EFFECTS OF URBANIZATION ON ARTHROPOD COMMUNITIES IN CAROLINA WREN (*THRYOTHORUS LUDOVICIANUS*) NESTS: A COMPARATIVE STUDY BETWEEN URBAN & RURAL HABITATS IN WALKER COUNTY, TEXAS

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by

Faith N Byrd

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EFFECTS OF URBANIZATION ON ARTHROPOD COMMUNITIES IN CAROLINA WREN (THRYOTHORUS LUDOVICIANUS) NESTS: A COMPARATIVE STUDY BETWEEN URBAN & RURAL HABITATS IN WALKER COUNTY, TEXAS

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DEDICATION

To my grandfather, who taught me the value of learning.

ABSTRACT

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As urban sprawl increases, the need for better understanding of anthropogenic effects on songbirds also increases. Humans continue to alter natural environments by introducing non-native plant species and disturbing ecosystems with houses and maintained yards. These alterations have been shown in past studies to not only alter animal behaviors, but to affect what animals are present in a given space. This is particularly concerning given recent studies showing a dramatic decline in arthropod populations globally. I evaluated the relationship between plant communities, human dwellings and arthropod communities found in the nests of a cavity-nesting songbird species, the Carolina Wren (*Thryothorus ludovicianus*) to establish if species richness of arthropods in microhabitats has been affected by human influence. Avian nests are important habitats for arthropod species that live and reproduce in nesting material. Some of these arthropod species impact vertebrate fitness, and many play an important role in nutrient recycling by breaking down decaying materials. The results of this study suggest that urbanization shifts community structure of nest-dwelling arthropods. Species richness was greater in rural habitats and when nests were located near native plants, though species populations between habitats were not significantly different. Future studies should consider more factors of urbanization, as well as the impact of urban densification on other microhabitats.

KEY WORDS: Carolina Wren, Nest, Arthropod, Community structure, Urban, Rural, Species richness

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PREFACE

"If you talk to the animals they will talk with you and you will know each other. If you do not talk to them you will not know them and what you do not know, you will fear. And what one fears, one tends to destroy."

-Chief Dan George

“Everyone likes birds. What wild creature is more accessible to our eyes and ears, as close to us and everyone in the world, as universal as a bird?”

-Sir David Attenborough

“If you think you are too small to make a difference, try going to bed with a mosquito in the room.”

-Unknown

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CHAPTER I

Introduction

Songbird populations are declining in North America due to habitat loss, climate change and pesticide use (Lancaster and Rees, 1979; Wilcove, 1985; Bock *et al.*, 2008; Jackson *et al.*, 2015). This has been a concerning topic for decades. Perhaps most famously, Rachel Carson discussed how the use of pesticides could eventually lead to the extinction of most if not all songbirds. While her work was published in 1962, frustratingly, little has been done to prevent habitat loss for songbird species. As human population growth continues to drive urbanization, it is important to monitor how this destruction of habitat is impacting not only birds, but the species that rely on birds as well (Clergeau *et al.*, 1998). Communities of arthropods found in bird nests have only been sporadically studied, and changes to their communities could have unpredictable consequences in the food webs where they are found (Johnson, 2000; Schmidt *et al.*, 2005).

The Carolina Wren (*Thryothorus ludovicianus*) is an ideal species for comparing ecological differences between urban and rural areas since it has successfully gained foothold in both habitat types. Carolina Wrens are small generalist songbirds that are found ubiquitously in the Eastern United States and parts of eastern Central America. They are permanent residents and prefer wooded areas for foraging and nesting. Carolina Wrens exhibit philopatry, and maintain a territory with their mate, which they pair with year-round (Haggerty and Morton, 2014). Both male and female wrens assist with nest building and chick care, and prefer to build in cavities, though they have also been known to utilize garden pots, or objects such as shoes left outside for long periods of time. They

generally prefer to build nests no more than two meters off the ground. Carolina Wrens raise between one and three clutches each breeding season, each consisting of four to five eggs. They use a wide variety of materials to create a domed, cup-shaped nest, and though nests are mostly composed of grass, leaves and twigs, wrens have been known to use snake skin, plastic bags, and human and animal hair to supplement their nesting materials (Nice and Thomas, 1948; McNeese, 2018). Carolina Wrens readily use nest boxes within urban and rural sites, simplifying nest collection for study. Since Carolina Wrens are commonly found in residential areas, and frequent bird feeders, the arthropods present in their nests could provide insight on zoonotic disease spread, food web alterations, and biomass decline in microhabitats (Reed *et al.*, 2003; Bradley *et al.*, 2008).

Past studies of other bird species have shown that examining the sheds and carcasses of arthropods in nest material can provide an accurate count of parasite load and can estimate arthropod populations (Dobroscky, 1925; Heeb *et al.*, 1996; King *et al.*, 2010; Tsakiris *et al.*, 2013). While there is a wide variety of ectoparasites that attach for a brief period, take a blood meal and then drop off their host, many specialized bird ectoparasites integrate themselves into the feathers or skin of their host (Haribal *et al.*, 2011). It was expected that bodies or exuviae of these ectoparasites may be left in the nest and could be catalogued (Dobroscky, 1925; Philips, 1990). Ectoparasites are certainly worth noting due to their impact on songbird fitness, however this study catalogued all arthropod species found in the nest, most of which exist as part of the microhabitat that a birds' nest provides. Due to the lack of similar studies I sought to find and identify all arthropods within the wren nests collected. I also wished to establish if non-parasitic arthropods are impacted by urbanization as parasitic species have shown to

be impacted in previous studies. Previous studies of various bird and small mammal species have shown that urbanization can have either positive or negative effects on the vertebrates building nests. In some cases, urbanization can actually decrease nest parasites, as has been shown in studies where members of the tit family used nicotine-laced cigarette butts within their nests (Monserrat Suárez-Rodríguez *et al.*, 2013). In other studies, however, changes in an animal's habitat can negatively impact its fitness, either by increasing parasite load, or decreasing food availability (Reynolds *et al.*, 2016). This exploratory study sought to determine what arthropods can currently be found in an urban or rural wren nest so that future studies can observe changes in these communities as urban sprawl increases.

