Volume 12 Article 5

2023

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Shelby Johnson
DePaul University, sjohn233@depaul.edu

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Acknowledgements

I would like to acknowledge Dr Christie Klimas, Dr Mark Potosnak, and Dr Matthew Nelsen for their help and guidance throughout the research process. I would also like to thank the College of Science and Health at DePaul University and the Field Museum.

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Shelby Johnson*

Department of Environmental Science

Christie Klimas, PhD; Faculty Advisor

Department of Environmental Science

ABSTRACT Both anthropogenic change and the spread of invasive species have led to changes in urban and forest tree diversity. Oak rust, acute oak decline, and emerald ash borer have all had a detrimental effect on tree species in the Chicagoland area. *Quercus* species, or oak, are well known habitats for lichen species including *Physcia millegrana, Physcia stellaris, Punctelia rudecta, Flavoparmelia caperata, Xanthomendosa,* and *Candeleria concolor.* As the traditional *Quercus* habitats for lichen have been decreasing, there has been an increase in nonative and nontraditional tree species being introduced, particularly in cities. This study aimed to compare the number and diversity of lichen species between trees outside of Chicago (forest locations) and trees inside the city (city locations) to determine if lichen would be observed on new host tree species. We hypothesized that in the absence of *Quercus* species, lichens would be observed on new host tree species. Lichens were surveyed along transects in urban and forest preserves, with tree species and geographic location recorded. A generalized linear model was plotted. It was found that *P. milegrana* was consistently found on oaks (*Quercus*) and honey locusts (*Gleditsia*) in forest preserves, while *P. stellaris* were found on forest floors. *P. rudecta* and *F. caperata* were found along isolated honey locusts in forest preserves and urban areas while *Xanthomendosa* and *C. concolor* were found throughout both locations and tree species. In urban areas, *P. milegrana* was found to live on maples in absence of preference species of oaks, however it was found mostly on *Quercus* species. *P. rudecta* and *F. caperata* were found on honey locusts both in city and in forest preserves. P-scores less than 0.05 indicated a statistical difference between forest and city locations and between *Quercus* and non-*Quercus* species, with non-*Quercus* species hosting significantly less lichens than *Quercus* species. While lichens were present on nontraditional tree species, the number of lichens on nontraditional were on average less than lichen species observed on the traditional tree species, *Quercus*.

*sjohn233@depaul.edu

Research Completed in Fall 2022

INTRODUCTION

While trees in the *Quercus* family are traditional habitats for lichen, Chicago has experienced a decline in the number of live oaks over the past ten years. This has occurred, and continues to occur, due to several factors, including sudden oak death, a condition which is characterized by early leaf fall and a loss of canopy cover and branches (Oak Decline NPS). Climate, age, and other underlying diseases also lead to oaks needing to be cut down or succumbing to natural causes (Oak Decline NPS). Oak decline makes oaks more susceptible to pests, such as the two-lined chestnut borer beetle, or bacterial infections.

Oak populations have also been impacted by a decline in oak recruitment. Tree species such as *Gleditsia triacanthos*, or honey locust, and *Acer*, or maple trees, have fast grow times and have grown in popularity due to their leaf colors in the fall. These factors have made the trees favorites when new buildings or parks are constructed, pushing out oaks that have slow grow times.

Oak recruitment has also declined due to invasive species. *R. cathartica*, commonly known as buckthorn, originates from Eurasia but was introduced to America in the 18th century (Oak Decline NPS). The shrub is shade tolerant, matures quickly, and does not require soil disturbance to colonize, making it highly successful in wetlands, pastures, and woods (Glossy Buckthorn Acadia NPS). Buckthorn has also been shown to alter the soil's composition and consume resources at faster rates, letting the shrub outcompete oak samplings (Heneghan et al., 2006).

Changing tree composition can have cascading impacts. Tree species provide important habit for lichen. Diversity of lichen species is associated with host tree identity (Llewellyn et al., 2020). Specific tree traits also determine lichen diversity and subsequent abundance (Sebald et al., 2022).

While multiple species of lichen can be found in a single ecosystem, their importance is often overlooked. Previous studies and data also suggest that lichen can be an energy source for soil microorganisms and synthesize secondary metabolites, impacting their plant substrate (Piznak & Backlor, 2019). Several lichens species have been used as bioindicators in previous studies due to their abundance and higher tolerance of nitrogen while also acting as nitrogen sinks (Rai & Gupta, 2022). Recent studies have also begun to use lichens as bioindicators for sulfur (Elias et al., 2022).

