DePaul Discoveries

Volume 5 | Issue 1 Article 8

2016

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Acknowledgements

We would like to thank Ramsey Milton for assisting us in the collection of plant diversity data in the summer of 2015. In addition, we would like to thank Mason Fidino and Liza Watson Lehrer from the Lincoln Park Zoo Urban Wildlife Institute for their support throughout the entire process.

Investigating the Relationship between Plant Diversity and Wildlife Species Richness in Chicago Area Forested Greenspaces

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ABSTRACT Factors related to urbanization have altered the pre-settlement landscape of Chicago from native prairie and woodland, to one dominated by non-native plant species. This study examined how the plant community influences urban wildlife by investigating how vegetation structure (as measured by three indices) relates to the wildlife richness of 24 forested sites in the Chicago region. We found negative relationships between both Floristic Quality Index (FQI) and native plant diversity with wildlife richness. We propose that the generalist mammal species that were detected using the camera trap method do not require high quality forested habitat and seem to prefer lower quality forests that have fewer native plants, most likely dominated by dense invasive shrubs such as buckthorn. Habitat structure and landscape level parameters are likely stronger predictors of wildlife species richness in this highly urbanized landscape.

INTRODUCTION

Over the past 150 years the landscape of the midwestern United States has drastically changed (Fahey et al., 2014). Historically, the Chicago area was dominated by both prairies and wooded ecosystems, but the remaining greenspaces now feature a dominance by shade tolerant sugar maple (*Acer saccharum*) and invasive European buckthorn (*Rhamnus cathartica)* as well as a much higher canopy cover and stem density (Fahey et al., 2014). Human influences such as urbanization and the removal of a fire disturbance regime have been a major contributor to these changes.

Factors related to urbanization have caused a significant change in plant community diversity and structure. Vakhlamova et al. (2014), analyzed the changes in plant species composition along an urban-rural gradient in Central Asia. They found that with distance from the city center plant species diversity increased and non-native plant species decreased. Their research pointed to urbanization causing a decrease in the diversity

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Research Completed in Winter 2016

of plant species and an alarming increase in the presence of non-native plant species. This trend could be a result of non-native plant species being better adapted to finding resources in urban habits than native plants. In addition, McKinney (2008) found that different levels of urbanization effect plant and vertebrate richness differentially. They discovered that different degrees of urbanization influence the diversity of species found in a particular region. For example most plant species show an increase in diversity with moderate urbanization. While there has been some research on how non-native plant species affect urban wildlife, relatively little research has been done to analyze the effect that the rapidly disappearing native plants have on wildlife species richness.

One of the most prevalent non-native species in the Chicago area is the European buckthorn (*Rhamnus cathartica*). Vernon et al. (2014) analyzed the effects of European buckthorn on wildlife species habitat use and determined that buckthorn affected the distribution of white-tailed deer, coyotes, and Virginia opossums in the Chicago area. They concluded that mesocarnivores such as coyotes, raccoons and opossums were much more likely to be found in sites that had been invaded with buckthorn due to higher prey availability, while white-tail deer tended to avoid buckthorn invaded environments, presumably because buckthorn thickets impeded movement of these relatively large animals.

Nature preserves are often established with the goal of conserving biodiversity. In Illinois the Illinois Nature Preserves Commission has established a network of nature preserves that harbor rare/endangered species or contain high quality remnant habitat. While there is evidence that non-native invasive plants alter urban wildlife habitat use, it is not well know how native plant diversity or quality alters wildlife habitat use in urban areas. In this paper, we will compare plant and wildlife richness from sites designated as Illinois Nature Preserves with non-designated sites to assess how native plants affect urban wildlife. Greater understanding of how native plants species and habitats influence urban wildlife will improve conservation recommendations and restoration planning.

One of the many ways to measure plant diversity and quality is through the Floristic Quality Index (FQI). The FQI is a commonly used index of plant quality by natural resource managers and conservation planners, and is utilized to determine the conservation value of an area. Swink and Wilhelm (1994) developed the FQI to assess the quality of plant species cover in the Chicago area. All plant species in a region are assigned a coefficient of conservatism ("C value") by expert botanists, and indicate the likelihood that a species will occur in a habitat unchanged or unaltered by humans. Plant species found only in undisturbed areas will have a higher FQI rating. Matthews et al., (2005) used FQI to determine habitat quality for wetlands in the Chicago area. They discovered that there is a positive relationship between wetland area and the conservation value of a site, but determined that site area may not be the only factor affecting FQI.