Since bird nests provide adequate microhabitats for ectoparasites and other nest-dwelling arthropods, I expected to find a high to variable diversity among and between sites. I also considered what factors of urbanization may account for arthropod community differences. This study considered two aspects of urbanization: one, the presence of human residences, and two, the plant composition near nest boxes including percentage of native and non-native plants. Mimicking previous urban-rural studies, I considered the presence of human residences to be indicative of an urban area. This study only considered urban and rural sites and did not create a gradient including suburban as in Reynolds et al., 2016. Because human beings are largely the force responsible for the introduction of non-native species, I considered both the presence of human residences and mostly non-native plants together to be considered urban, while an area with few to no human residences nearby and mostly native plants was considered to be rural, allowing me to assess differences in two habitat types. While considering other options

for this study's definition of "urban" and "rural," I reasoned that the presence of human houses would also lead to the presence of more non-native plants due to maintained lawns and front gardens. This led me to consider what plant types were found near nest boxes, and what percentage of these plants were native. Previous studies have indicated that songbird species have been impacted by the presence of non-native plant species. Arthropod species populations have been found to decrease where non-native plants have replaced native plants. This change negatively impacts insectivorous songbirds that rely on specific arthropod species as a food source (McIntyre, 2000; Narango *et al.*, 2017; Lister and Garcia, 2018).

Invasive plants have caused ecological damage on many levels, and with each new study, they are shown to be more damaging than previously thought. One study in particular found that invasive and non-native plants actually benefit from global climate change more than native plants, causing a positive feedback loop of non-native invasion that is swiftly altering not only urban landscapes, but many rural areas as well (Henderson, 2001; McCary *et al.*, 2016).

I compared plant community differences between the urban and rural habitats to account for any observed differences in arthropod species richness between the two habitats (Andow, 1991; Honek, 1997). In areas where active nest boxes were placed, I assessed plant size and native or non-native status. I then compared these variables to determine if they relate to the difference in arthropod species richness between the two habitats.

CHAPTER II

Materials and Methods

Study Sites

I compared rural and urban habitats located in Walker County, Texas. For this study, the rural habitat was defined as an area with less than one human residence per 50 square meters. I considered the urban habitat to be any area with greater than one human residence per 50 square meters. The yards of Huntsville, Texas citizens who live east of Interstate 45 represented the urban area. These yards are routinely maintained (e.g. mowed, watered, fertilized, etc). The rural area was the Sam Houston State University Center for Biological Field Studies (CBFS), located 11 kilometers northeast of Huntsville, Texas. This research area is a 100 hectare property that abuts the Sam Houston National Forest. There is one residence on the property; however, no pesticides are utilized by the tenant and none of the nests collected were within 150 meters of the residence. The majority of the 100-hectare area is dominated by pine and hardwood forest, with some areas of open prairie and riparian areas along two creeks that run through the property (Dent and Lutterschmidt, 2001). Research was conducted in 2015 and 2016 during the field (breeding) season of Carolina Wrens, February to August (Haggerty and Morton, 2014). At the beginning of the field season, I placed approximately 100 untreated pine wood nest boxes throughout each of the study sites.

In the urban site, I placed two or three nest boxes in each of the front yards of participating owners' residences. In both areas, I spread the nest boxes at least ten meters apart, and placed them near bushes or shrubs to increase the likelihood that wrens used

each box. My undergraduate assistants and I checked the boxes at least once a week for nesting activity.

Once a nest was in progress, we checked the boxes twice a week. When nestlings hatched, I captured adults with mist nests and banded them using metal USFWS bands and unique color bands to assist with future studies and identification purposes where possible; some pairs were banded from previous research. The same pairs were not necessarily used between years in the current study, as the primary focus was to collect successful wren nests regardless of individual success. In cases of failed or deserted nests, I cleaned and moved the nest box to a different location in the same yard, as was done in previous studies (Neudorf *et al.*, 2013).

Collection of Nests

I monitored nest boxes closely to observe which boxes were active. I monitored nestlings until they fledged or expired due to disease or predation. Upon fledging, I removed the entire nest from the box while wearing disposable nitrile gloves. All nesting material was placed in a sealable freezer bag, along with sand, feather dust, and other debris, ensuring collection of as many nest-dwelling arthropods as possible. I collected all of the nests included in this study within 48 hours of fledging. I removed any failed or abandoned nests. I kept only successful nests, that is, nests that successfully fledged at least one wren, for this dataset. The removal of used nests does not negatively impact birds that have used them. Carolina Wrens do not reuse old nests, so the removal of nests allowed for multiple clutches to be raised in the same area (Haggerty and Morton, 2014).

Storage of Nests

I labeled all collected nests with the date, location and habitat type, and placed them in a -30°C freezer for storage before removing arthropods instead of using a Berlese funnel *in situ*. This preservation and collection method was modified from Hicks' "Check-List and Bibliography on the Occurrence of Insects in Birds' Nests." Previous studies on arthropod populations in birds' nests used Berlese funnels *in situ* to collect insects for a set period, then discarded the rest of the nest (Dobroscky, 1925; Woodroffe, 1953; Hicks, 1959; Sabu *et al.*, 2011). While collection with Berlese funnels is an effective method, it requires remaining on site immediately after a nest is collected. By freezing the nests and looking at them closely in the lab later, all arthropods, both living and dead in the nest at the time of collection can be found and identified instead of only those arthropods that respond to light and heat. Additionally, it reduces the amount of time spent in the field since the arthropods are sorted out of the nests later in the lab, and is a useful method for collecting large numbers of nests at a time in a particular habitat. Failed nests were excluded from this study. In almost all cases, the failed nests were saturated with water. When the nests were frozen, arthropods were damaged, leaving me unable to reasonably identify arthropod species.