Lichens *P. millegrana, P. stellaris, P. rudecta,* and *F. caparata* host trees have traditionally been found and associated with oaks. *P. millegrana* has been shown to thrive on isolated oak trees (Hale, 1955). With oak decline and a loss of oak recruitment, traditional tree habitats for lichen are declining. The goal of this study was to compare the number and diversity of lichen species between trees outside of Chicago and trees inside the city to determine if lichen would be observed on new host tree species. We hypothesized that in the absence of Quercus species, lichens would be observed on new host tree species.

METHODS

This hypothesis was tested in two locations; (1) woodland forest preserves outside the city of Chicago and (2) small greenspaces within the city of Chicago. Both city locations were North of Central Chicago. The forest locations were chosen for their close proximity to major roadways to emulate city trees surveyed. Preserve locations chosen were Busse Woods

and Allison Woods, shown as a brown and green marker in Figure 1 respectively. At each location, a 50-meter-long tract was selected along the outside of the woods to be surveyed as the "edge location". Edge locations chosen due to the similarity to city locations as the trees were exposed to more light and anthropogenic contact, such as cars.

Throughout the selected tract, tree trunks were examined at 1.5 meters above the ground. If any lichens were observed, as seen in Figure 2, the tree species, tree number, and lichen or lichens observed were recorded. If there was an absence of lichen species on trees, "None" was recorded under lichen species. For the city data, there were two sublocations in Lincoln Park and North Halsted, shown as a red and yellow marker in Figure 1, respectively. City locations were chosen based on Cardinal location, as both forest locations were North of Chicago, and geographic closeness to forest locations. The city locations had a similar latitude as forest locations, with ±1.00 degree of difference.

The species of any lichen observed was recorded, as was the absence of lichen from the tree. Tree species were identified using a tree field guide from the Field Museum and iNaturalist. Lichen species were identified from a Common Lichens of Chicagoland [Field Museum]. The number of trees observed, individual tree species, and lichen species found on tree from a height of 1.5 meters were recorded for both forest and city location. Lichen species *P.millegrana*, *P. stellaris*, *P. rudecta*, *F. caperata*, *Xanthomendosa*, and *C. concolor* observed on trees were recorded for each location. Number of tree species observed in forest preserve sites and tree species observed in city location were compared. To determine whether presence and absence of lichen species differed by location and tree species (non-oak and oak) I used a generalized linear model in R with a Poisson distribution.

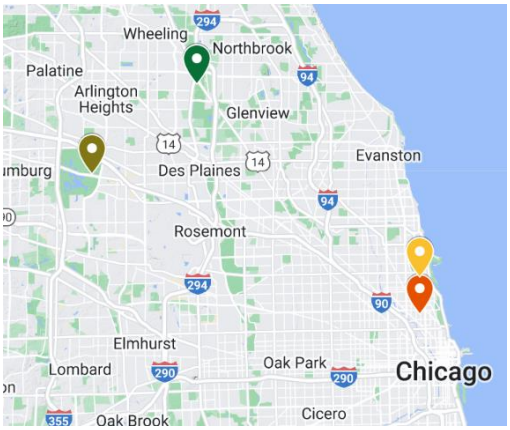

Figure 1. Marked forest and city locations of Busse Woods, brown, Allison Woods, green, Lincoln Park, red, and North Halsted, yellow.

Figure 2. Lichens that were observed on 1.5 meter area of tree trunk.

RESULTS

Tree Species

The forest preserve site of Busse Woods was observed to have tree species primarily in the *Quercus* family (Table 1). Allison Woods site was observed to have been primarily *Quercus* and *Acer* tree species. Urban areas had greater tree species diversity when compared to forest preserves. Higher species diversity in urban areas was demonstrated by the large populations of *G. triacanthos*, *Gingko biloba*, *Fagus*, *Quercus*, and *Acer* present in the same observed transect while forest preserves were observed to

be primarily composed of only one or two genera. Oaks accounted for the most tree species observations in forest preserve locations, with 65% of observed species in Allison Woods and 61% of observations as *Quercus* in Busse Woods. In city locations these numbers dropped by almost 50%, where only 31% of trees in Northalstead and 27% of Lincoln Park trees were *Quercus*.

