Urbanization Effects on Leaf Mining Densities and Leaf Damage of White Oak (*Quercus alba)* in Guilford County, North Carolina

Abstract

The urban habitat is the fastest growing ecosystem on Earth. Some organisms may respond to urbanization negatively by becoming locally extinct, while others respond positively and increase in numbers or densities. Leaf miners are insects whose larvae eat and live inside the leaves of plants until they pupate and emerge as adults. White Oak (*Quercus alba)* trees are common hardwood trees in Guilford County, and are well known hosts of leaf miners. In this study, the effects of urbanization on leaf miners and leaf damage by other herbivorous insects on white oak trees was examined. Six urban and rural parks were selected for investigation. In each park, three trees were selected and 50 leaves were picked at random for analysis. I hypothesized that leaf damage will be lower and leaf miner density will be higher in urban than rural areas. Leaf damage was significantly lower in urban areas than rural areas. Leaf miner abundance was lower in urban areas, but not significantly so. The mechanisms for lower leaf damage and possibly lower leaf miner densities in urban areas should be examined more in detail. The different type of leaf damage (e.g., chewers, skeletonizers, sap feeders, etc.) should also be investigated to test if urbanization differently affects insect feeding guilds.

Keywords: Folivorous Insects, Urban Ecology, Forest Fragments

Introduction

The urban ecosystem is the fastest growing habitat worldwide (Grimm et al, 2008). Urban habitats impose selective filters on organisms because of pavements (impervious surfaces), heat islands, soil disturbances, lighting, and various other aspects (McKinney 2002). Urban ecology studies fall into four categories: comparison of differing land use types in an urban setting, comparison of an urban area to a natural area, rural to urban gradient analysis, and urban development dynamics (McIntyre et al. 2000). The definition of "urban" and "rural" varies widely. Rural areas are locations of where there is assumed little to no anthropogenic influence (McIntyre et al. 2000). Many studies view "urban" as the presence of humans and "rural" as the absence of humans (McIntyre et al. 2000). However, other studies have used the presence of impervious surfaces and land cover instead of human density as a way to quantify the degree of urbanization (McDonnell et al. 1997).

Urban ecosystem effects on diversity and abundances of animals, plants, and microbes have been well studied (Grimm et al. 2008). In general, animal species richness decreases, whereas plant species richness increases in urban cities (Faeth et al 2011). For arthropod species, diversity declines but abundances of some taxa may increase in cities (Faeth et al. 2011, Raupp et al. 2011). Meineke et al. (2013) found a positive correlation between insect pest abundances and urban heat island effect. Raupp et al. (2011) suggested that few studies have provided clear mechanisms for explaining insect abundance patterns in urban areas.

With urbanization of the land comes fragmentation of preexisting ecosystems. This is commonly seen within city parks where there is an abundance of biota encased in a colossal network of impervious surfaces. This network of impervious surfaces separates the city parks from the original forest creating a patchy network of forest fragments within a city. There are many impacts on wildlife in and between these forest fragments. Bolger et al. (2000) found that arthropod point diversity and abundance was positively correlated with forest fragment size and negatively correlated with forest fragment age. Rickman and Connor (2003) have suggested that small herbivorous insects, with a sufficient amount of host plants present, are not impacted by the fragmentation of a natural forest due to their relatively small size.

Leaf miners are insects whose larvae live and eat inside the parenchyma or epidermis tissues of many plant species (Needham et al. 1928, Hering 1951). Most of these species are moths (Lepidoptera), but some are flies (Diptera), beetles (Coleoptera), and sawflies (Hymenoptera) (Rott & Godfray 2000). These insects are considered pests in urban areas due to their destruction of leaves. They leave a discolored tunnel, which comes in various shapes (e.g., serpentine and blotch), depending on the species. Some leaf miners will pupate inside of the leaf they occupy, while others will exit the leaf to pupate. Each species makes a unique pattern in the leaf. Leaf miners are excellent study species because each species has a specific mine morphology, and survival or cause of mortality can be determined from the mine (Rickman & Connor 2003, Opler 1974). This makes data recording considerably easier because the actual insect is not needed for the collection. To determine the species, one just has to examine the mine morphology. The number of mines per leaf determines the leaf miner density.