Our study aimed to examine the complex relationship between measures of plant diversity and urban wildlife along an urban to rural gradient. We predicted that there would be a positive relationship between native plant richness and wildlife richness, but a negative relationship between non-native plant richness and wildlife richness. We predicted that Chicago area wildlife would prefer the sites with more native plants because those are the plants they historically ate or hunted in. We predicted that FQI and wildlife richness would increase with distance from city center as deleterious urban impacts should be less amplified farther away from the city. Finally, we predicted that both FQI and wildlife richness would be higher in Illinois Nature preserves, as these sites are selected based on maintaining historical community compositions. Illinois Nature preserves are also more protected and less disturbed than non-nature preserves so there should be a high amount of quality native plants.

METHODS

This study took place in the Chicagoland area during the summer of 2015. A total of 24-forested sites were chosen from an ongoing study conducted by the Lincoln Park Zoo's Urban Wildlife Institute (UWI) along north, west and south-west transects radiating out from downtown Chicago (see Figure 1). During each season, the Urban Wildlife Institute places Bushnell motion-triggered infrared trail cameras at each of the sites for four consecutive weeks (Vernon et al., 2014). The cameras are mounted on trees at a height between 1.5 to 2 m and are aimed downward at the floor. Three different animals lures are also placed around the camera to entice animals (Vernon et al., 2014). We analyzed data from the camera traps collected during July 2015 and calculated the wildlife species richness of each site by adding the total number of species observed at each site.

Vegetation sampling occurred during August 2015. A nested design was used in order to analyze the different strata of vegetation (canopy, shrub, and ground layers) at each site. For each of the 24 sites we sampled within 1000 m^2 circular plots, with a radius of approximately 18 meters (Figure 2). We centered each plot on the camera trap, in an effort to best characterize the vegetation associated with wildlife habitat use.

Within the 1000 m^2 circular plot we analyzed the canopy, shrub, and ground layer. In order to quantify the tree canopy of each site, we measured the diameter at breast height (dbh) of all trees >10cm dbh within the 1000 m^2 plot and identified the species of all measured trees. Nested within the 1,000 m^2 area we placed four, 50 m^2 shrub density plots ~9 m north, south, east and west of the plot center. To quantify the ground later, nested within each of the shrub plots we placed a 1 m^2 quadrat frame and estimated the percentage cover of all ground layer species present.

Three different vegetation indices were calculated to characterize the plant community of each site. Native plant richness (i.e., the number of species) was calculated by determining the number of native plants present at each site. Non-native plant richness was calculated by adding the number of non-native plant species present. Floristic Quality Index was determined by assigning the conservation values (Swink and Wilhem 1994) ranging from 0-10 of all native plant species present. The average coefficient of conservatism (C) for the entire site was calculated and then multiplied by the square root of the total number of native plant species found at the site (N) to determine the FQI (Mathew et al., 2005).

$$FQI = C\sqrt{N}$$

In addition the distance to city center was calculated for each site and the sites were classified into those designated as Illinois Nature Preserves (n=5) and those that were non-nature preserves (n=19).

Linear relationships between wildlife richness, plant quality indices and distance from city center were tested using linear regression. To test if FQI and wildlife richness were greater in designated Illinois Nature Preserves, we used t-tests. Statistical tests were conducted using R. With an alpha value of 0.05 any p values below that were considered significant.

RESULTS

COMPARISON OF VEGETATIVE INDICES AND WILDLIFE RICHNESS

We observed a strong negative relationship between wildlife richness and FQI (R^2=0.421, p=0.0006; Figure 2) sites with higher FQI values had fewer animal species visiting and the site featuring the highest FQI had a wildlife richness of zero. A similar negative relationship was found between native-plant richness and wildlife richness (R^2=0.269, p=0.0093; Figure 3). There was no significant relationship between non-native plant richness and wildlife richness (R^2=0677, p=0.219; Figure 3).

Since no wildlife was observed at the site with the highest FQI (MacArthur Woods), we re-ran the analysis after removing this data point. We determined that if this site is removed from the analysis, there is still a negative relationship between FQI and wildlife richness with an R^2 of 0.227.

