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Arthropod Density In a Fragmented Urban Landscape Along the Northern Coast of the Gulf Of Mexico

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The University of Southern Mississippi

Arthropod density in a fragmented urban landscape
along the northern coast of the Gulf of Mexico

By

Anna Beth Williams

A Thesis

Submitted to the Honors College of
The University of Southern Mississippi
In Partial Fulfillment
Of the Requirements for the Degree of
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In the Department of Biological Sciences

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Problem Statement

Ecologists once focused their research on “pristine” habitats that were considered untouched by human activity. As urbanization rapidly increases, the concept of pristine habitats becomes obsolete. Urban habitats must be studied in order to understand the ecology of our increasingly developed society. Rapid urbanization greatly affects coastal habitats. Popular real estate, strip malls, casinos, and resorts all fragment urban landscapes. Much of the northern coast of the Gulf of Mexico is a fragmented urban landscape caused by rapid development. That same coastal landscape is ecologically important and includes habitats important to many different organisms, among them intercontinental migratory songbirds that stop along the coast to rest and to meet the energetic demands before and after the long flight over the Gulf of Mexico. In addition to access to appropriate landing sites, migratory songbirds depend on local arthropod populations to meet the energetic demands of migratory journey. The interaction of anthropogenic factors linked to urbanization and local arthropod communities is important to understand because of the roles arthropods play in functioning ecosystems, such as nutrient cycling, pollination, and food webs. Arthropod communities in an urbanized landscape are not well studied or understood.

Coastal Mississippi provides a setting within which to study arthropod communities in a fragmented urban landscape. I studied arthropod diversity and densities on the Mississippi Gulf Coast at sites that varied in size of wooded habitat: 2 small sites of approximately 1 hectare of wooded habitat and 2 large sites of approximately 160 hectares of wooded habitat. It is unknown whether arthropod communities thrive best in large or small wooded fragments within an urban landscape. I hypothesized that arthropod density would vary with size of habitat, and I predicted that large wooded areas would support a higher density of arthropods than small wooded areas.

I also hypothesized that arthropod diversity would vary with size of habitat, and I predicted that the arthropod community confined to a smaller space would be more diverse than an arthropod community associated with a larger space.

Literature Review

In the past, ecologists hesitated to study urban habitats and considered urban landscapes of secondary importance to other habitats (Niemela 1999). Ecologists are changing their attitudes about the value of studying urban habitats, and ecological research in urban settings has recently increased (Niemela 1999). In addition to scientific value, Niemela (1999) points out that urban ecology studies can benefit city planners. Urban expansion may have positive and negative effects on the ecology of an area, and urban landscapes provide field test sites to study the effects (Niemela 1999). For example, McKinney (2002) points out the threat urbanization poses to conservation and native species, while Stracey and Robinson (2012) find that urban areas provide successful habitats for native northern mockingbirds (*Mimus polyglottos*). A common phenomenon of rapid urban expansion is the creation of habitat “patches,” or fragments, caused by the urban matrix (Niemela 1999). Urbanization presents new problems for local populations of plants and animals. Many interactions between anthropogenic factors linked to urbanization and plant and animal populations are still largely unknown and warrant study, especially as urbanization continues to rapidly increase (Schocat et al. 2006). McKinney (2008) studied the effects of urbanization on local populations of plants and animals, and found that animal species richness tends to be reduced in areas with more urbanization. Increased biodiversity has positive ecological, aesthetic, recreational, and educational value (McKinney 2008).

Coastal landscapes have been strongly influenced by rapid urbanization. Desirable real estate, strip malls, casinos, and beach resorts all contribute to the fragmentation of coastal habitats. Oivanki et al (1995) reported that developed land use tripled on the Mississippi Gulf Coast from the 1950s to 1992, and resultant fragmentation may have negative effects. For example, Burke and Nol (1998) tested a hypothesis that changes in food and nest site availability limited settlement of female Ovenbirds in small forest fragments. Small fragments with high amounts of light and leaf litter desiccation had reduced density of arthropods, and the reduced density of arthropods led to reduced density of Ovenbirds within those fragments. Burke and Nol (1998) concluded that urban fragmentation could reduce insect availability, and that arthropod abundance was significantly reduced in sites along city edges and in small woodlands than in larger, denser sites.

Robinson (1998) commented on Burke and Nol's study and suggested that foliage dwelling arthropods may have higher density at the edge of sites where foliage is denser, and that birds might choose these sites based on food availability despite increased predation along the edge of forested habitat. Robinson (1998) also commented on the possible negative effects of urban fragmentation on migrating songbirds. Arthropod density at test sites for study of migratory birds is an important factor to consider as many species of birds may depend on arthropods for refueling after a long flight (e.g., Graber and Graber (1983)). Stracey and Robinson (2012) cautioned that a full understanding of how urbanization affects the biology of birds, for example, depends on the level of urbanization

McIntyre (1999) discussed the need for urban arthropod studies and encouraged ecologists to conduct these types of studies. Arthropod density in different habitat types in Phoenix, Arizona, reveal that agricultural sites have the highest richness and abundance of

arthropods, and research further explains that understanding the effects of urbanization on arthropod communities is important because of the roles arthropods play in functioning ecosystems, such as nutrient cycling, pollination, and food webs (McIntyre et al. 2001). Gibb and Hochuli (2002) studied the effects of urban fragmentation on arthropod community composition in Australia and reported that habitat fragmentation affected insect abundance and diversity as well as interactions between arthropods and other organisms. Gibb and Hochuli (2002) discovered that large fragments did not support more species per unit area than small fragments and suggested that arthropod responses to fragmentation are not only limited to reduced habitat area and urban proximity, but also fire regimes and degradation of habitats may also have roles in arthropod assembly in urban landscapes.

Methods

Data was gathered at 4 sites that differed in size (see Figure 1 below). Hellmers Lane and

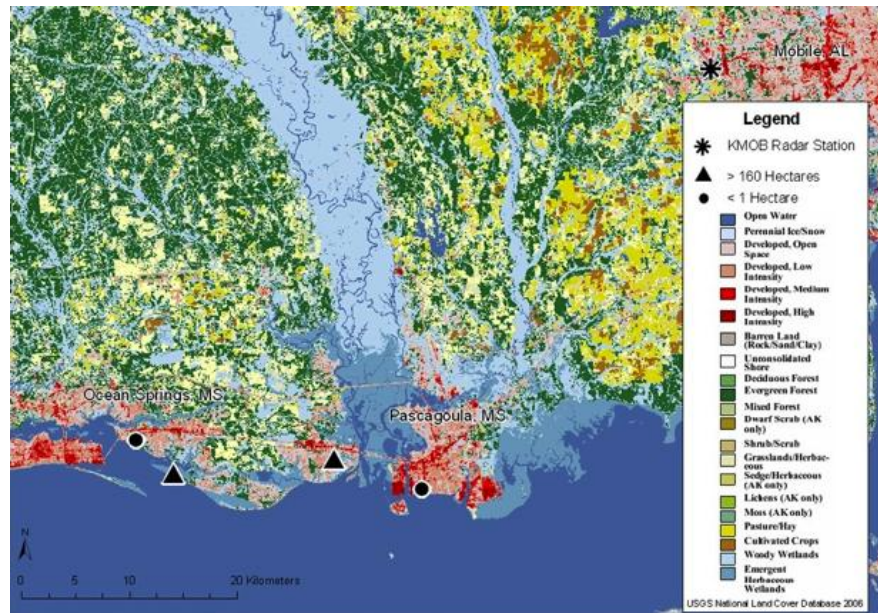


Figure 1: Map of Test Sites. From west to east, Hellmers Lane (small), Davis Bayou (large), Shepard State Park (large), and Don’s Woods (small) are shown.