Previous studies have used leaf miners to evaluate the effects of urbanization. Kahn & Cornell (1989) showed that *Phytomyza ilicicola*, a leaf mining insect, has a greater abundance on American holly *(Ilex opaca*) leaves in urban areas due to lower rates of parasitism. Alternatively, Rickman & Connor (2003) showed that the species richness and total abundance of Lepidoptera leaf miner species on coast live oak (*Quercus agrifolia*) trees was not positively or negatively associated in a consistent manner with urbanization.

White oak (*Quercus alba)* trees are deciduous trees that are common in the southeastern forests of North America. They go through abscission in the fall (around November) and grow leaves in early spring. White oak trees are very common in leaf miner studies and the complement of leaf mining species is well known (Hering 1951). On white oaks, the majority of the leaf miner species are moths.

Besides leaf miners, other herbivorous insects may be influenced by urbanization. There is a hypothesis that herbivory is greater on urban trees due to the larger abundance of herbivorous insects, although this is based on studies determining insect abundances rather than actual leaf damage (Nuckols & Connor 1995, Matter et al. 2012). However, Nuckols & Connors 1995 and Matter et al. 2012 showed that leaf damage was not different between urban and rural trees and in natural versus ornamental settings. In contrast, Meineke et al. (2013) found higher densities and higher survival rates of scale insects on urban trees due to the warmer city temperatures.

In this study, the differences in densities of leaf miners on white oak (*Quercus alba)* trees in urban and rural sites were examined. The amount of insect damage or necrotic area on white oak leaves was examined as well. Since Khan & Cornell (1989) found a lower parasitism rate of leaf miners on holly trees in urban areas, I hypothesized that the density of leaf miners on white oak (*Quercus alba)* trees will be higher in urban areas than rural areas. Numerous studies have noticed a decline in herbivorous insect abundance with urbanization (Faeth et al. 2011, Raupp et al. 2011, Denys & Schmidt 1998). With a lower presence of herbivorous insects, there should be less consumption of leaves. Therefore, I hypothesized that leaf damage or necrotic area will be lower in urban areas than rural areas. This study gives insight on the impact that urbanization has on insect pests and could be used in pest management and monitoring. Additionally, it gives further insight on the herbivorous leaf damage differences in urban versus rural areas, which is a poorly studied area (Matter et al 2012).

Methods

The study locations were in Guilford County, North Carolina at six different parks (Appendix A). The three urban parks were: The Bog Garden, Peabody Park, and Lindley Park. The three rural parks were: Hagan-Stone Park, Haw River State Park, and Southwest Park. Urbanization was defined by human population density. All urban park locations were inside the city limits of Greensboro, which had the highest human population density of all Guilford County (U.S. Census Bureau 2010). All rural locations were located outside the city limits of Greensboro.

Three trees of approximately equivalent size were selected from each of the parks and GPS coordinates were recorded for each tree (Appendix A). Each tree was either a part of a forest (rural study sites) or forest fragment (urban study sites) and not in an ornamental setting. Fifty leaves were collect by hand at random from each of the trees. Only leaves from the understory were collected. I attempted to pick leaves from well-established white oak trees to prevent any damage to the tree. There were 18 trees in all (nine in urban and nine in rural locations) and a total of 900 leaves (450 in urban and 450 in rural locations).

The leaves were analyzed in a lab for two parameters: leaf miner presence and the amount of necrotic/damaged area of each leaf. The number of leaf miners on each leaf was recorded and the type of leaf miner determined (e.g., blotch, serpentine, etc.). Necrotic leaf area was determined by a visual analysis. Each leaf was given a number from zero to four. Zero was assigned to leaves which had no visual area of damage, one to leaves that had 1% to 25% of its area damaged, two to leaves which had 26% to 50% of its area damaged, three to leaves which had 51% to 75% of its area damaged, and four to leaves with 76% to 100% of its area damaged. To prevent any discrepancies in the data, one person performed the entire analysis of necrotic leaf area.

Descriptive statistics were used (mean and standard errors) to show differences. An analysis of variance (ANOVA) was used to test for significance between and within urban and rural sites, with each tree used as replicate (three trees at each site; three sites per habitat).

