed every ten meters where the soil moisture and temperature in Celsius were recorded. To prevent any bias from the bait deployer, the baits were coded with a series of numbers. In the attempt to control temperature, sampling occurred during early afternoons to early evenings. Due to the number of sites and time restriction, the sites were dived up and done in two consecutive days.

Pitfall traps were set up to measure the available arthropod prey at each habitat. The pitfall traps consisted of urine cups buried until the rim of the cup was at ground level and filled with pet friendly antifreeze. A total of three traps were set and scattered across a site with different spots used on each month. These spots were preferably near a tree for reference purposes. Due to high rainfall occurrences, pitfall traps were left anywhere from 2-4 days. There were some lost data as some pitfalls were unsuccessfully retrieved, but most sites had at least two pitfalls traps of data. Collected pitfall traps were taken into the lab and placed in a refrigerator until they were processed and identified. Arthropods were identified to the family taxonomic level using field guides, dichotomous keys, and Bugguide.com.

To test the hypothesis, a linear regression was used to look at ant abundance versus arthropod diversity on Microsoft Excel. Normality test were used to test the distribution of ant abundance to arthropod diversity. Graphs were made using scatterplot and used to see the trends of ant quantities based on bait type, arthropod diversity, temperature, and soil moisture.



Picture 1. Map of downtown Chattanooga with stars representing a sampling site.

Picture 2. An example of the coded baits that were deployed. The 1.5 mL Eppendorf tube would be half way filled with a bait of either a gel with a concentration of oil, water, or a 20% sucrose solution.

Picture 3. On the right, an example of the pitfall traps used at each site. On the left, a container with arthropods that have identified from a pitfall trap.

RESULTS

I had predicted that ants' preference towards oil would be high when faced with a low arthropod abundance due to oil scarcity. I found that in the 0.1% and 1% oil bait concentrations there was a downward trend of ant counts as the average number of arthropod families increased. However, the relationship in both baits does not appear to be strong due to the p-value being more than 0.05 and the R^2 being closer to 0 in both baits. In the oil bait 0.5%, ant count shows an unexpected upward trend as arthropod diversity increased (Figure 2.). The relationship found at 0.5% was also not significant as its p-value was 0.34 and R^2 was 0.017. The difference in oil concentration trends could mean that there are other factors involved in their diet preference. Unlike my prediction, there was not a higher number of ants found at the 1% oil concentration bait compared to the other baits. The highest number of ants was 298 at the 0.1% oil bait, 131 at the 0.5% oil bait, and 175 at the 1% oil bait. Most of the ant count data is accumulated between 7-12 average number of arthropod families, meaning that is has the highest ant activity level.

When viewing if temperature influenced ant abundance in oil baits, I found an upward trend with a p-value of 0.017 and an R^2 of 0.019 (Fig. 4). This means that temperature most likely had a significant effect on the ants' ability to forage for oil during the month of August and September. Most of the activity is between 10°C and 30°C since a high number of ant count data has congregated there. The highest number of ant counts was of 298 occurring at 28°C. The lowest temperature recorded was of 4.2°C and the highest was of 53.1°C. However, the lowest temperature for ant activity was at 5°C and the highest at 43.2°C.

There was a horizontal trend with a p-value of 0.90 and R^2 of 5.12E-5, when looking at the possible effect soil moisture had on ant abundance in oil baits (Fig. 5). Meaning, that soil moisture most likely did not have a significant effect on the ants' ability to forage for oil during the of August and September. While we had ants present throughout our 0-10 range, most of the ant activity was at a soil moisture of 8. The highest number of ants was of 298, found at a soil moisture of 10.