Lichen

Lichens that were observed in forest preserves were primarily found to be *P. milegrana* or *P. stellaris*. *P. milegrana* were observed to be mainly on *Quercus*, while *P. stellaris* and *P. rudecta* observed on *G. triacanthos* as seen in Figure 2. In urban sites, *P. milegrana* was primarily found on members of *Quercus* family while *P. stellaris* was predominantly found on *G. triacanthos*. A greater amount of lichen diversity was seen on *G. triacanthos* in both urban areas and in forest preserves (Figure 3).

Location	Tree Species	Observed
Allison Woods	Oak	13
Allison Woods	Basswood	5
Allison Woods	Maple	2
Busse Woods	Oak	17
Busse Woods	Black Cherry	4
Busse Woods	Shagbark	4
Busse Woods	Maple	2
Busse Woods	Honey Locust	1
Lincoln Park	Oak	9
Lincoln Park	Birch	2
Lincoln Park	Ash	1
Lincoln Park	Shagbark	1
Lincoln Park	Linden	2
Lincoln Park	Elm	2
Lincoln Park	Maple	5
Lincoln Park	Honey Locust	10
Lincoln Park	Ginko	1
Northalstead	Maple	4
Northalstead	Oak	4
Northalstead	Pine	1
Northalstead	Walnut	1
Northalstead	Elm	2
Northalstead	honey locust	1

Table 1. Number of observations of individual tree species per location.

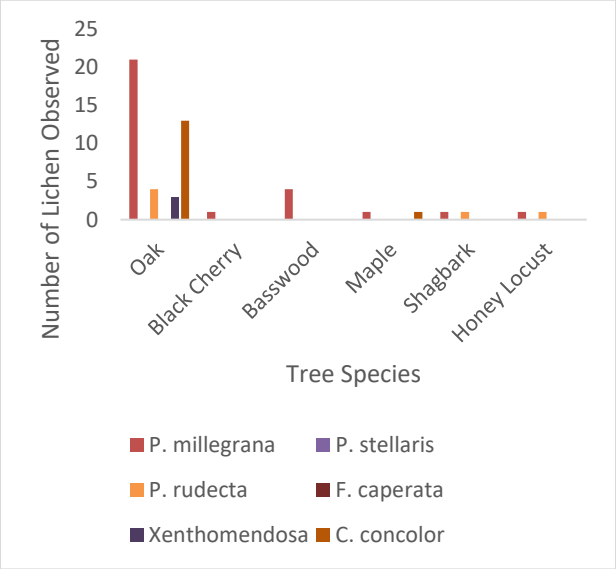

Figure 2. Number of lichen species per tree species observed in Forest Preserve sites Busse Woods and Allison Woods.

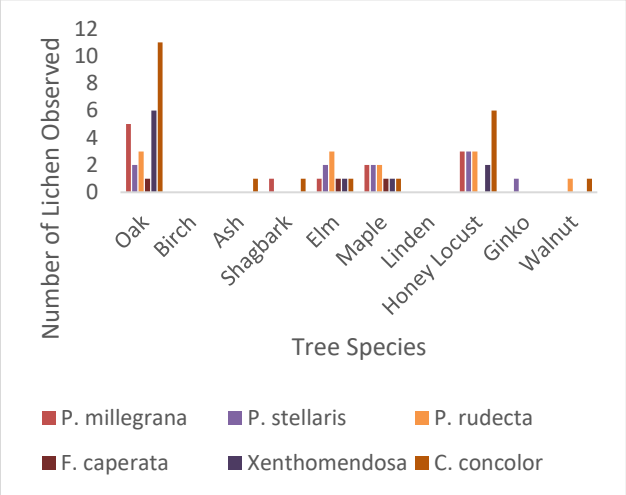

Figure 3. Number of lichen species observed per individual tree species in Lincoln Park and Northalstead neighborhoods of city locations.

The distribution of total lichens was not normal: a poisson distribution was the best fit for this variable. Generalized linear models with a poisson distribution were used to test for difference in total lichen presence by location (city; forest preserve) and tree species (oak; not oak). Lichen presence was significantly higher in the city, with $p<0.00354$, and on oak trees $p<0.00162$ (Figures 4 and 5).