Don's Woods both have less than one hectare of wooded habitat, while Davis Bayou and Shepard State Park both have approximately 160 hectares of wooded habitat. Arthropods were sampled along 500 meter transects (large sites) and 300 meter transects (small sites) established at each site. Transects were identified by number of meters along the total testing site transect. Branch clippings of both *Ilex*, common name Holly, and *Quercus*, common name Oak, were obtained at each transect, and leaf litter samples were taken at 3 of the 6 transects at each site.

Three leaf litter samples were obtained at each testing site. The transect points for leaf litter sampling at Hellmers Lane were points 75, 150, 225, at Davis Bayou points 75 (south), 75 (north), 150, 300 at Shepard State Park points 150, 300, 425 and at Don's Woods points 100, 25, 125. Leaf litter samples were obtained using a quadrant, a timer, and a ruler. The quadrant was placed gently on the ground, and a timer was set for 3 minutes. All arthropods observed were recorded by length and taxonomic order. Data sheets included the test site name, transect, and date of observation. Observers knelt over the quadrant and recorded all arthropods seen within the quadrant or flying insects that landed in the quadrant. The leaf litter was not disturbed during testing, and insects that flew over but did not land within the quadrant were not counted. Figure 2 shows the leaf litter sampling technique.



Figure 2: Leaf Litter Technique. For each leaf litter sample, the quadrant was carefully placed on the ground. A timer was set for 3 minutes, and all arthropods observed within the quadrant were recorded by length and order. Leaf litter was not disturbed during sampling, and flying insects were only counted if they landed within the quadrant.

Branch clippings of both Ilex and Oak were obtained at each transect of each testing site (Figure 3). Johnson (2000) established the branch clipping method as an effective way to study arthropods through his study in Jamaica. At each transect, a branch from the desired plant species that was approximately 12'' long was selected. Branches that did not have many seedheads and were not intertwined with other plant species (such as vines) were ideal. A 12 gallon plastic bag was carefully placed around the branch, disturbing the branch as little as possible. Once the bag was around the branch, clippers were used to cut the branch off at the

opening of the bag. Insecticide was then sprayed into the bag through a small opening. The bag was opened as little as possible to prevent arthropods from escaping. Enough insecticide was sprayed to coat the sample, but not so much that the bag was saturated. Over saturating the sample with insecticide would make sorting difficult. After spraying the insecticide, the bag was sealed carefully and quickly. The bag was shaken vigorously to distribute insecticide throughout the sample (Figure 3).



Figure 3: Branch Clipping Technique. Branches of approximately 12 inches were selected. A gallon size bag was placed over the branch and held shut. The branch was cut just above the opening of the bag. Insecticide was sprayed into a small opening in the bag. The bag was then quickly sealed to prevent arthropods from escaping. Finally, the bag was shaken to distribute insecticide throughout the sample.

Branch clippings were brought to the laboratory for processing. For each branch clipping, the sealed bag containing the branch was first shaken to dislodge any insects. Then, the bag was opened and vegetative material removed. Each branch was carefully inspected for insects that were not dislodged. Vegetative material was put into a plastic container on a scale to be weighed. All insects were removed from the bag and classified to order and then measured. The whole plastic bag was carefully inspected for small insects. The date of sampling, site name

and transect point, invertebrate order, length of invertebrate in millimeters, plant species, and plant weight in grams were recorded (Figure 4).



Figure 4: Lab Techniques. Each branch clipping sample was shaken to dislodge any arthropods. Then, vegetative material was removed and placed in the dish. The bag was carefully inspected for arthropods that were not dislodged. Vegetative material was separated from arthropods and placed on a scale and recorded in grams. Arthropod lengths were measured in millimeters. All arthropods were classified to order.

For both the branch clipping and leaf litter data, a regression equation was used to transform arthropod length in millimeters to mass in milligrams (Rogers et al 1976). Once the weight of each arthropod was established in the branch clippings data set, the total arthropod mass per branch (48 branches total) was calculated. Then, the arthropod mass in milligrams divided by plant mass in grams was calculated for each branch to examine arthropod density. Because of many samples with no arthropods collected, which created a non-normal distribution, a zero-altered negative binomial model was executed using the program R, (Zurr et al 2009).

Once the weight of each arthropod in the leaf litter data set was established, the data was log transformed to shift the data to a normal distribution. An analysis of variance was performed on the transformed values to test the significance of date and site as variables affecting the data. These methods were used on the leaf litter data to deal with the problem of many zeros in the data set.

Results

Branch clipping data showed that arthropod density varied among sites. The two large sites, Davis Bayou and Shepard State Park, were characterized by both the lowest and the highest arthropod density, and the two small sites, Don's Woods and Hellmers Lane, had arthropod densities that fell between the two large sites (Figure 5). Overall, large sites had a higher arthropod density than small sites. Arthropod density also varied across the spring season (Figure 6). After the end of March, values were consistently higher at the large sites with the exception of the last sampling day in mid-May.