Examination of Nests

I thawed and dried frozen nests before searching them for arthropods. I gently pulled apart each nest in a large plastic pan to prevent specimen loss, while loosening the material enough to inspect for large arthropods with a head magnifier. After I searched the nesting material with the naked eye and a head magnifier, I placed the nest by aliquots into a 2-mm mesh metal sifter and shook it over a smaller pan. I searched the

metal sifter under dissection microscope to ensure that no arthropods were caught in the mesh. Sifting the nesting material separated very small material from the bulk of the nesting material so that it could be observed under a dissection microscope. I then separated this sifted material into smaller aliquots and searched it for arthropods under a dissection microscope for arthropods that are not usually seen with the naked eye. Each aliquot of sifted material was only enough to thinly cover the bottom of a glass dissection dish so that all arthropods present in it were readily visible and easy to collect using probes and soft forceps. After manually searching in the dissection dish, I then submerged the sifted material in 70% alcohol. The remaining arthropods and exuviae floated to the top of the fluid were I collected them via plastic pipette. To ensure that most, if not all, arthropods were collected, I collected 10 portions of the material that precipitated to the bottom of the ethanol at random via plastic pipette and searched for any missed arthropods under dissection microscope. Between each of the ten random portions, the ethanol/nest sifting mixture was thoroughly agitated. I stored all collected arthropods in 70% ethanol for preservation when not being identified.

Identification of Arthropods

I identified all arthropods using dichotomous keys and guide books (e.g. A Manual of Acarology by G.W. Krantz, The Chewing Lice by R.D. Price, et al.). However, some arthropod groups did not have a dichotomous key, so I used online resources such as iNaturalist and university arthropod identification sites, especially those owned by Texas A&M and Iowa State University, to identify morphospecies. I magnified arthropods for identification using an Olympus SZ stereo microscope, and an Amscope T390 compound microscope, where necessary. Arthropods were first sorted into

morphospecies. I then attempted to match morphospecies to correct species names, however, some could only be identified to family due to a lack of reliable or complete keys. Morphospecies that could not be confidently identified to a particular species name were still counted as a unique species when determining arthropod species richness for each nest. I made all identifications using morphological characteristics as molecular study of the species found was unnecessary for the scope of this study.

I compared arthropod species richness and diversity between habitats using Shannon's diversity index. Relative species abundance of arthropods was calculated from species richness and species abundance per nest.

Plant Sampling and Identification

I sampled plant communities during the field season of 2016 during the months of April and May, which is in the middle of the breeding season. I used a 1-inch PVC pipe to make a 1 - m2 square frame to randomly sample plant data at nest sites. To avoid bias, I took care not to favor more open or grassy areas around nest boxes. In most cases, I handed a field assistant the sampling frame and pointed them in a random direction before indicating that they should toss the frame to attempt to make selection as random as possible. The randomly-selected quadrat's closest outer edge was no farther than 6 meters from the nest box for each sampling, and some randomly chosen quadrats included the nest box. I morphologically identified each plant observed within a quadrat to species, using guides such as Sibley's Guide to North American Trees, as well as iNaturalist, United States Department of Agriculture, and Texas Parks and Wildlife plant databases. I categorized all plant species found within the sampled quadrats as tree, shrub, or grass, or other. I also categorized each plant species as native or non-native

based on state and federal data (Cooperative Extension Service, 1970; Arcese *et al.*, 2014; Mutze *et al.*, 2016; USDA, 2019).

Statistical Methods

Statistics were conducted with R v. 3.5. Descriptive statistics (Welch t-tests, Wilcoxon signed-rank test, ANOVA/MANOVA) were used to establish if there were significant differences in species richness and populations between habitats and between study years.

The Shapiro-Wilk test was used to establish if the dataset could be treated as normal (due to the limited amount of data). The Shapiro-Wilk test tests the null hypothesis that a sample came from a normally distributed population. I ran the data on arthropod species populations by habitat, and on arthropod species richness by habitat. Plant species richness and urban arthropod population were found to be non-normal (urban plant species richness, both native and non-native non-normally distributed, p-value = 0.05; rural plant species richness non-native non-normally distributed, p-value = 0.001; urban arthropod population non-normally distributed, p-value = 0.002). The results of the test show that samples in this dataset are not normal due to an inadequate sample size. Given a greater sample size, the dataset would be normal so I used descriptive statistics for normalized data sets and confirmed those with similar non-normal tests such using the Welch t-test and verifying with Wilcoxon signed-rank test.

The Pearson product-moment correlation was used to establish if the arthropod data was consistent for each habitat across the two study years so that the all data from each habitat could be treated as one dataset. For this test, relative arthropod species abundance was calculated for each nest in each habitat and then the two years were

compared. Using arthropod species abundance, I found the following: rural habitat strongly correlates from 2015 to 2016 (r = 0.7343, p-value = 4.66e-08); urban habitat correlates from 2015 to 2016 (r = 0.6588, p-value = 5.586e-05). Given this, I treated the data from both years from one habitat as a dataset, i.e. rural 2015 and rural 2016 data is "rural habitat data," and likewise for urban data. I also used the Pearson product-moment correlation to determine correlations between native or nonnative plants and arthropod species richness.

Because some of the data was non-normally distributed, the Wilcoxon signed-rank test was used to verify statistical results from parametric statistical tests since it is robust for non-normal datasets. Both a t-test and a Wilcoxon signed-rank test were used to test urban species richness by year, rural species richness by year, and by habitat (Sokal and Rohlf, 1994).

The Pearson's product-moment correlation was used to compare relative arthropod species abundance between years to determine if the data between years was similar enough to combine all each habitat's data from both years. Pearson's product-moment correlation was also used to determine if native plant species are correlated with greater arthropod species richness. This statistical formula measures the strength between variables and relationships between variables (Benesty *et al.*, 2009).