Results

Leaf miner abundance was greater in rural than urban study sites (Figure 1), but this difference was not significant (F-value: 1.154, df: 1, P: .324). Leaf damage was significantly different between urban and rural study locations (F: 22.566, df: 1, P; .003). There was more leaf damage on rural trees than urban trees (Figure 2). For both leaf damage/necrosis and leaf miner densities, study sites did not significantly differ in and between urban and rural study sites (leaf damage: F-value: 1.067, df: 4, P-value: 0.448 and leaf miner density: F-value: 0.468, df: 4, P-value: 0.862). Furthermore, trees in and between urban and rural study sites did not significantly differ for leaf damage/necrosis and leaf miner abundance (leaf damage: F-value: 0.697, df: 6, P-value: 0.664 and leaf miner density: F-value: 0.389, df: 6, P-value: 0.862).

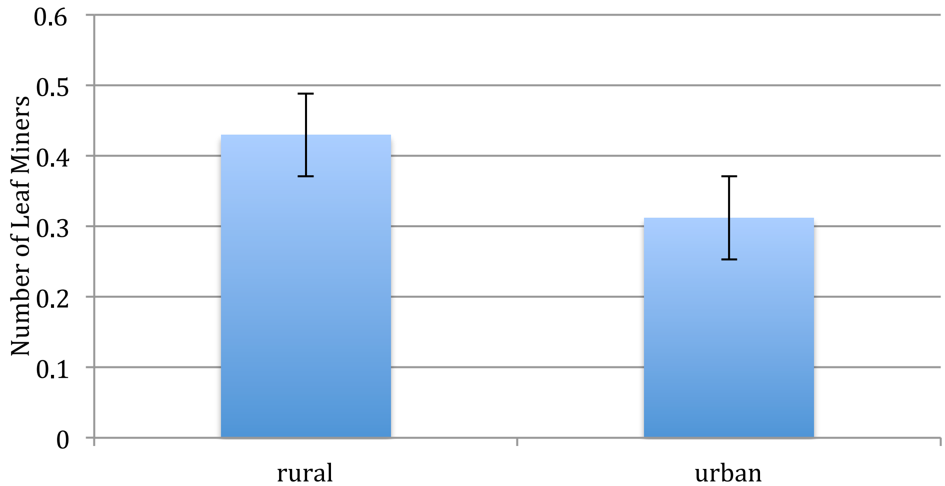

Figure 1. Leaf miner abundance averages in rural and urban areas. Standard error shown with black bars.

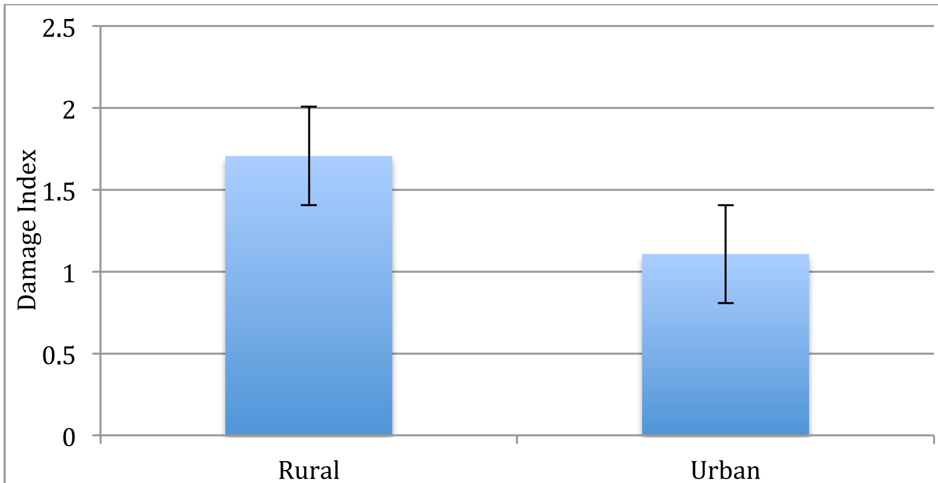

Figure 2. Leaf damage averages in urban and rural areas. Standard error shown with black bars.