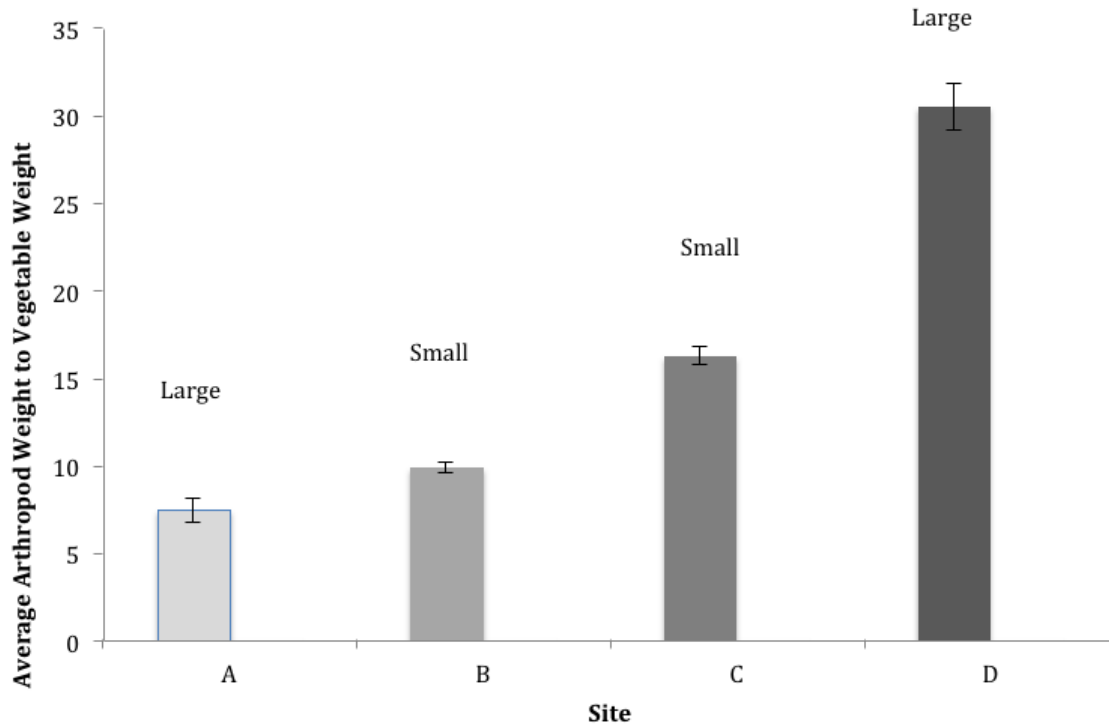


Figure 5: Average Arthropod Weight in Branch Clippings per site. For each site, (A) DAV-Large, (B) DON-Small, (C) HEL-Small and (D) SHE-Large, average milligrams of arthropods to grams of vegetation is shown.

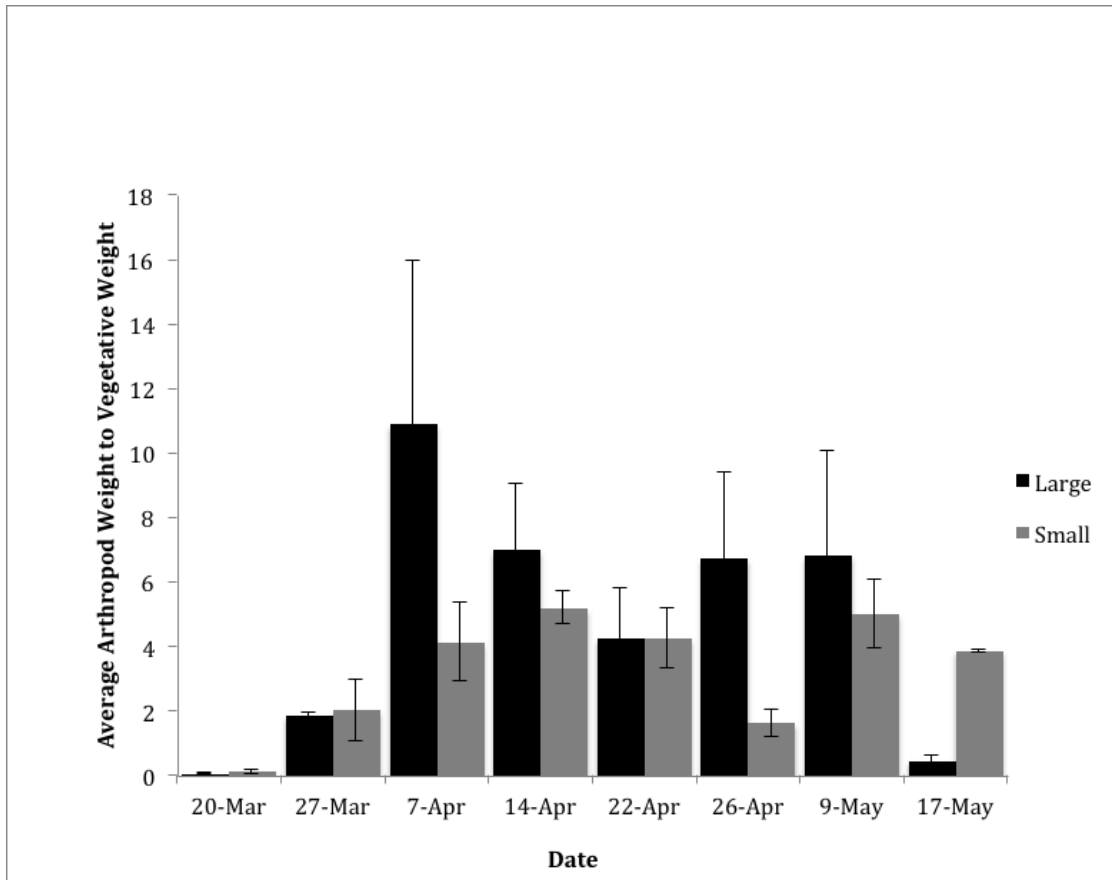


Figure 6: Average Arthropod Mass in Branch Clippings per Week. For each sampling date, average milligrams of arthropods to grams of vegetation are shown for Large (DAV and HEL) and Small (DON and HEL) sites.

A zero-altered negative binomial model was executed using the program R to examine the effect of week, site size, and sample year on the branch clipping data. Arthropod abundance estimated from branch clippings did vary with week ($\chi^2=15.206$, DF=6, and $p = 0.01872$), but did not vary significantly with site ($\chi^2=1.9502$, DF=1, and $p = 0.1626$) for year (2011 and 2012) ($\chi^2=0.169$, DF=1, and $p = 0.681$).

Leaf Litter data showed that Don’s Woods, a small site, had the highest mass of arthropods in leaf litter, while Shepard State Park, a large site, had the lowest. Hellmers Lane, a small site, had a density that was close to Shepard State Park’s. Overall, small sites had a greater mass of arthropods than large sites (Figure 11).