Location analysis for SumLichen, average lichen presence, was greater in the city location than the forest, (Figure 4). The Tree Species analysis was less for non-*Quercus* than *Quercus* in the Tree analysis, indicating that *Quercus* had more lichen observed than non-*Quercus* (Figure 5). The calculated p-values for both the Sum of Lichen and Tree Species comparison and the Sum of Lichen Species and Location were both >0.05. For the location analysis, there was a negative direction for the p-value, indicating that the city had greater observation, or presence, of lichen, as seen in Figure 4. The tree species comparison between Oak and Non-Oak had a positive direction, which, combined with the significant p-value, indicated that Oaks had more observed lichen than non-Oaks, as seen by Figure 5.

Figure 4. Boxplots of Sum of Lichen observed on trees comparing Locations: City and Forest Preserve.

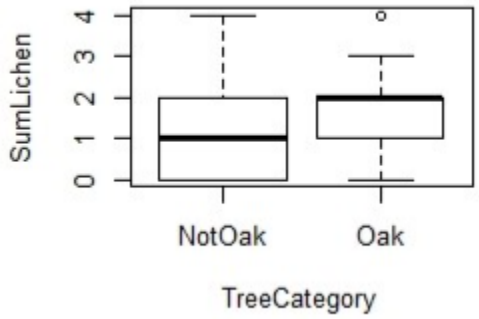

Figure 5. Boxplot of Sum of Lichen observed on individual tree species comparing Tree Categories of Oak and Not Oak.

DISCUSSION

When comparing the city locations and forest locations, the city locations had more lichen. This higher rate of lichen observations was likely due to light availability. Lichens are a mix of fungi and photobyionts and need light in order to photosynthesize food. The recorded trees in urban areas were also highly isolated while trees in forest preserves were densely packed creating a difference in canopy openness and light availability. Isolated trees, or trees with little to no flora nearby, have been shown to have more lichen species living and thriving on them when compared to trees in forests (Hale, 1955). The isolated trees are similar to trees in cities which have few, if any, tall trees nearby allowing for light to reach lichen. But light availability is not the sole factor for lichen observations.

Previous studies have noted that lichen abundance is dependent on several factors (Pinho, et al., 2008 & Sebald et al., 2022). One of the factors that has been studied is tree species; however, how tree species influence lichen diversity is not universal. Some authors have argued that non-native trees reduce lichen diversity (Calvino-Cancela, et al., 2013; Rios et

al., 2014), while other authors (Quine & Humphrey, 2010; Gonzalez-Montelongo & Vargas, 2021) have shown that non-native trees are not guaranteed factors for the reduction or change of lichen diversity. Individual tree species have been shown to have lichens that prefer those tree species when compared to others (Kubiak & Osyczka, 2019). The results gathered from the city and forest locations in this study showed that *Quercus*, the native tree species in Illinois, had more lichen observed when compared to non-*Quercus* tree species. This higher rate of observations on *Quercus* trees than non-Quercus trees supports previous studies that found that *Quercus* density has previously been shown to influence lichen species richness (Paltto, et al., 2006; Westerberg et al; 2017). *P. milegrana* did particularly well on *Quercus* trees in both forest and city locations. The higher rates of lichen species observations in areas with more *Quercus* when compared to non-*Quercus*, in an absence of *Quercus* lichen were still observed. These observations of lichens even in locations where a majority of trees were recorded as non-*Quercus* support the hypothesis that lichen are present in areas of *Quercus* absence.

CONCLUSION

The lichen *P. millegrana, P. stellaris, P. rudecta, F. caperata, Xanthomendosa,* and *C. concolor* were not observed to be completely absent from tree species when traditional tree habitats were absent. While lichens were seen on new host tree species, *Quercus* had higher numbers and diversity of lichen species even in areas of lower density as seen in city locations. Further analysis is needed to determine if specific tree species are greater contributors to lichen species population and diversity, specifically *G. triacanthos*. In the future the neighborhoods and forest preserves observed could be expanded including neighborhoods in Central, South, and West Chicago with forest preserves outside of Chicago being included. Further lichen species could be included to develop a broader picture of lichen species diversity in forest and city locations.

ACKNOWLEDGEMENTS

The author acknowledges the support of Dr Christie Klimas and Dr Mark Potosnak, as well as the Field Museum and Dr Matthew Nelsen.

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