I also computed each habitat's arthropod species diversity using Shannon's diversity index, which is defined as:

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

Where:

R is species richness

i is a species

p_i is the relative abundance of species i

Shannon's diversity index describes the uncertainty in predicting the identity of an individual randomly selected from the habitat. For Shannon's diversity, a more diverse habitat has a diversity index distant from "0" (Carpio *et al.*, 2019).

CHAPTER III

Results and Discussion

I collected a total of eighteen successful nests from the rural habitat, eight in 2015 and ten in 2016. I collected seventeen successful nests from the urban habitat, seven in 2015, and ten in 2016. A total of forty-nine species of arthropods were found in the nests. Of these forty-nine species, twenty-three were present in both the urban and rural habitats (Tables 1, 2). The rural habitat contained eighteen species that were not found in the urban habitat, and eight species were found in the urban habitat that were not found in the rural habitat. The species found ranged from commensal beetles and moth larvae, to parasitic species such as bedbugs and ticks, as well as some introduced species of insects. I found that non-parasitic species were more common than parasitic.

Arthropod Species Found

Androlaelaps casalis was the most commonly found mite in nests from either habitat. This mite feeds on other mites and small arthropods, so it was expected to be found in nests in large numbers. *Oribatula tibialis* was found frequently in rural nests. This mite feeds on fungi and detritus found in leaf litter and habitats similar to bird nests. *Schleroribates* spp and *Nothrus borussicus* were also commonly found in both habitats and are found in the same group as *O. tibialis*. Both of these mite species also feed on fungus and decomposing plant and fungal matter and are expected in moist leaf litter that is used in wren nests. Other common species between habitats included a Bradysia fly species and a thrip (*Baenothrips moundi*). Several booklice and springtail species were commonly found in both habitats. Based on the habits and diets of the species most commonly found, it appears that these arthropods were present due to the food resources

in the birds' nests. The list of most common species in each habitat can be found in tables 1 and 2, and a list of arthropod populations by taxa is listed in table 3. All arthropod species found in all nests may be found in Table A1 in the appendix.

Mites (Order Acari) are commonly associated with songbirds and their nests, and made up the most populous group in both habitats. Several species of mites breed and live in bird's nests; mostly detritivorous and predatory mites were found in nests both in urban and rural environments. Very few parasitic mites were found in the nests in this study, possibly because predatory mites were also present in the nests. It is possible that most of the parasitic mites left with the fledglings, and those that did not were consumed by predatory arthropods prior to nest collection. It is also possible that Carolina Wrens do not successfully breed when carrying a high ectoparasite load, a hypothesis that would be interesting to address in future studies. The mite species most prevalent in this study were non-parasitic mites that consume detritus and/or other small arthropods and may also be found in songbird nests. A large number of mite species are found in forest detritus that Carolina Wrens commonly forage in, including leaves and twigs that may end up as nesting material, and as a result, many were found in the nests that were collected (Hoy, 2009). Non-parasitic mites were the most common arthropod type found in the collected nests in both the urban and rural habitats.

Though bird lice (suborders Ablycera and Ischnocera) are the most common type of songbird ectoparasite, no bird lice were found in any of the nests in this study (Gillott, 1995). It is possible that the method of nest collection missed lice that may have been present. More data is needed to establish the reason for their absence.

Though not as common as lice, fleas (Order Siphonaptera) are also associated with and parasitize songbirds. Adult fleas spend most of their time in a host's nest, and only move onto a bird host to feed, before returning to nesting material however (Bates and Rothschild, 1962; Acosta *et al.*, 2013). Fleas were not a common species in the nests collected. The lack of flea species could be due to sample size, lack of fleas dropping into the nests before collection, or a lack of preference for Carolina Wrens as hosts.

Other parasitic insect orders may be present on the birds, but were not found in any nesting material. A single mosquito was found in one nest, but may have been an incidental capture while collecting nest material. Blowflies were found in some nests; several species of blowfly use nestlings as their host during their larval stage and can be detrimental to chick development (Order Diptera) (Dobroscky, 1925; Gillott, 1995).

Ticks (Suborder Ixodida) are also occasionally found on North American songbirds, and generally attach to wingpits, brood patches, throats, and eyelids. Some ticks were found in the nests included in this study, and were likely present due to encountering an adult bird and dropping into the nest after a meal, or were brought on nesting material (Hoy, 2009).

Some spider species (Order Araneae) were incidentally collected with nesting material. Most spiders found in nests were small (less than 2 cm in total body length); Carolina Wrens regularly consume spiders (Gillott, 1995; Haggerty and Morton, 2014). Only small spiders are likely to utilize a wren's nest while evading the birds themselves, though some are successful at this. It is likely that the two wolf spiders taken from nests in this study were escaped or dropped food items and were not living in the nest.

Moths and caterpillars (Order Lepidoptera) were found in the study nests as well, including a snout moth. Some species of gnat (Order Diptera, Suborder Nematocera) were also found, likely due to the presence of potential food and nesting items, such as moss, fungus, and dead wood and leaves (Hicks, 1959).

Some beetle (Order Coeloptera) and wasp (Order Hymenoptera) species have been documented in birds' nests as predatory species that hunt other arthropods, particularly the larvae of moths, and the study nests were no exception (Woodroffe, 1953). Several small species of beetles and at least one wasp species was found in the nests.

Several species of springtails (Order Collembola) were also found in the nests and were common in both the rural and urban nests. Springtails are omnivorous organisms that prefer wet organic matter. They are an important part of decomposition since they fragment organic matter and assist with the balance of soil microbe communities (Thimm *et al.*, 1998; Brady and Weil, 2010). This group of microorganisms is nearly ubiquitous in soil and decomposing vegetation, so it was expected that many of them would be found in wren nests (Bird *et al.*, 2004).