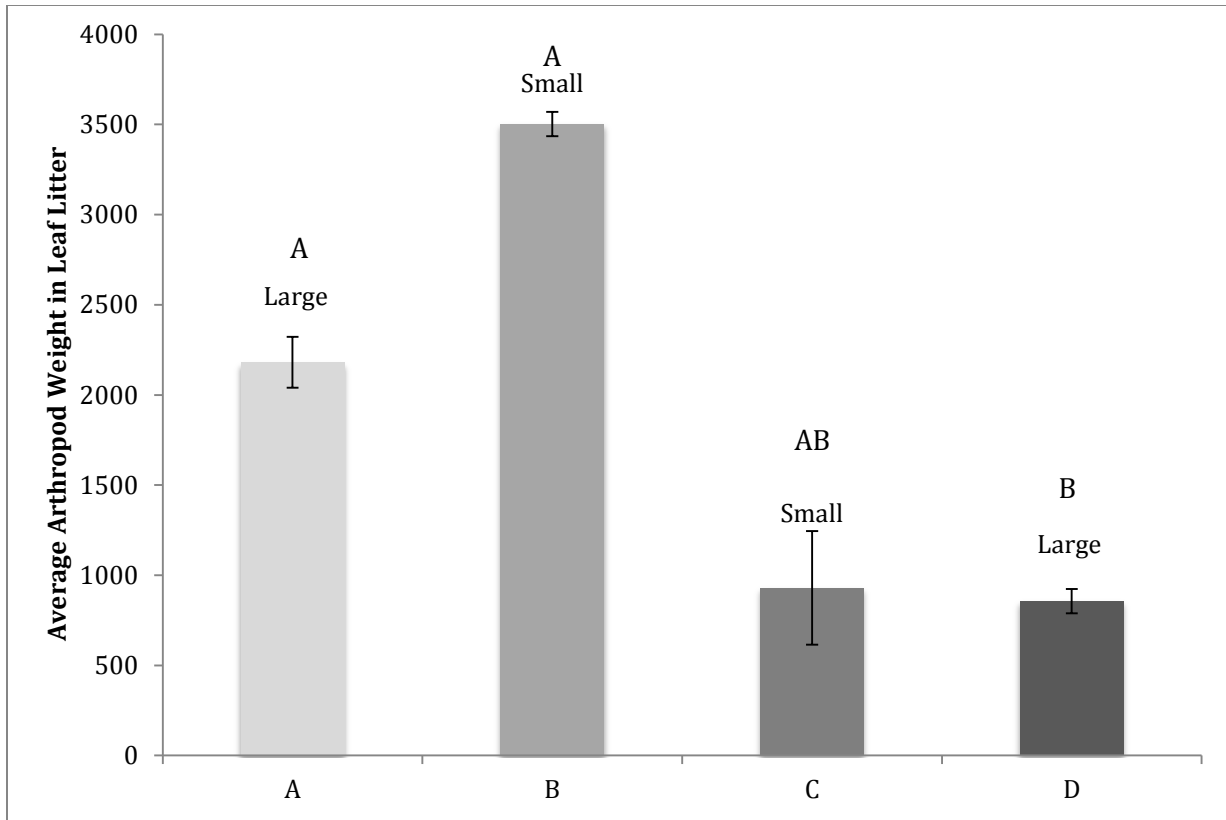


Figure 7: Average Arthropod Weight in Leaf Litter per Site. For each site, (A) DAV-Large, (B) DON-Small, (C) HEL-Small and (D) SHE-Large, average milligrams of arthropods from Leaf Litter is shown.

Arthropods in leaf litter increased over the season, and differences in arthropod abundance from leaf litter between large and small sites is unclear (Figure 12).

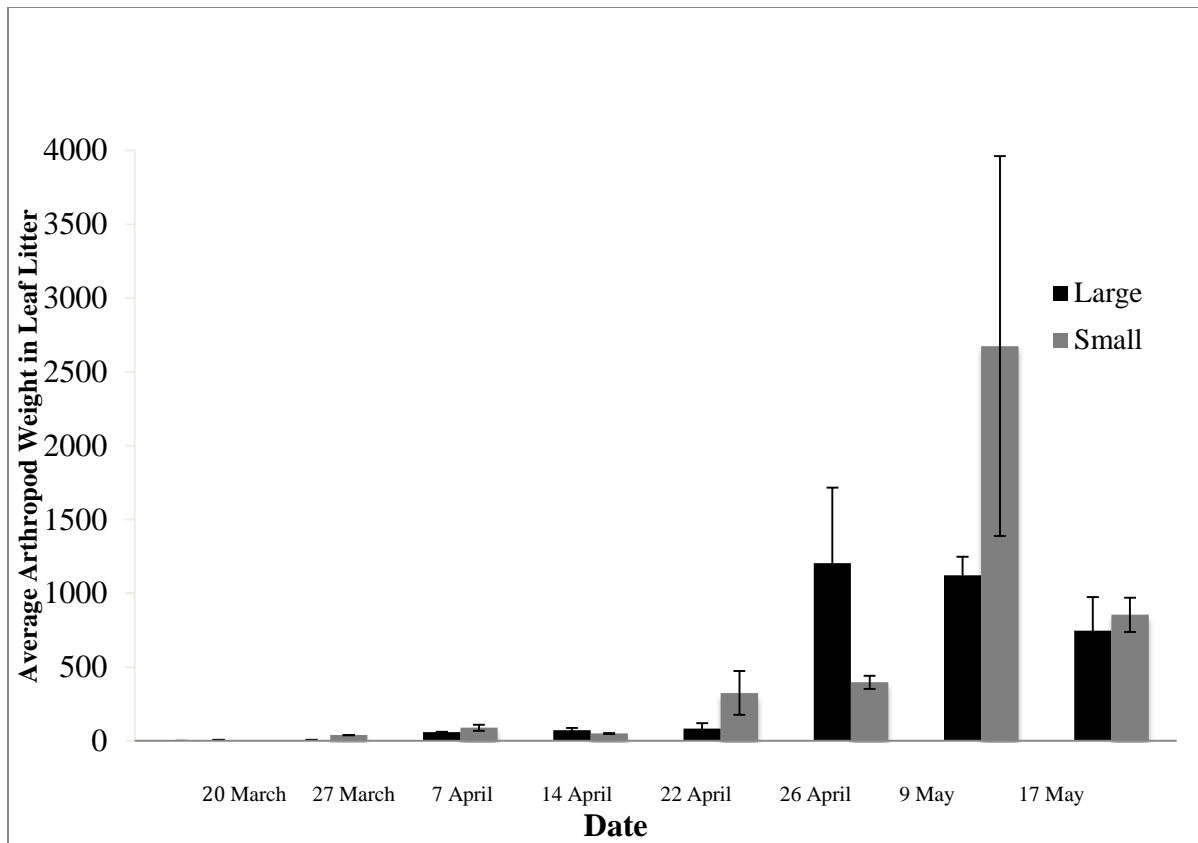


Figure 8: Average Arthropod Weight in Leaf Litter per Week. For each sampling date, average milligrams of arthropods from leaf litter is shown for Large (DAV and SHE) and Small (HEL and DON) sites.

An analysis of variance was used on the log transformed leaf litter data to test the significance of sample week and site on arthropod abundance. There was a significant effect of sample date on arthropod abundance at the $p < 0.05$ level [F ratio = 25.0835, DF = 8, and $p = < .001$]. There was a significant effect of site on arthropod abundance at the $p < 0.05$ level [F ratio = 4.7234, DF = 3, and $p = 0.0044$]. Figure 7 shows the results of the Tukey HSD test. Levels not connected by the same letter are significantly different.

Arthropod diversity counts of branch clippings showed that small sites (HEL and DON) had the greatest diversity of arthropods. Arachnids and Coleopterans made up the majority of the arthropod population in both large and small sites, but a higher diversity of arthropods in small

sites can be seen (Figures 7 and 8). When Arachnids and Coleopterans are removed from the population counts, the higher diversity of arthropod orders in small sites is clear (Figures 9 and 10).