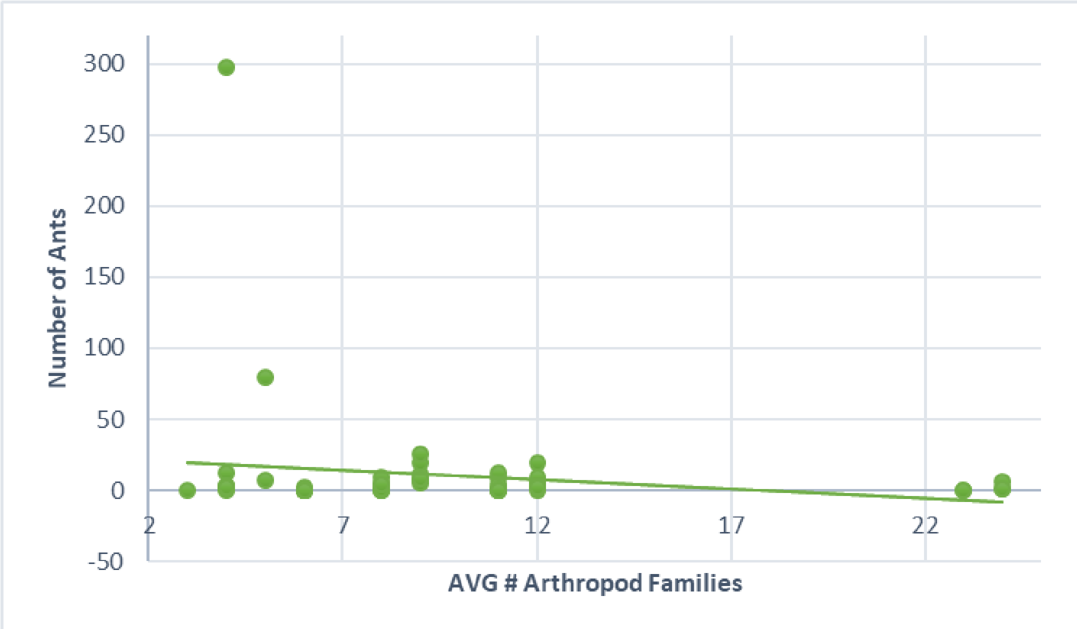


Figure 1. Linear regression with the number of ants in the 0.1% oil baits versus the average number of arthropod families found in the months of August and September. Demonstrating a downward trend with a p-value= 0.23 and R^2= 0.027.

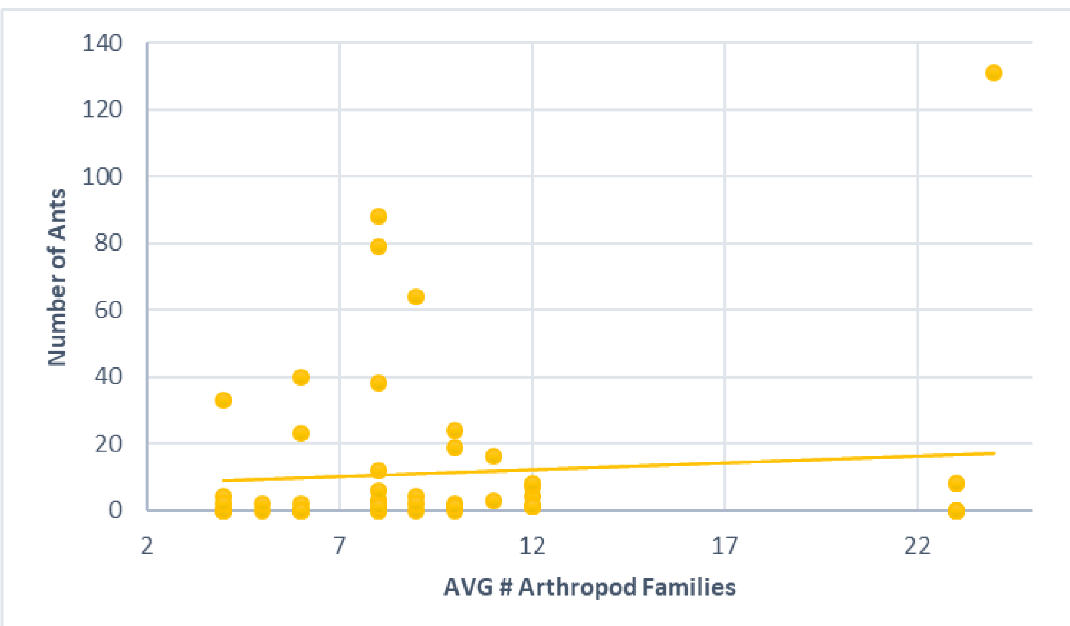


Figure 2. Linear regression with the number of ants in the 0.5% oil baits versus the average number of arthropod families found in the months of August and September. Demonstrating an upward trend with a p-value= 0.34 and R^2= 0.017.