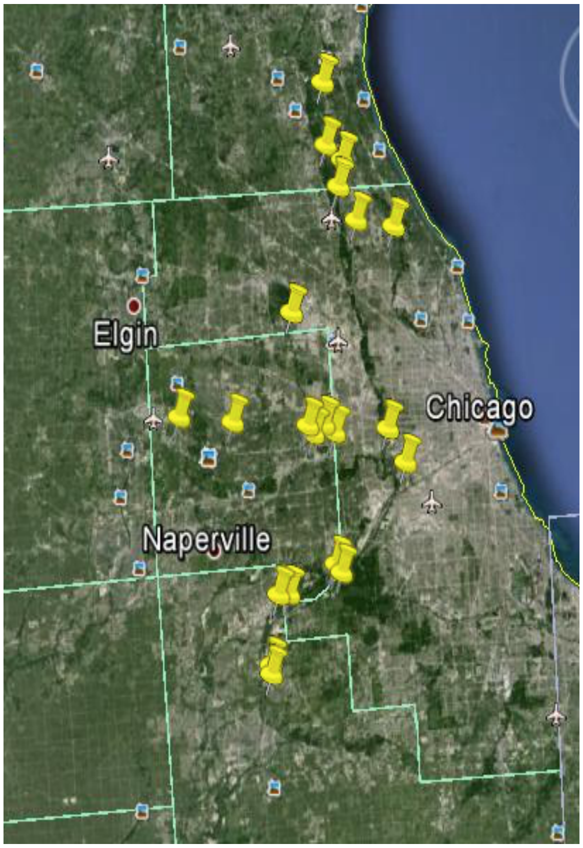

Figure 1. Map of 24 Chicago area forested sites where vegetation and urban wildlife data were collected during summer 2015.

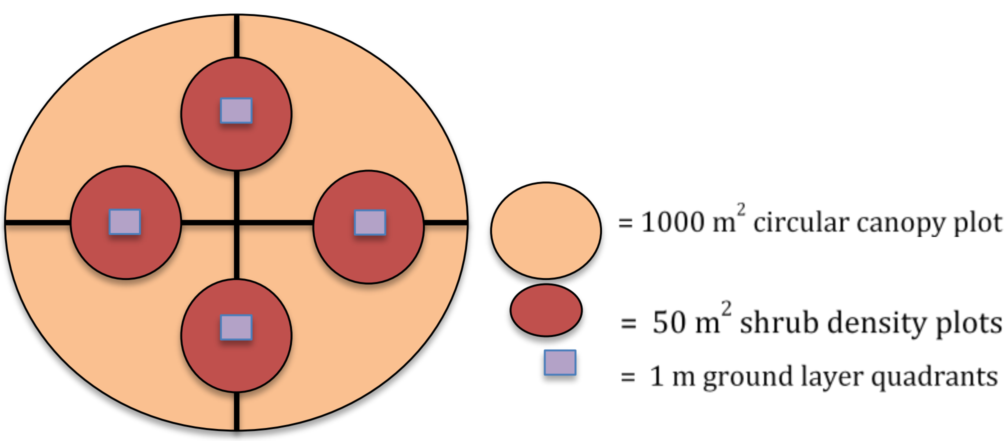

Figure 2. Example of nested design used to collect vegetation data

Table 1. Complete list of all the plant species observed in the 24-forested sites in the Chicago area. Not all plant species could be classified past their genus.