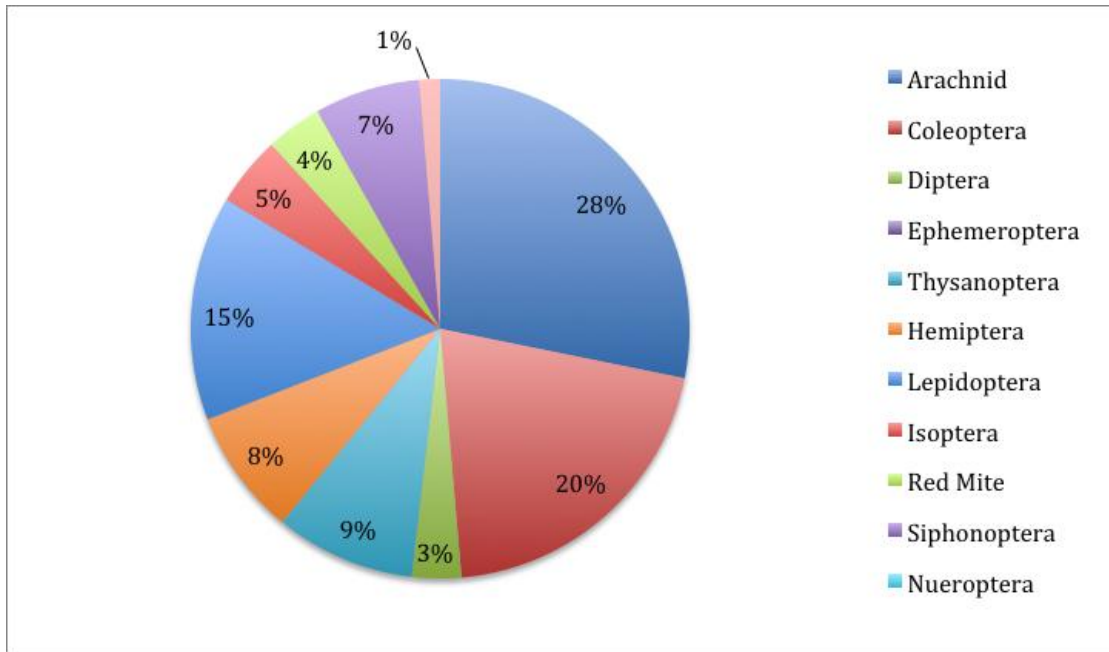


Figure 9: Arthropod Diversity from Branch Clippings in Large Sites. Total diversity counts of arthropod orders from branch clippings over the entire season are shown for Large (DAV and SHE) sites.

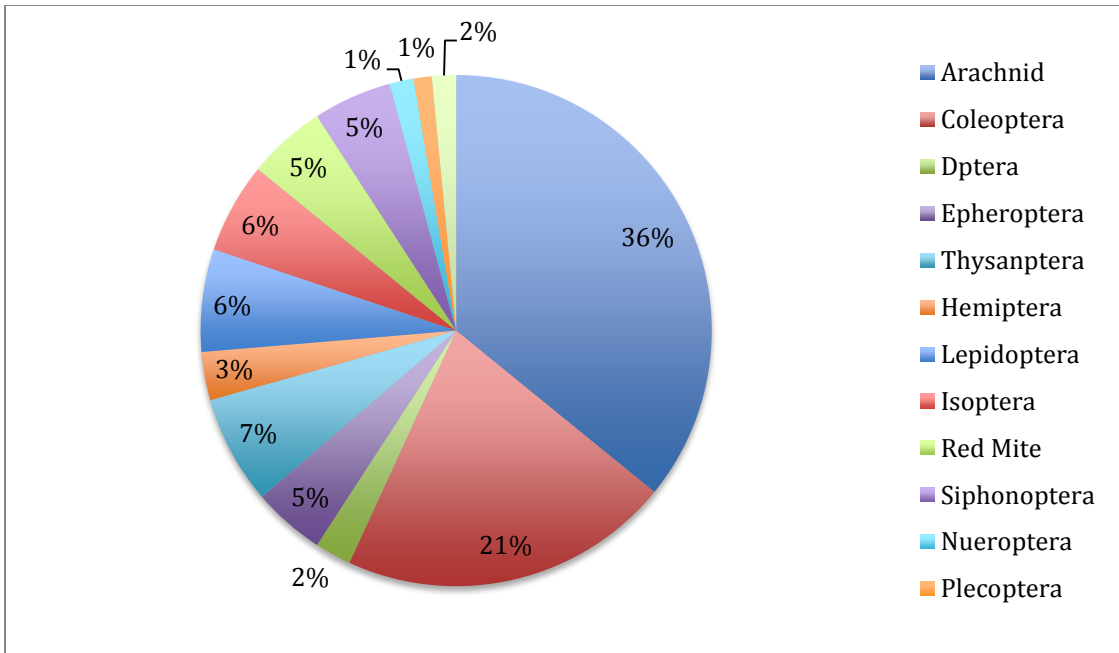


Figure 10: Arthropod Diversity from Branch Clipping in Small Sites. Total diversity counts of arthropod orders from branch clippings over the entire season are shown for Small (HEL and DON) sites.

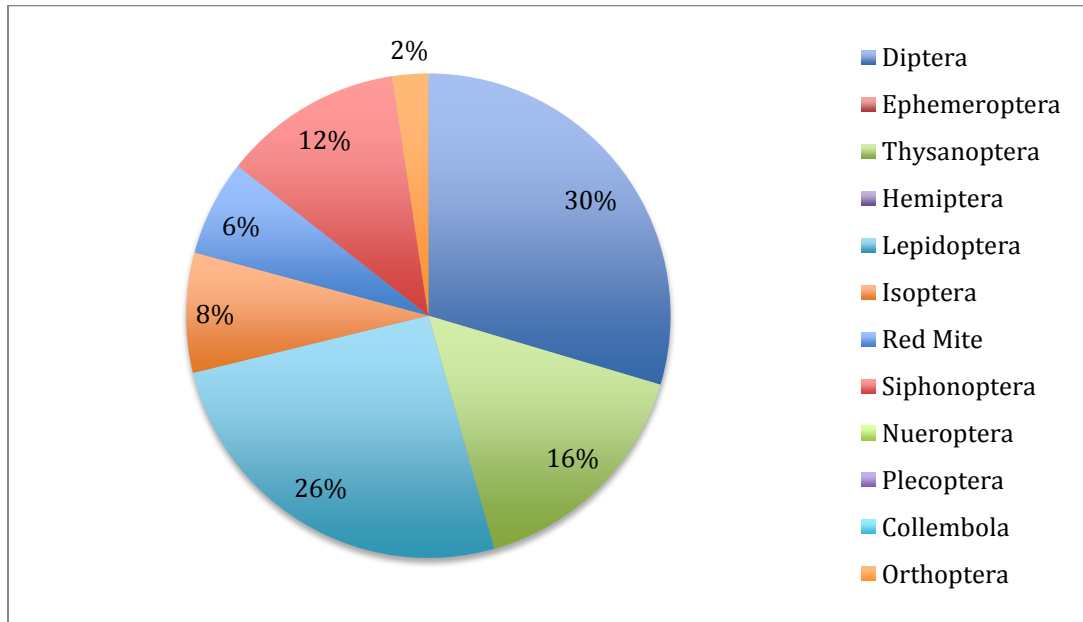


Figure 11: Arthropod Diversity from Branch Clipping in Large Sites without Arachnids and Coleopterans. Diversity counts of arthropod orders without majority orders (Arachnids and Coleopterans) are shown for Large (DAV and SHE) sites.