Discussion

There was a general trend of decreasing leaf miner abundance with urbanization, although this difference was not significant. However, the results could be insignificant due to a small sample size. Increasing the sample size to increase the power of the test may have revealed significant differences. The results of this study coincide with Rickman & Connor (2003) in that there was no significant difference in urban and rural habitats. This is attributed to the persistent characteristic of leaf miners in small fragmented forest patches (Rickman & Connor 2003). Leaf miners are generally small insects, and small insects have been shown to have robust populations in relatively small habitat patches (Abensperg-Traun & Smith 1999, Hafernik 1993). Thus, fragmentation may have lesser effects on small insects than larger ones. This study opposes Kahn & Cornell (1989) where a higher density of native holly leaf miners was found on urban holly trees due to a lower parasitism rate in urban areas. Parasitism may not have as big of an impact on leaf miner densities on white oak trees, however there is no evidence from this study to support this hypothesis. Further study is necessary to determine if the trend towards lower leaf miner densities on white oak trees in the urban setting is real.

Leaves were significantly more damaged in rural than in urban areas. This suggests that urbanization lowers the rate of herbivory. In rural areas there is less of a human impact on herbivorous organisms and therefore more damage is dealt to white oak trees. Nuckols & Connor (1995) found a similar result in that urban forest fragments saw lower leaf damage than rural, however their results were not significant. Nuckols & Connor (1995) attributed the lower leaf damage on urban trees to either higher levels of plant resistance or lower survival rate of insects. Other studies have found that forest fragments inside heavily urbanized areas are less likely to be recolonized and fragmentation has more of an impact on insects than patch size (Rickman & Connor 2003, Kozlov 1996, Van Dyck & Matthysen 1999). Although with small herbivorous insects, the presence of a sufficient amount of host plants (in this case, white oak trees) may be enough for a persistence population in isolated, urbanized forest fragments (Rickman & Connor 2003). In this study, patch size and distance from other patches was not evaluated, but without the recolonization of fragments, there could be a conceivable lower herbivorous insect species richness (similar to Bolger et al. 2000 results) and one could suspect a general decrease in leaf damage as compared to rural, continuous forests. It could also be proposed that lower leaf damage in urban areas was due to a higher presence of pesticides. Generally with more pesticides, the abundance of insects would be lower. Since there is a lower insect presence, the leaves are less damaged. However, there is no evidence from this study to support this idea; it should be examined further in the future.

Leaf miner density and leaf damage was not different in urban and rural habitats for both sites and trees (e.g., urban trees were found not to be statistically different within the three urban parks: Lindley Park, The Bog Garden, and Peabody Park). This suggests a uniform impact of urbanization between different locations throughout Greensboro.

There are limitations to my study other than sample size. It is important to mention that leaf damage analysis was determined on a visual scale, and not numerically quantified. If one were to recreate this observation with a more exact measuring method of leaf damage, it would even further the results found in this observation. That being said, the data was all retrieved by one person and statistically, none of the urban or rural study sites differed from each other. Therefore, one could say that this study is a good indicator of leaf damage and leaf miner density differences in urban and rural areas.

The result of lower leaf damage in urban areas is an important finding with many insights for further investigation. For example, does the lower rate of herbivory suggest a lower abundance of herbivorous organisms, or does it suggest a lower rate of food consumption? The different types of leaf damage should be examined, similar to what was done in the study by Nuckols & Connor (1995). Knowing what insect feeding guild damages leaves more often than others might suggest which groups are more impacted by urbanization.

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Appendix A. Study site locations and individual tree GPS coordinates.

Urban				Rural			
Location	Tree	GPS coordinates		Location	Tree	GPS coordinates	
The Bog Garden	A	N 36.089195	E -79.838469	Haw River State Park	A	N 36.250171	E -79.754411
	B	N 36.089576	E -79.839330		B	N 36.250302	E -79.754194
	C	N 36.089064	E -79.838715		C	N 36.250509	E -79.754093
Lindley Park	A	N 36.071035	E -79.839561	Hagan-Stone Park	A	N 35.953499	E -79.735667
	B	N 36.070958	E -79.839389		B	N 35.953747	E-79.735195
	C	N 36.070148	E -79.842355		C	N 35.957766	E -79.737119
Peabody Park	A	N 36.073092	E -79.810163	Southwest Park	A	N 35.942809	E -79.872925
	B	N 36.03114	E -79.810892		B	N 35.942891	E -79.872911
	C	N 36.072603	E -79.811211		C	N 35.943441	E -79.872453