Acer saccharum	*Carya cordiformis*	*Eutrochium purpureum*	*Lycopus americanus*	*Prunus virginiana*	*Symphyotricium pilosum*
Acer saccharinum	*Carya ovata*	*Eupatorium maculatum*	*Lysimachia nummularia*	*Quercus macrocarpa*	*Taraxicum officinalis*
Acer negundo	*Caulophyllum thalictroides*	*Eupatorium serotinum*	*Mentha arvensis*	*Quercus rubra*	*Tilia americana*
Acer rubrum	*Celastrus orbiculatus*	*Fallopia convolvulus*	*Mimulus ringens*	*Quercus alba*	*Typha x glauca*
Ageratina altissima	*Celtis occidentalis*	*Fragaria virginiana*	*Morus alba*	*Ranunculus sp.*	*Ulmus americana*
Alliaria petiolata	*Cercis canadensis*	*Fragaria vesca*	*Ostrya virginiana*	*Rhamnus cathartica*	*Unk aster*
Allium sp.	*Circea lutiana*	*Fraxinus quadrangulata*	*Oxalis stricta*	*Rhus toxicodendron*	*Unk aster 2*
Arctium minus	*Cirsium arvense*	*Fraxinus americana*	*Panicum virgatum*	*Rhus typhina*	*Unk seedling*
Arisaema triphyllum	*Convallaria majalis*	*Galium triflorum*	*Parthenocissus quinquefolia*	*Ribes missouriense*	*Urtica dioica*
Asarum canadense	*Cornus racemosa*	*Geranium maculatum*	*Phalaris arundinacea*	*Rosa multiflora*	*Valeriana officinalis*
Asclepias sp.	*Crataegus mollis*	*Geum canadense*	*Phragmites australis*	*Rubus allegheniensis*	*Verbesina alternifolia*
Athyrium filix-femina	*Cyperus esculentus*	*Glechoma hederacea*	*Phytolacca americana*	*Rubus occidentalis*	*Vernonia gigantea*
Barbarea vulgaris	*Daucus carota*	*Hackelia virginiana*	*Pilea pumila*	*Rudbeckia laciniata*	*Viburnum opulus*
Berberis thunbergii	*Desmodium illinoense*	*Helianthus divaricatus*	*Plantago lanceolata*	*Rudbeckia hirsuta*	*Viburnum acerifolium*
Bidens vulgata	*Diervilla lonicera*	*Heracleum lanatum*	*Poa sylvestris*	*Rumex acetosella*	*Viola sororia*
Brickellia eupatoriodies	*Dulichium arundinaceum*	*Hypericum punctatum*	*Podophyllum peltatum*	*Scutellaria lateriflora*	*Vitis riparia*
Calamagrostis canadensis	*Echinacea purpurea*	*Hystrix patula*	*Polygonum hydropiper*	*Smilacina racemosa*	*Zizia aurea*
Carex sp	*Elymus virginicus*	*Impatiens capensis*	*Polygonum virginiana*	*Smilax lasioneura*	
Carex pensylvanica	*Epilobium coloratum*	*Iris pseudacorus*	*Polygonum virginianum*	*Smilax tamnoides*	
Carex tribuloides	*Equisetum arvense*	*Juglans nigra*	*Populus deltoides*	*Solidago canadensis*	
Carex vulpinoidea	*Erechtites hieracifolia*	*Juncus tenuis*	*Potentilla simplex*	*Solidago nemoralis*	
Carex grayi	*Erigeron strigosus*	*Juniperus virginiana*	*Prunella vulgaris*	*Solidago rigida*	
Carpinus caroliniana	*Euonymus atropurpureus*	*Lonicera tatarica*	*Prunus serotina*	*Stachys tenuifolia*	