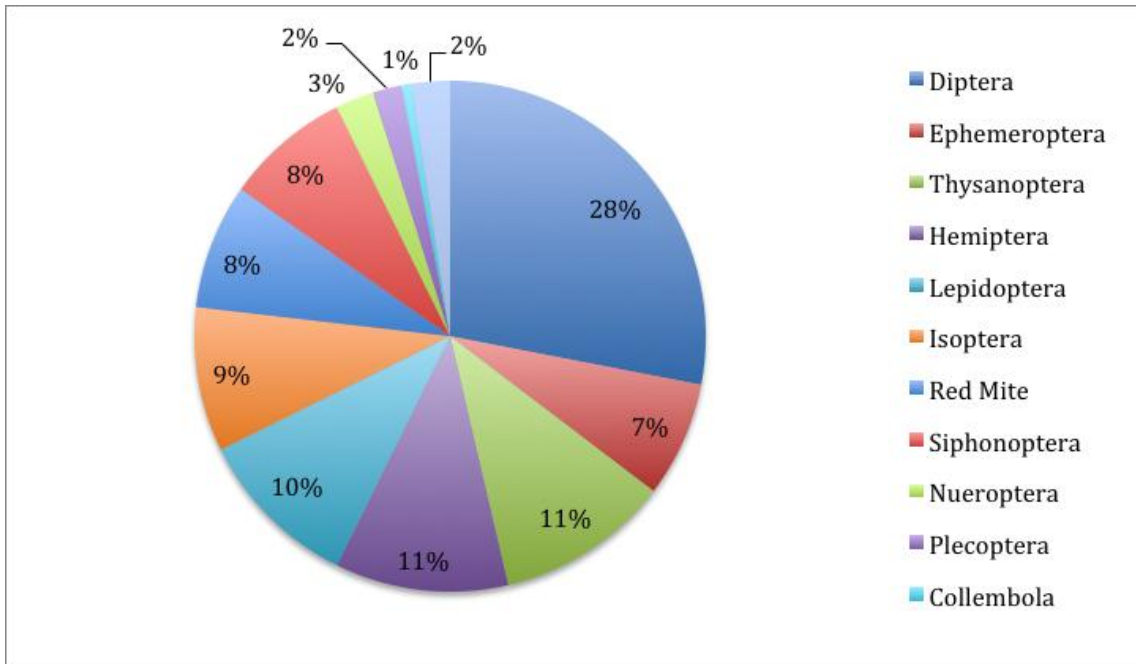


Figure 12: Arthropod Diversity from Branch Clippings in Small Sites without Arachnids and Coleopterans. Diversity counts of arthropod orders without majority orders (Arachnids and Coleopterans) are shown for small (HEL and DON) sites.

Arthropod diversity counts from leaf litter showed few differences between large and small sites (Figure 13 and 14). Hymenopterans and dipterans make up the majority of arthropods for both site sizes. When hymenopterans and dipterans are removed from diversity counts, both site sizes appear to have similar levels of arthropod diversity (Figures 15 and 16).

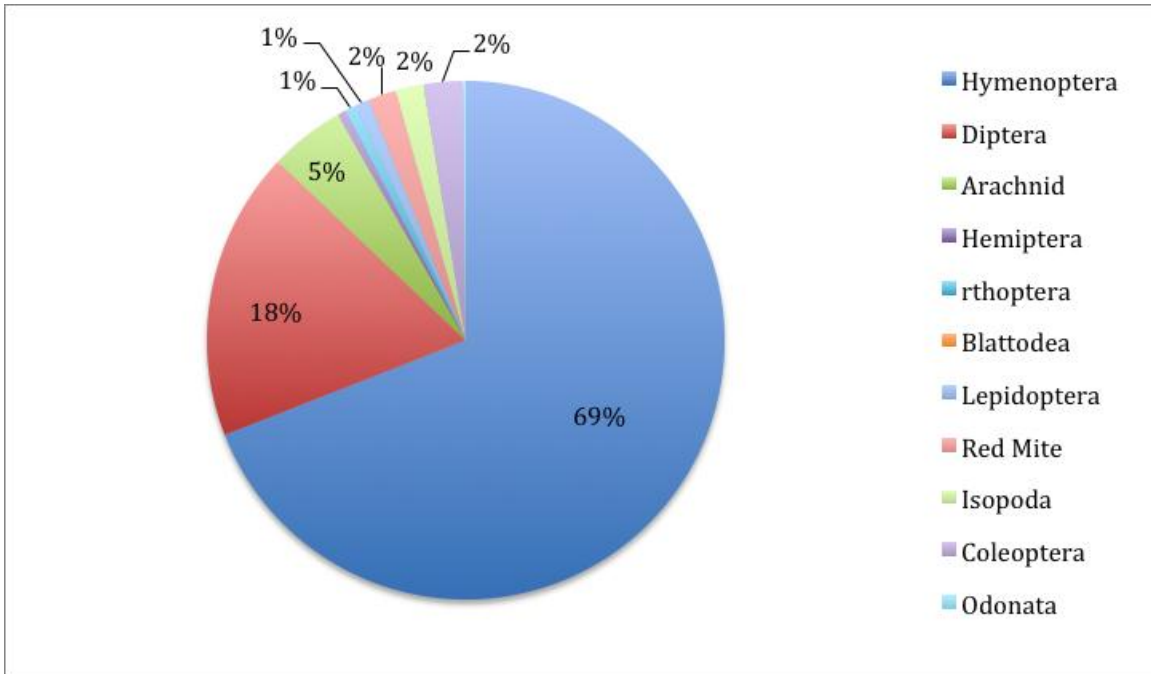


Figure 13: Arthropod Diversity from Leaf Litter in Large Sites. Total diversity counts of arthropod orders from leaf litter over the entire season are shown for large (DAV and SHE) sites.

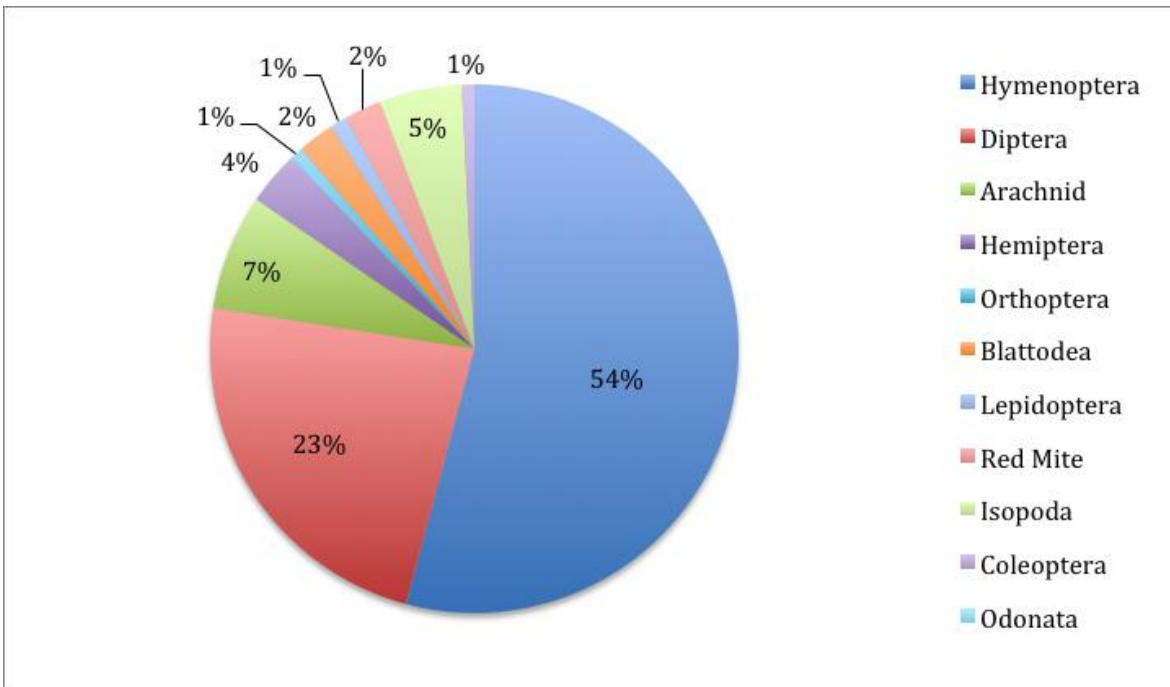


Figure 14: Arthropod Diversity from Leaf Litter in Small Sites. Total diversity counts of arthropod orders from leaf litter over the entire season are shown for small (HEL and DON) sites.