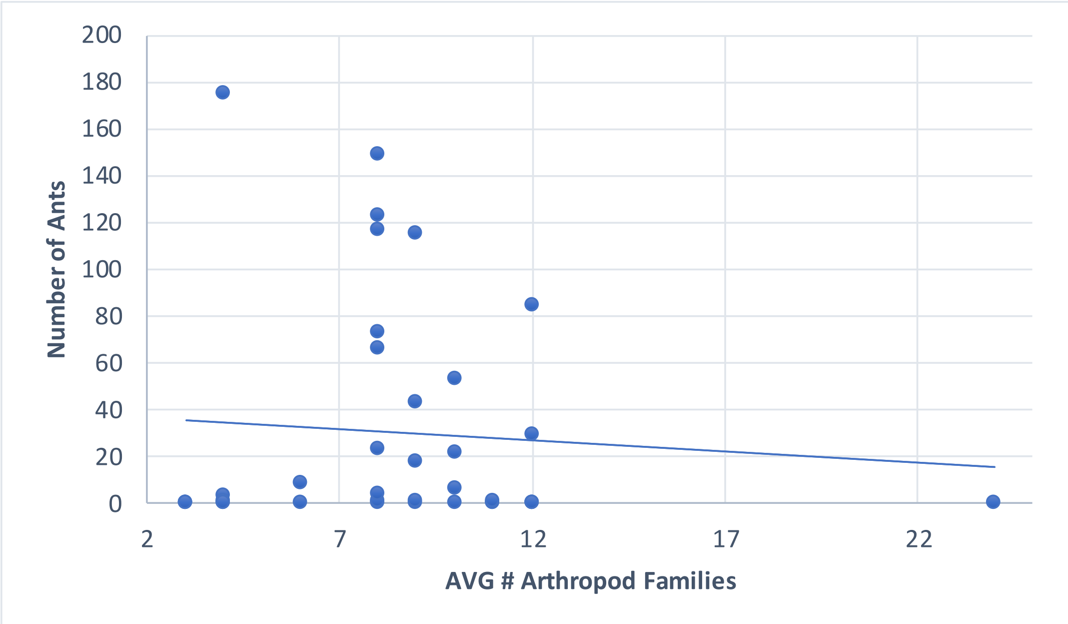


Figure 3. Linear regression with the number of ants in the 1% oil baits versus the average number of arthropod families found in the month of August and September. Demonstrating a downward trend with a p-value= 0.66 and R^2=0.0057.

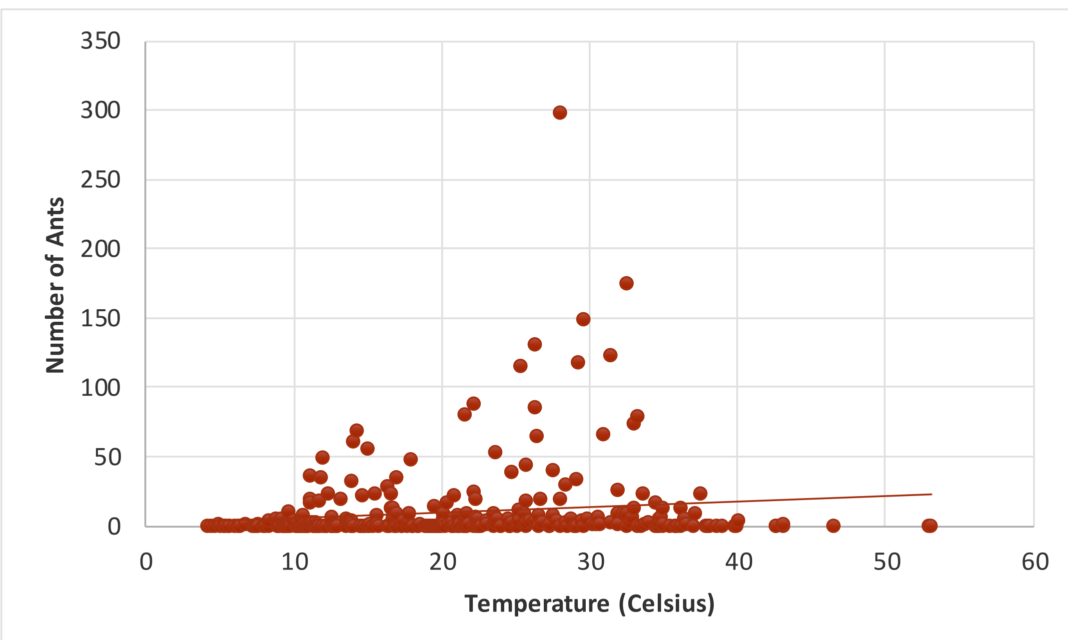


Figure 4. Linear regression of the number of ants found in all the oil concentration baits versus temperature in Celsius for the months of August and September. Demonstrating an upward trend with a p-value= 0.017 and R^2= 0.019.