As expected, several species of thrips were also found in the nests. These small arthropods spend their lives feeding on plant material and were likely utilizing the nests as a source of food. They are generally considered pest species because they feed on agricultural crops and landscaped plants. They can be considered a significant source of economic loss, as well as motivation for pesticide use in residential lawns as they often destroy azaleas, a popular non-native cultivar in Huntsville, Texas (Lewis, 1973; Murai, 1988).

It is likely that most non-parasitic and non-predatory species were present in bird's nests because the materials that comprise a nest often make excellent microhabitats for small insects and arachnids by providing food, shelter, and a possible place for breeding or laying eggs. This reliance on plant materials is why it is significant that plant communities are often composed of exotic species in urban areas. With recent studies showing the importance of host plants to some arthropod species such as moth and caterpillar larvae, it is likely that the same goes for other arthropods such as mites, lice and flies. It is reasonable to hypothesize that altering plant communities by adding non-natives and removing natives will result in arthropod community shifts as well, possibly even with increases in pest species such as thrips and springtails that damage ornamental plants (Murai, 1988; Lopezaraiza–Mikel *et al.*, 2007; Haddad *et al.*, 2009; Potapov *et al.*, 2018).

All nests collected contained oak leaves and pine needles. Previous studies suggest that nest composition can impact arthropod presence (Juan Moreno *et al.*, 2009; Pires *et al.*, 2012). I searched each nest for cigarette butts or other obvious pesticidal materials, but found none. I also found no aromatic plant material aside from the pine needles in any of the nests, so I suspect that nest composition did not shape arthropod communities. I was unable to determine if nest material was previously exposed to pesticides, though I would suggest testing for pesticide residue in future studies.

Plant Species Richness and Diversity

Plant species richness was not significantly different between the two habitats. There were only three additional species of plants in the urban habitat (Urban plant species richness= 38; rural plant species richness= 35). The urban habitat had greater plant species richness overall, native plant species richness was greater in the rural habitat where 89% of plant species observed were native, and only 45% of plant species observed in the urban habitat were native. The rural habitat had significantly higher native species richness (N=23 t-test; p= 0.0001; Wilcoxon signed-rank; p= 0.0003). The urban habitat had significantly higher non-native species richness (N=23 t-test; p= 0.0001; Wilcoxon signed-rank; p= 0.0005). A list of all plant species observed may be found in Table A2 in the appendix. Previous studies have established that native species are important for ecosystem success due to arthropod's reliance on host plants. While this study did not assess pesticide use, it has been noted in other studies that in areas where non-native plants are used, pesticide use is also generally higher, which could impact the arthropod community. It is possible that the lower arthropod species richness in the urban habitat is at least partially due to pesticide use, as well as yard management such as mowing and trimming, which have also been shown to impact arthropods and birds (Blair, 2001; Batáry *et al.*, 2012; Aronson *et al.*, 2017).

Arthropod Species Richness, Diversity and Abundance

As expected, arthropod species richness was found to be significantly different between the two habitats. Arthropod species richness was higher in the rural habitat (N= 35; t-test; p= 0.0001; Wilcoxon signed-rank; p= 0.0005; Figure 1). Based on results of previous studies, species richness was expected to be greater in an area that has less of a

human impact, in this case plant species richness and housing density. The urban area of Huntsville is greatly different from the rural area when comparing plant communities and housing density. Each of the urban sample sites had at least one human residence within 150 meters of the nest box. The plant community in the urban area has been changed from native species, and is managed by mowing, watering, fertilizing, weeding and pesticide use. Though this study focused the native status of plants, it is possible that all of these factors alter microinvertebrate communities (Lopezaraiza–Mikel *et al.*, 2007; Ramula *et al.*, 2008; Skurski *et al.*, 2013). I found strong correlations between arthropod species richness and if the plants near the nests were native.

I found that the rural arthropod diversity is slightly greater using the Shannon index (rural habitat diversity = 1.66, urban habitat diversity = 1.25). I found that arthropod total nest populations were not significantly different between habitats (N= 35; t-test; p= 0.84; Wilcoxon signed-rank; p= 0.68; Tables 1&2), which served to disprove our hypothesis that there would be a greater abundance of each arthropod species in the urban environment due to less species diversity (Figure 2). It could be that the small sample size, or the nest collection method skewed the data, or it is possible that this effect simply does not happen in Carolina Wren nests (Heck *et al.*, 1975). Comparisons using other bird nests in similar areas might address this result in future studies.

Due to the small sample size of this project, I consider this project to be an exploratory study, and expect that with further sampling, the trend of higher rural arthropod species richness will continue.

Tables

Table 1

Top ten most populous arthropod species found in the rural habitat during both study years shown with mean populations of each species per nest.

Species	Total	Mean	Standard Deviation
Androlaelaps casalis (mite)*	731	40.61	39.16
Oribatula tibialis (mite)	327	18.17	50.8
Schleroribates spp (mite)*	324	18	16.34
Nothrus borussicus (mite)*	293	16.28	16.57
Bradysia spp *1* (fly)*	206	11.44	17.97
Liposcelis spp (booklouse)*	200	11.11	16.63
Solenopsis spp (ant)*	171	9.5	37.33
Protocalliphora spp (blowfly)	152	8.44	17.69
Tapinella spp (booklouse)*	104	5.78	15.47
Baenothrips moundi (thrip)*	85	4.72	10.41

Note. The asterisk (*) indicates that this species was in the top ten most abundant in both habitats

Table 2

Top ten most populous arthropod species found in the urban habitat during both study years shown with mean populations of each species per nest.