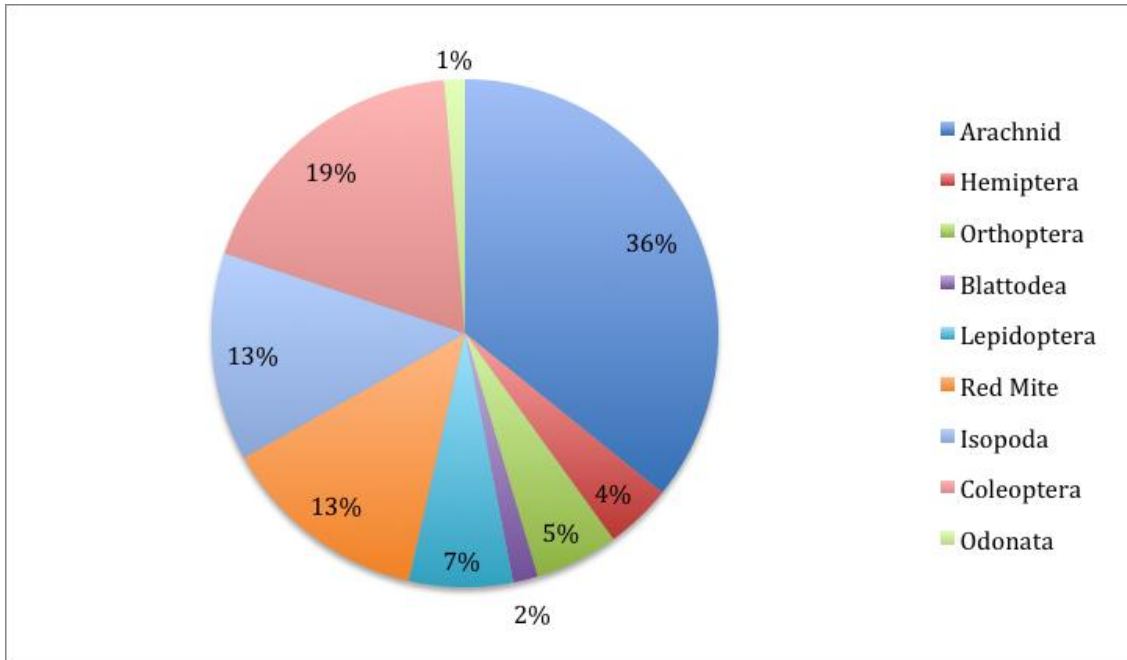


Figure 15: Arthropod Diversity from Leaf Litter in Large Sites without Hymenoptera and Diptera.

Diversity counts of arthropod orders without hymenopterans and dipterans are shown for large (DAV and SHE) sites.

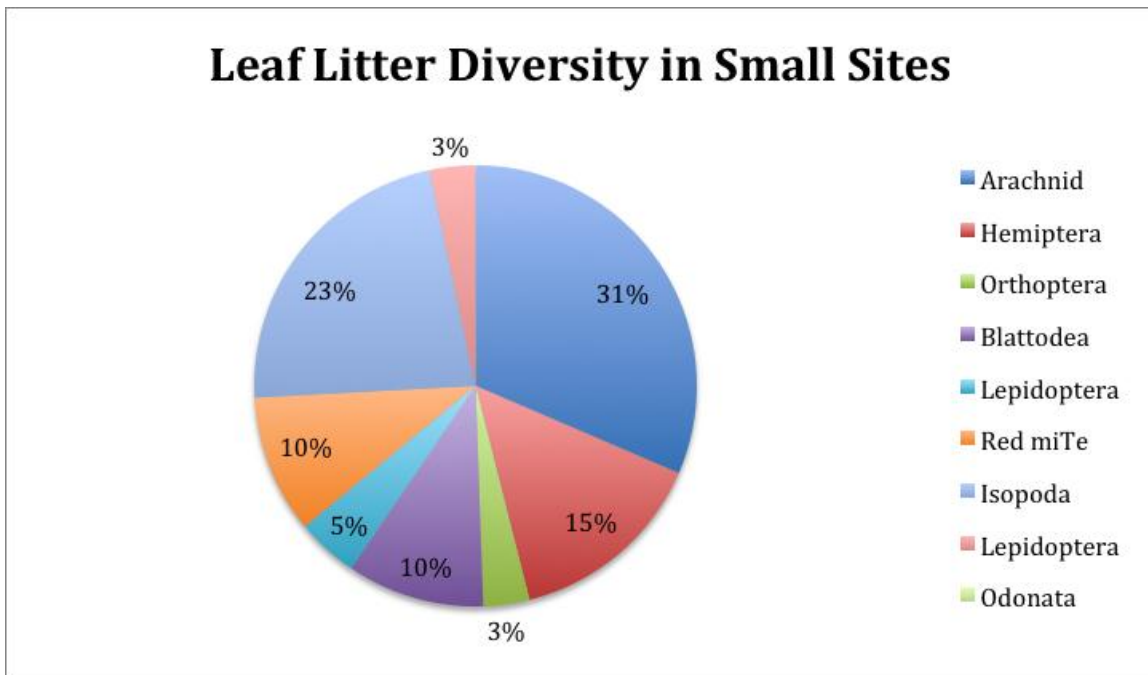


Figure 16: Arthropod Diversity from Leaf Litter in small sites without Hymenoptera and Diptera.

Diversity counts of arthropod orders without hymenopterans and dipterans are shown for small (HEL and DON) sites.

Discussion

Arthropod Density

I hypothesized that arthropod density would vary with size of habitat, and I predicted that large wooded areas would support a higher density of arthropods than small wooded areas. My leaf litter results had higher abundance than branch clippings, and leaf litter abundance was higher in small sites. Date was significant for density in leaf litter, and arthropod density in leaf litter increased over the spring. This was expected since arthropods mature and become increasingly active as the weather becomes warmer. Site was significant for abundance in leaf litter. Shepard State Park (large) was different from Davis Bayou (large) and Don's Woods (small). Hellmers lane was not significantly different from any of the sites. My results indicate that arthropod abundance in leaf litter is higher in small urban fragments than in large urban fragments.