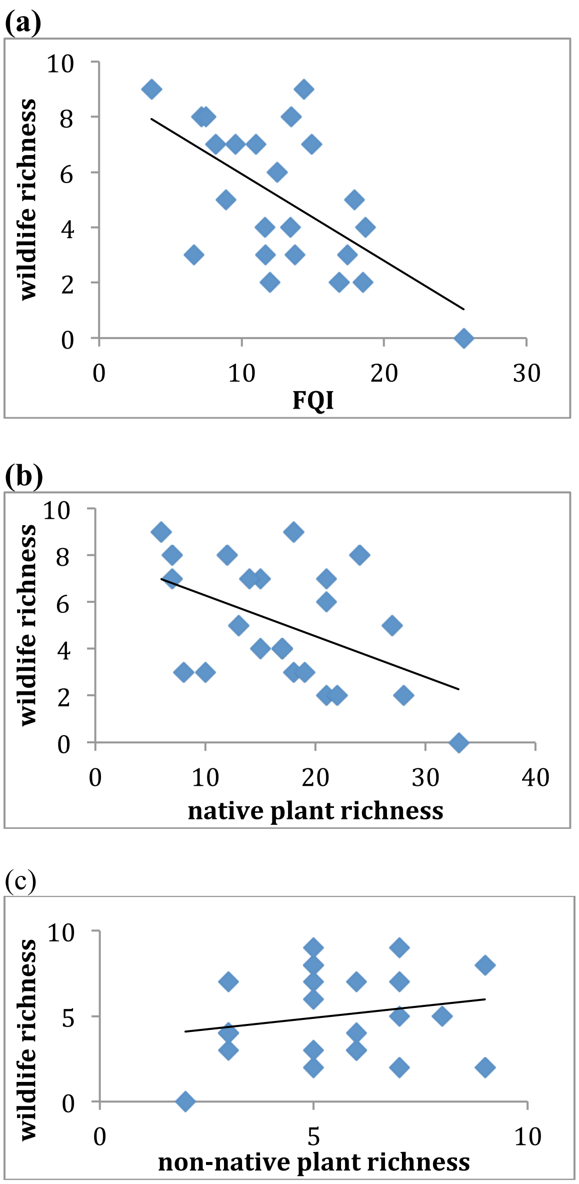

Figure 3. Relationship between FQI (a), native plant richness (b) and non-native plant richness (c) with wildlife richness. Data are from 24 forested greenspaces in the Chicago area, collected in summer 2015.

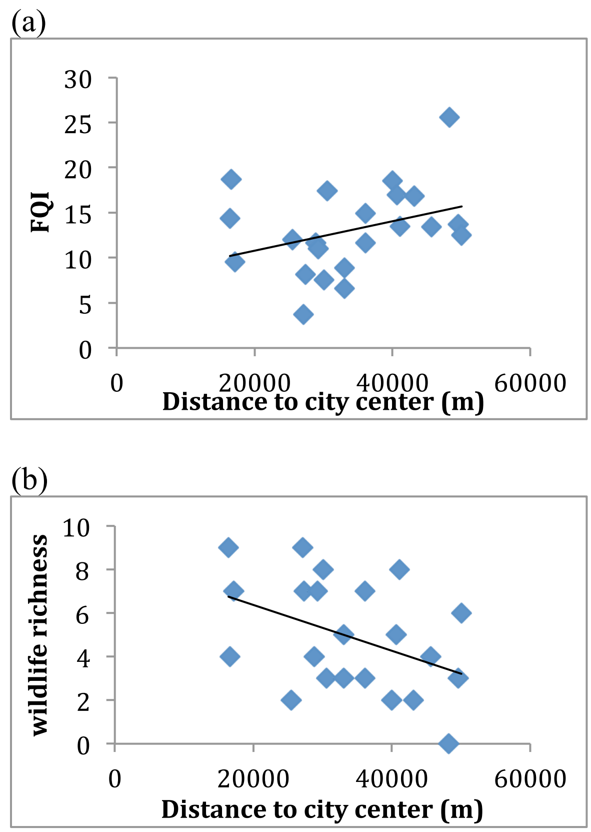

Figure 4. Relationship between distance to city center with FQI (a) and wildlife richness (b) for 24 forested greenspaces in the Chicago area, collected in summer 2015.

ANALYZING FQI AND WILDLIFE RICHNESS ALONG AN URBAN TO RURAL GRADIENT

We observed no linear relationship between FQI and the distance to city center that was not statistically significant (R^2=0.117, p=0.119; Figure 4). However we observed a negative relationship between distance to city center and wildlife richness (R^2=0.177, p=0.051; Figure 4).

DO ILLINOIS NATURE PRESERVES HARBOR GREATER PLANT AND WILDLIFE DIVERSITY?

To determine if designated Illinois Nature Preserves possess a higher quality of plants than non-nature preserves, we compared the FQI of five Illinois Nature Preserves to the rest of the sites sampled. We discovered that Illinois Nature Preserves had significantly higher FQI values than non-nature preserves (t=-2.53, p=0.019; Figure 5). Wildlife richness was slightly higher in non-nature preserves, but these results were not statistically significant (t=-1.94, p=0.066; Figure 5).