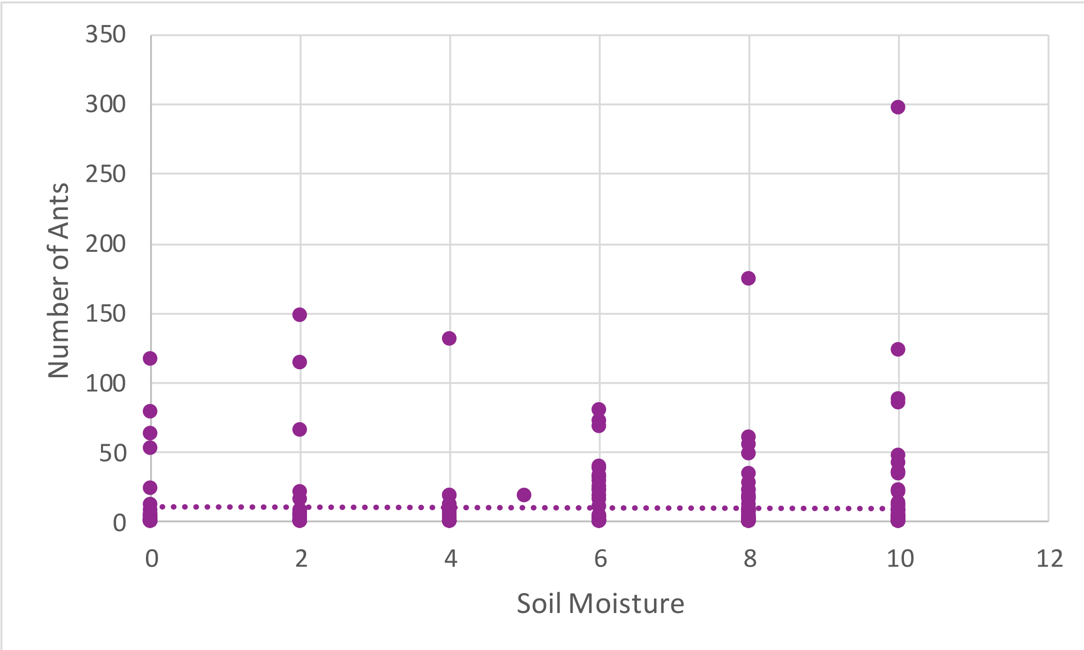


Figure 5. Linear regression of the number of ants found in all the oil concentration baits versus soil moisture for the months of August and September. Demonstrating a horizontal trend with a p-value= 0.90 and R^2= 5.12E-5.