Week was also significant for branch clippings, and abundance increased over the spring as it did in leaf litter. Site size was not significant for branch clippings—overall, it appears that large sites have a higher abundance than small sites. Shepard State Park had the highest abundance of all sites, but Davis Bayou, the other large site, had the lowest arthropod abundance in branch clippings. The field and lab methods used for branch clippings were designed to eliminate the possibility of different branch clipping weights but similar arthropod weights on each branch. Only oak and ilex trees were used, and specific trees were selected at the beginning of the season. Selected branch clippings met certain criteria (approximately 12" in length, lack of seedheads) before clipping. The transect I used in Shepard State Park was directly over a swamp. Proximity to water could have influenced arthropod abundance in the Shepard transect.

The Davis Bayou transects I used were not in direct contact with water as in Shepard. With this difference and the abundance in small sites in mind, my results do not indicate a clear difference in arthropod abundance in branch clippings between large and small urban fragments.

My arthropod density results are contrary to Burke and Nol (1998), who concluded that urban fragmentation could reduce insect availability, and that arthropod abundance is reduced along city edges and in small woodlands as compared to larger, denser sites. However, Burke and Nol suggested that small fragments with high amounts of light and leaf litter desiccation are what resulted in the reduced density of arthropods. Robinson (1998) commented on this study and suggested that foliage dwelling arthropods could have high density in edge sites with dense foliage. The small sites I used did not have high light or leaf litter desiccation. Since arthropod density was not clearly reduced in urban fragments in my study, Burke and Nol's comment appears to be correct, and Robinson suggestion is consistent with my density results.

Arthropod Diversity

I hypothesized that arthropod diversity would vary with size of habitat, and I predicted that the arthropod community confined to a smaller space would be more diverse than an arthropod community associated with a larger space. My results show that arthropod diversity from branch clippings was highest in small sites, and arthropod diversity in leaf litter did not depend on fragment size.

My results are contrary to McKinney 2008, who found that species richness tends to be reduced in areas with a great deal of urbanization, but also stated research was needed to understand urbanization/biodiversity and that the effects of urbanization could be good and bad. My results are consistent with Gibb and Hochuli (2002), who studied the effects of urban fragmentation on arthropod community composition in Australia and reported that habitat

fragmentation affected insect abundance and diversity as well as interactions between arthropods and other organisms. Gibb and Hochuli (2002) discovered that large fragments did not support more species per unit area than small fragments and suggested that arthropod responses to fragmentation are not only limited to reduced habitat area and urban proximity, but also fire regimes and degradation of habitats may also have roles in arthropod assembly in urban landscapes.

The results of my study indicate that coastal fragmented urban landscapes do not negatively affect arthropod biodiversity. My diversity counts revealed higher arthropod diversity in small urban fragments. However, as mentioned in the literature review, a problem with urban ecology studies is differences in the level of urbanization at different test sites. “Urban” has different meanings depending on the study, and this confusion causes difficulty in making absolute conclusions about my results. Since the definition of urban varies between studies, it is difficult to state for certain that my arthropod diversity counts are higher than in other urban landscapes. Even more difficult is understanding how my urban arthropod diversity counts compare to diversity in non-urban landscapes. Future studies examining arthropod diversity in urban fragments as well as non-urban landscapes would clarify my results and lead to greater understanding of how arthropod assemblages differ in urban and non-urban environments.

Several arthropod orders were found in branch clippings from small sites only. Among these orders were Ephemeroptera (Mayflies), Plecoptera (Stoneflies), Neuroptera (Lacewings), and Hymenoptera (ants). Ephemeropterans were found in branch clippings from Hellmers Lane (a small site) on March 20, the first sampling date of the season. Since Ephemeropterans have short life spans, it is not unusual that I found this order on only one day of the season. However, I do not know why this order only appeared in Hellmers Lane. The majority orders from branch

clippings in both large and small sites, Arachnids and Coleopterans (spiders and beetles) were not surprising for branch clippings from the level of forest that I studied.

Diversity counts in leaf litter revealed that arthropod diversity does not depend on fragment size. Hymenopterans and Dipterans dominated diversity counts in leaf litter in both large and small fragments. Hymenopterans (ants) made up 69% of the arthropod population in leaf litter in large sites and 54% in small. This is not surprising for leaf litter counts of arthropods. With Hymenopterans (ants) and Dipterans (flies) removed from arthropod counts in leaf litter, interesting differences between large and small sites are revealed. Blattodea (cockroaches) made up 10% (without Hymenopterans and Dipterans) of the arthropod population in small sites and 2% in large sites. Hemipterans (true bugs) made up 15% of (without Hymenopterans and Dipterans) the arthropod population in small sites and 4% in large sites. Isopodans (roly poly) made up 23% of (without Hymenopterans and Dipterans) the arthropod population in small sites and 13% in large sites. Coleopterans (beetles) made up more of the population in large sites than in small, 19% in large (without Hymenopterans and Dipterans) and 3% in small.

The most exciting results of my diversity counts are my findings that diversity of arthropod populations in leaf litter is higher in small sites than in large. The small sites I studied were residential. My results indicate that backyards in urban neighborhoods are not a damaging environment for arthropods. In fact, the residential areas I studied support more biodiversity in arthropod populations than in the large sites (state parks). While diversity counts of arthropods in branch clippings did not reveal more biodiversity in either large or small sites, the lack of a difference is still an exciting result. Again, my results do not indicate that urban neighborhoods are damaging to arthropod biodiversity in trees. The results of my arthropod diversity counts are

an example of how urbanization is not always negative to biodiversity. Urbanization can have negative and positive impacts on different areas of a community, and studies in urban ecology are important to understanding the full effects of urbanization.

Confounding Factors

Confounding factors existed primarily in field methods. Throughout the season, I brought different people to assist me in gathering sample. I trained each assistant in the field, and most of their help was in gathering branch clippings. However, assistants stayed with me along each transect, and I was present to supervise and check their branch clippings. Assistants only helped in leaf litter samples by helping me to spot arthropods—I classified and measured the arthropods in leaf litter. Another confounding factor to consider in field methods is consistency in insecticide. Efforts were made to distribute a similar amount of insecticide to each sample, but this certainly varied (different people spraying insecticide, differences in insecticide in a full bottle versus an almost empty one). Also, Some arthropods likely escaped the plastic bags before the bag was sealed. Varying bird populations between sites could also affect the arthropod data I received, but until other studies in these same test sites are completed, differences in bird abundance between the four sites is unknown. Finally, all four test sites are located in Jackson County, which is subject to periodic spraying of insecticide for mosquitoes by Mississippi Mosquito Control Incorporated. This mosquito control method could have affected numbers of mosquitoes I found in my samples. However, I did not test directly for flying insects. Mosquitoes that did not land within the leaf litter quadrant during testing were not counted.

In addition to confounding factors with the actual sampling techniques we used, it is important to note that the field methods used for this study are not the only methods for gathering arthropod samples. I only sampled two layers of vegetation, and other methods could have been used to sample higher levels of vegetation, flying arthropods, ticks, etc.

Confounding factors in laboratory techniques include classifying the arthropods. I could have made mistakes in classifying some of the arthropods, and some arthropods I found may have been disfigured enough (sometimes from over-saturation of insecticide) to cause an incorrect taxonomic classification. In addition, errors may have occurred in weighing the branch clippings.

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