Species	Total	Mean	Standard Deviation
Androlaelaps casalis (mite)*	986	58	129.94
Schleroribates spp (mite)*	645	37.94	55.06
Solenopsis spp (ant)*	374	22	36.35
Tapinella spp (booklouse)*	168	9.88	14.14
Liposcelis spp (booklouse)*	159	9.35	15.89
Bradysia spp 1 (fly)*	130	7.65	12.33
Nothrus borussicus (mite)*	123	7.24	7.7
Baenothrips moundi (thrip)*	54	3.18	6.86
Cerobasis spp (booklouse)	47	2.76	11.4
Entomobrya atrocincta (springtail)	23	1.35	3.32

Note. The asterisk (*) indicates that this species was in the top ten most abundant in both habitats

Figures

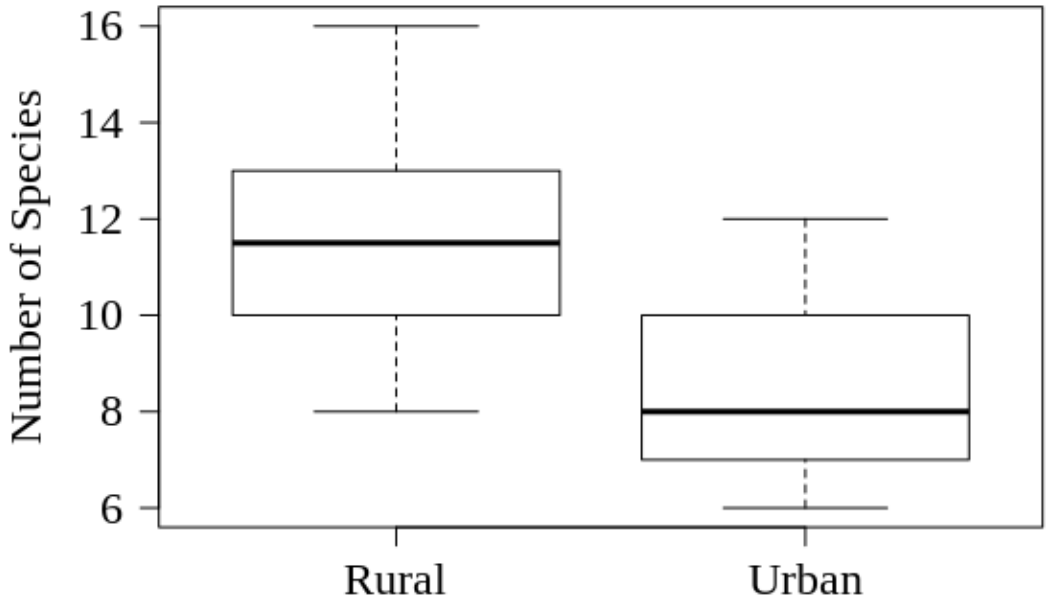

Figure 1. Arthropod species richness per nest from urban and rural habitats during both 2015 and 2016. Rural arthropod species richness was significantly greater than urban arthropod species richness. N= 35; t-test; p= 0.0001; Wilcoxon signed-rank; p= 0.0005.

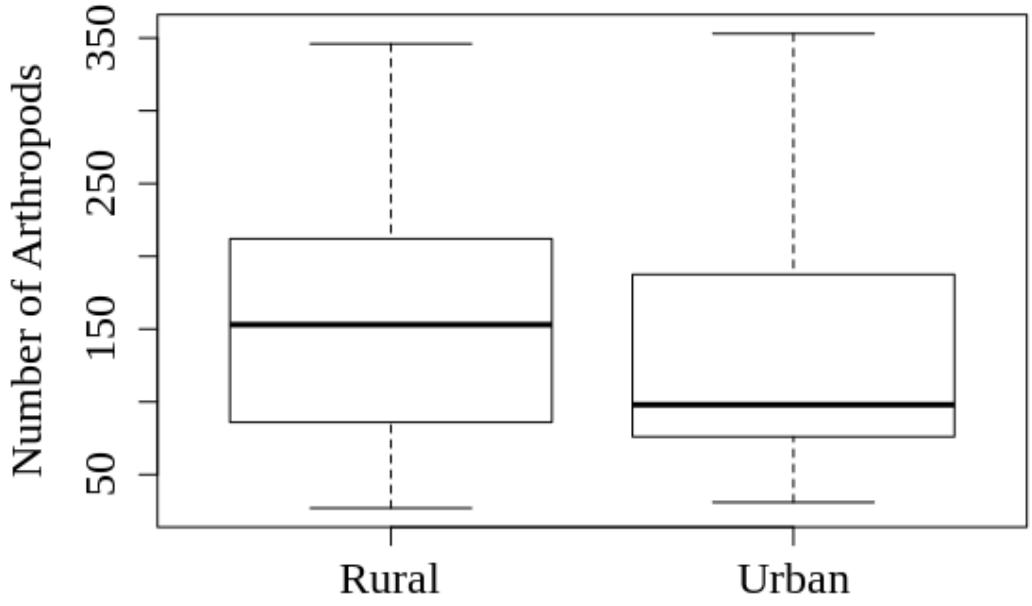

Figure 2. Total arthropod population per nest in rural and urban habitats from both 2015 and 2016 nests. Arthropod populations were not significantly different between the two habitats. N= 35; t-test; p= 0.84; Wilcoxon signed-rank; p= 0.68.

CHAPTER IV

Conclusion

This study provides insight into the arthropod communities found in bird nests and how humans may be causing a change in these communities. Arthropod species richness and diversity were investigated to determine if they were significantly lower in areas with more non-native plant species, and a higher concentration of human residences. I found that arthropod species richness is significantly higher in areas where human residences are not present, and where plants near nests were mostly native. These results mirrored previous studies that compare communities in urban and rural habitats (Coppin *et al.*, 2002; Niemelä *et al.*, 2002; Kühn and Klotz, 2006).