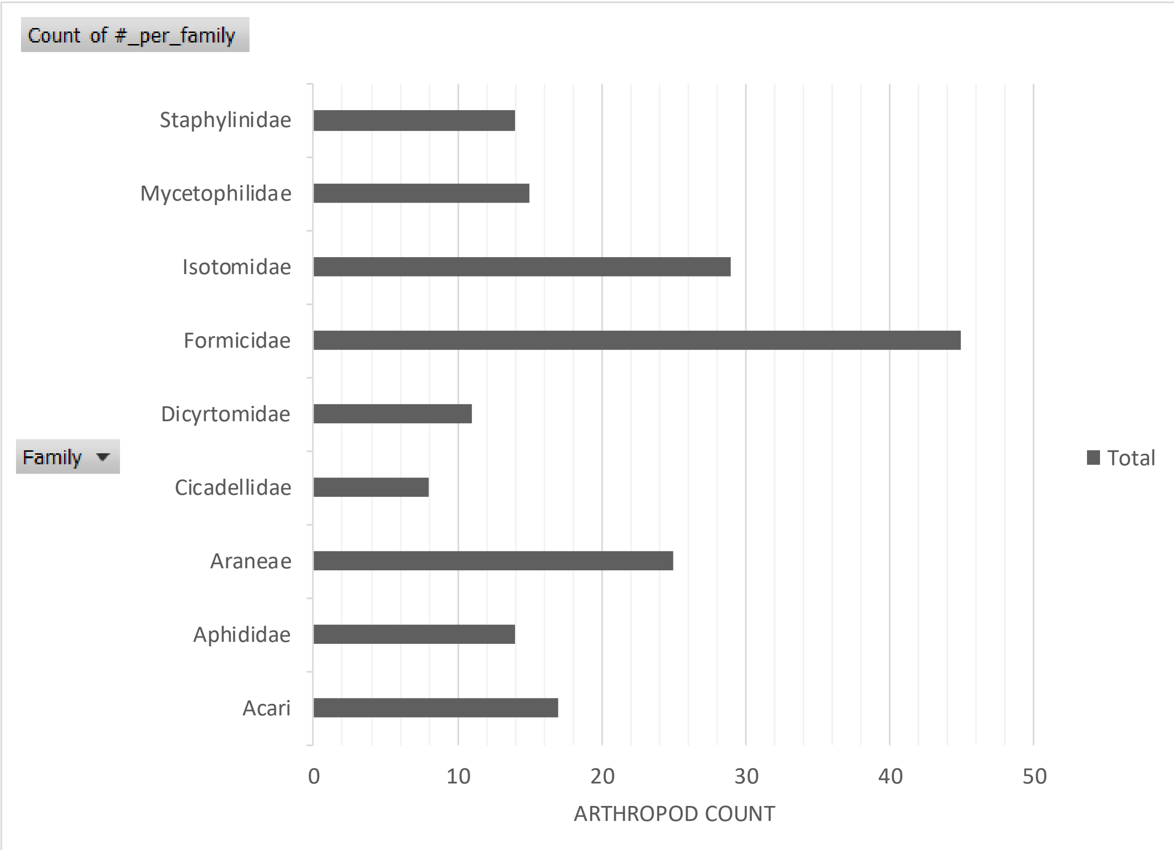


Figure 6. Nine of the most abundant arthropod families obtained from the August & September pitfall traps measured by the number of individuals in each family.

DISCUSSION

Overall, our results show a weak relationship between ant oil preference & arthropod diversity in urban environments. However, there was weak evidence of a downward trend for most of the oil baits as arthropod diversity increased. This could mean that the ants had enough oil resources making their search for oil decline. We also found an upward trend in the 0.5% oil concentration bait as arthropod diversity increased, but it was not significant. The differences between the different ant counts in oil bait concentrations could mean that there are other factors affecting their oil preference and not just the available arthropods.

Potential factors affecting the relationship between oil preference and available arthropods are other food sources. Lipids can be obtained in omnivorous ants through a diet of arthropods, seeds, and plant exudates (Rosumek et al., 2017). Ants have been found to consume human foods which could be an oil source for ants (Penick et al., 2015). Arthropods may also not provide all the necessary nutrients ants need which may make them turn to other food resources. Judd suggest that in seed consuming ants, foraging can occur when necessary nutrients are not being sufficiently provided by seeds (2006). However, it is important to note that for ants to have lipids it is not necessary to consume just oils, as neutral lipid fatty acids (NLFAs) can be synthesized from sugars (Rosumek et al., 2017).

Other factors that can affect arthropods like ants is temperature as previously seen. Due to their temperature sensitivity, their activity levels can be affected. In a study by Lee and Chong found that the foraging rate of *T. indicum* to decreased as temperature exceeded 30°C and had higher rates between 15°C-30°C (2006). I did find the majority of ants in our study were found between temperatures of 10°C - 20°C. In addition, temperature can affect the fluidity of fatty acids which needs to be maintained for proper body functions (Rosumek et al., 2018).

While there was not concrete evidence found to support my hypothesis based on our data set, more research can be made on the oil preference of ants. Further research could look if lipids are used differently in the physiology of urban ants. This would help demonstrate what functions of fatty acids are used to help adapt to urban environments. Additional research could look at the role of vegetation in regard to ants' oil preference. This would allow us to see if increased vegetation could decline the number of ants foraging for oil. Another interesting research would be to look if there are any differences in oil preference between ants in urban habitats and natural habitats.

There are still gaps in our knowledge when it comes ants and their oil consumption. When ants, just like any other animal, must be able to balance their nutrient intake to stay healthy. Knowing more about the diet of insects could help understand issues that can develop in the future.

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