Overall, this study provides more information to determine how changing the natural environment impacts species on many trophic levels. Future studies should focus on other causes of changes, such as pesticide use, release of non-native arthropod species, and materials utilized by birds to build their nests. Of particular interest could be a study of whether nests inside a nest box versus those built within a bush or tree may differ in their arthropod communities. Though it is easy to disregard microinvertebrates that are barely visible to the naked eye, changes in their communities could have lasting consequences that may be unpredictable. As humans change the world around them, it is important to account for changes to the environment that may impact ecosystems in irreparable ways. While the extinction of a mite species may not be considered newsworthy, the extinction of a bird or mammal species, while more memorable, could be prevented if we first understand human impacts at a lower trophic level. This will be especially important as ecosystems experience increases in urbanization; due to

increasing populations, more houses will be built, more forests levelled, and more invasive ornamentals planted, all without understanding what impacts these actions have on the environment. Further study should attempt to determine how changes in nest arthropod communities are impacting the birds they live alongside. It is my hope that future impact studies will expand their scopes to consider all fauna, both great and small, not only because of their impact on charismatic species, but on their own merit as well.

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USDA. 2019. Introduced, Invasive, and Noxious Plants | USDA PLANTS.

APPENDIX

Table A-1

A list of all arthropod species found in each habitat. The habitat where each species was found is indicated in adjacent columns.

Arthropod Species	**Rural**	**Urban**	**Arthropod Species**	**Rural**	**Urban**
Androlaelaps casalis mite	x	x	*Nothrus borussicus* mite	x	x
Anystis baccarum mite	x	x	Orange detritivorous mite	x	
Atropacarus spp mite	x	x	*Oribatula tibialis* mite	x	x
Baenothrips moundi thrip	x	x	*Ornithonyssus silvarium* mite		x
Bdellidae spp mite	x	x	*Ornithonyssus* spp mite	x	
Bradysia spp 1 fly	x	x	*Periplaneta americana* roach		x
Bradysia spp 2 fly	x		*Phthiracarus* spp mite	x	
Brown oribatid spp mite	x	x	*Protocalliphora* spp blowfly	x	
Caelifera spp grasshopper	x		*Psychodidae* spp fly	x	x
Cerobasis spp booklouse		x	*Pyralidae* spp moth		x
Cimex spp bedbug	x		*Rabidosa rabida* spider	x	
Cuculidae spp fly		x	Red Entomobrya springtail	x	
Dermanyssus gallinae mite		x	Red eyed thrip spp	x	
Diamond Haplothrips thrip	x		Round beetle spp	x	
Dicyrtomina minuta springtail		x	Round oribatid spp mite	x	
Duponchelia fovealis moth	x		Salticid spp spider	x	x
Entomobrya atrocincta springtail	x	x	*Schleroribates* spp mite	x	x
Epidapus spp fly		x	*Solenopsis* spp ant	x	x
Halyomorpha halys true insect	x	x	*Sphingidae* spp moth	x	
Haplothrips spp thrip	x	x	Tan Entomobrya springtail	x	x
Ixodidae spp tick	x		*Tapinella* spp booklouse	x	x
Liposcelis spp booklouse	x	x	*Tribolium castaneum* beetle	x	x
Megostigmata spp mite	x	x	Unknown insect spp	x	
Nanhermannia nana mite	x	x	Unknown spp moth	x	
Nasonia spp wasp	x	x			

Table A2

A list of all plant species found in each habitat. The habitat where each species was found is indicated in adjacent columns, as is the species' native or non-native status.

Plant Species	**Rural**	**Urban**	**Native**	**Non-native**
American Elm tree (*Ulmus Americana*)	x		x	
American Sycamore tree (*Platanus occidentalis*)	x	x	x	
Annual blue grass (*Poa annua*)		x		x
Atlantic Poison oak bush (*Toxicodendron pubescens*)	x		x	
Azalea bush (*Rhododendron spp*)		x		x
Bahia grass (*Paspalum notatum*)	x			x
Bermuda grass (*Cynodon dactylon*)		x		x
Buffalo grass (*Bouteloua dactyloides*)	x		x	
Cherry laurel bush (*Prunus laurocerasus*)		x		x
Common crab grass (*Digitaria sanguinalis*)		x	x	
Common lambsquarter (*Chenopodium album*)	x			x
Common Post Oak tree (*Quercus stellata*)	x		x	
Cypress Witch grass (*Dichanthelium dichotomum*)	x		x	
Dwarf Lilyturf (*Ophiopogon japonicus*)		x		x
Dwarf Palmetto bush (*Sabal minor*)	x		x	
Eastern Black Oak tree (*Quervus velutina*)		x	x	
Eastern Redbud tree (*Cercis canadensis*)	x		x	
Eastern Redcedar tree (*Juniperus virginiana*)		x	x	
Field Madder other (*Sherardia arvensis*)		x		x
Florida paspalum grass (*Paspalum floridanum*)	x		x	
Fountain grass (*Pennisetum setaceum*)		x		x
Golden bamboo bush (*Phyllostachys aurea*)		x		x
Greenbriar other (*Smilax rotundifolia*)	x	x	x	
Horseherb other (*Calyptocarpus vialis*)		x	x	
Horseweed bush (*Erigeron canadensis*)	x	x	x	
Huisache bush (*Acacia farnesiana*)	x		x	
Japanese boxwood bush (*Buxus microphylla*)		x		x
Loblolly pine tree (*Pinus taeda*)	x		x	
Longleaf Pine tree (*Pinus palustris*)	x	x	x	
Mondo grass (*Ophiopogon japonicus*)		x		x
Monkey grass (*Liriope muscari*)		x		x
Muscadine grape other (*Vitis rotundifolia*)		x	x	

Plant Species	**Rural**	**Urban**	**Native**	**Non-native**
Nut grass (*Cyperus rotundus*)	x			x
Oleander bush (*Nerium oleander*)		x		x
Pennycress other (*Thlaspi arvense*)		x		x
Pennywort other (*Hydrocotyle heteromeria*)	x	x		x
Photinia bush (*Photinia spp*)		x		x
Pipevine (*Aristolochia macrophylla*)	x		x	
Poison Ivy bush (*Toxicodendron radicans*)	x		x	
Privet bush (*Ligustrum sinense*)		x		x
Sacred Bamboo bush (*Nandina domestica*)		x		x
Sedge grass (*Cyperus spp*)	x		x	
Sensitive plant grass (*Mimosa pudica*)		x		x
Slender nettle bush (*Urtica gracilis*)	x		x	
Southern Dewberry other (*Rubus trivialis*)	x		x	
Southern Hackberry tree (*Celtis laevigate*)		x	x	
Southern Magnolia tree (*Magnolia grandiflora*)		x	x	
St. Augustine grass (*Stenotaphrum secundatum*)		x		x
Summer grape other (*Vitis aestivalis*)	x		x	
Sweetgum tree (*Liquidambar styraciflua*)	x		x	
Switch grass (*Panicum virgatum*)	x		x	
Texas Ash tree (*Fraxinus albicans*)		x	x	
Texas croton other (*Croton texensis*)	x		x	
Texas sedge grass (*Carex texensis*)	x		x	
Trumpet Creeper other (*Campsis radicans*)	x		x	
Virginia Creeper (*Parthenocissus quinquefolia*)		x	x	
Water Oak tree (*Quercus nigra*)	x	x	x	
Waxleaf Begonia bush (*Begonia spp*)		x		x
Western ragweed bush (*Ambrosia psilostachya*)	x	x	x	
Winter rye grass (*Lolium spp*)		x		x
Woodoats grass (*Chasmanthium latifolium*)	x		x	
Yaupon holly bush (*Ilex vomitoria*)	x		x	
Yellow Wood Sorrel grass (*Oxalis stricta*)		x	x	

VITA

FAITH N. BYRD

EDUCATION

Sam Houston State University, Huntsville, Texas. M.S. Biology – *In Progress*

Advisor: Dr. Diane L.H. Neudorf

Thesis: Effects of urbanization on arthropod communities in Carolina Wren (*Thryothorus ludovicianus*) nests: a comparative study between urban & rural habitats in Walker County, Texas

Texas A&M University, College Station, Texas. B.S. Wildlife & Fisheries Science – May 2014

Tyler Junior College, Tyler, Texas. A.S. Biology – May 2010

RELEVANT COURSEWORK

Ornithology, Natural History of the Vertebrates, Natural History of the Invertebrates, Zoology, Herpetology, Biogeography, Ecology, Entomology, Field Parasitology, Conservation Biology, Urban Wildlife Management, GIS, Wetland Ecology, Ecosystem Ecology

RESEARCH/ LABORATORY/FIELD EXPERIENCE

City of Bryan Animal Services – Animal Control Officer & Animal Care Technician

July 2018-present

- Assist local health authorities with monitoring outbreaks of zoonotic disease
- Care for and monitor the health of domestic animals surrendered to the city shelter
- Report and quarantine dogs, cats and ferrets who bite human beings
- Educate community on zoonotic disease
- Control wild, feral and domestic animals to prevent disease outbreak and increase public safety

Texas Veterinary Medical Diagnostic Laboratory- Molecular Diagnostician

February 2018-July 2018

Research: Monitoring of zoonotic disease throughout the state of Texas and Mexico

- Gel and real-time PCR analysis for diagnostic use
- Tissue identification and preparation
- Data collection and archiving

Houston Animal Hospital- Veterinary Technician

November 2017-February 2018

- Venipuncture, catheterization
- Diagnostic laboratory work
- Surgery assistance
- Proper restraint of animals
- Monitoring of anesthesia
- Compound Microscopy
- Autoclaving

SHSU Bird Laboratory Fieldwork- Graduate Student

June 2014-August 2016

Research: Effects of urbanization on arthropod communities in Carolina Wren (*Thryothorus ludovicianus*) nests: a comparative study between urban & rural habitats in Walker County, Texas

- Mist-netting, banding
- Field observation
- Collection of nest material
- Identification of arthropods and plants
- Data collection and analysis
- Compound, stereo and electron microscopy

Stable Isotopes for Biosphere Science Lab at Texas A&M- Lab Technician

November 2013-May 2014

Research: Assisted with a variety of projects using stable isotope analysis to study soil samples and tissue samples from many species of plants and animals

- Grinding and processing of samples
- Precision weighing
- Date recording

Texas A&M Wildlife & Fisheries Science Program- Research Assistant

August 2012-May 2014

Research: Assisted with an ecotoxicology study comparing contamination in resident and neotropical songbirds found in the Americas.

- Mist-netting, banding, blood sampling
- Mist-net repair
- Proper restraint of wild birds

- Bird surveys
- Collection and analysis of tissues
- GPS data collection
- Scientific report writing

Texas A&M Veterinary Teaching Hospital Equine Embryo Lab- Research Assistant

January 2012-May 2014

Research: Assisted with collection and identification of equine oocytes using specialized ultrasound equipment; studied with use of various media to keep oocytes viable and the effects of ovary and follicle manipulation on fertility.

- Sonography
- Compound Microscopy
- Autoclaving
- Proper handling and restraint of large animals

Biodiversity Research & Teaching Collections at Texas A&M- Ornithology Intern

May 2012-August 2012

- Data collection and organization
- Taxidermy
- Preparation and labelling of tissues and specimens

Caldwell Zoo- Veterinary Intern

May 2009-August 2009

- Capture and restraint of animals
- Surgery assistance
- Laboratory report-writing
- Preparation and packaging of tissue samples

TEACHING EXPERIENCE

Sam Houston State University, Graduate Teaching Assistant

August 2014-May 2016

- Foundations of Science Lab Instructor
- Environmental Science Lab Instructor

PRESENTATIONS

F.N. Byrd & Diane L.H. Neudorf (2016) *A survey of insects and arachnids found in the nests of Carolina Wrens (Thryothorus ludovicianus) in urban and rural environments.* NAOC Conference, August 2016. Washington, D.C..

F.N. Byrd & Diane L.H. Neudorf (2016) *A survey of insects and arachnids found in the nests of Carolina Wrens (Thryothorus ludovicianus) in urban and rural environments.* TAS Conference, March 2017. Temple, TX.