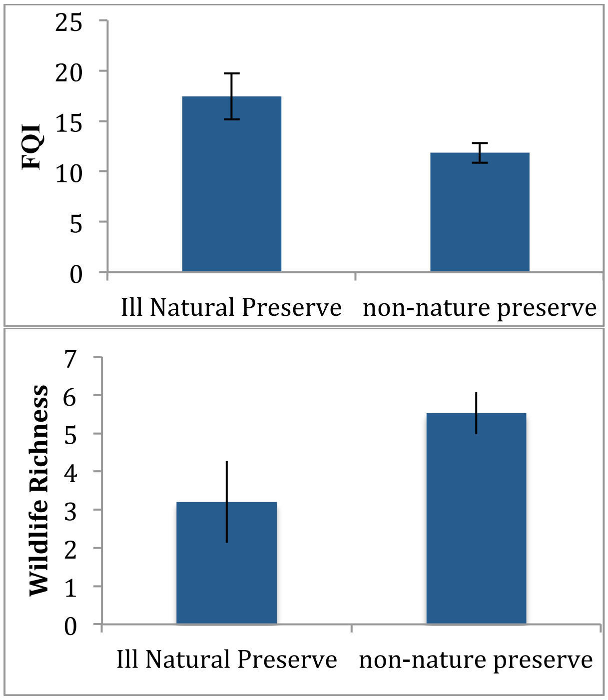

Figure 5. FQI and wildlife richness differed significantly between Illinois Nature Preserves (n=5) and not significantly between non- Illinois Nature Preserves (n=19) among forested Chicago area sites during summer 2015.

DISCUSSION

The data for the relationships between wildlife richness and plant diversity/quality suggest that wildlife richness decreases with increasing plant richness. We initially hypothesized that there would be a positive relationship between FQI and wildlife richness and between native plant richness and wildlife richness. Our data indicates that the opposite is true for the forested sites we tested: A strong negative relationship was observed. As seen in Figure 3, the forested site with the highest FQI had a wildlife richness of zero (MacAurthur Woods), which strengthens the negative relationship between FQI and wildlife richness.

FQI is an indicator of the amount of disturbance to a site or environment. The sites with low FQI are likely to be more disturbed, edgy and filled with weedy plant species. The majority of the wildlife species we observed could be considered opportunistic or "weedy" species (raccoons, coyotes and opossums) that are typically habitat generalists. These weedy wildlife species might be drawn to the disturbed nature of low FQI sites. Conclusions drawn by Vernon et al. (2014) supports this. They found that mesocarnivores in the Chicago area are much more likely to be found in sites with high buckthorn coverage due to potential prey availability. If we had used different methods to characterize wildlife habitat usage that captured "higher quality" mammals or even birds, arthropods or other taxa, we may have observed different results. If high quality wildlife species were compared to high quality vegetation, then the positive relationship we initially hypothesized might have been observed.

There was no statistical significance when comparing distance to city center, plant diversity/quality and wildlife richness. Despite there not being a statistical significance between these factors, there could still be an ecological significance. These results differ from past studies analyzing wildlife richness along an urban to rural gradient. When analyzing historical studies on the impacts of urbanization on wildlife richness, McKinney (2008) determined that 72.4 percent of past studies found that vertebrate species richness was highest at low levels of urbanization. McKinney's research included a variety of vertebrates including birds. Using camera traps to quantify wildlife richness of a site limited the type of wildlife we could observe and did not capture bird diversity. Further, using distance to city center may not be the most appropriate metric to characterize "urbaneness" in our study area, as there is a heterogeneity in housing density, impervious surface cover and other measures of human density in the Chicago region that might be more appropriate. Future analyses should consider examining other metrics of urban land use.

When comparing plant and wildlife diversity between Illinois Nature Preserves vs. non-preserves we observed greater FQI in nature preserves than in non-preserves which is consistent with our expectations and our findings when comparing FQI and wildlife richness. Illinois Nature Preserves were created as a network of environments that harbor rare/endangered species or contain high quality remnant habitat so it was expected that they would feature a high FQI. Wildlife richness was lower in Illinois Nature Preserves, which was surprising but further supports our conclusion that plant richness/quality is not predictive of wildlife richness in our study system.

Our data set was limited by the number of study sites and seasons in which we tested plant and wildlife relationships. We quantified the plant community at 24 forested sites, out of a possible 37 forested UWI camera trap sites, during the late summer. Plant phenology changes throughout the growing season with some species going senescent throughout the season. A more thorough sampling of plant diversity would have included visiting each site in late spring when spring ephemerals are evident, in addition to a late summer sampling. Additionally, we only tested relationships with wildlife during one season during one year, yet Chicago area wildlife are known to use different sites during different seasons. Further investigations of linkages between the vegetation and wildlife habitat usage in the Chicago area should investigate how individual wildlife species respond to indices of plant diversity, as well as how structural attributes of a site such as shrub density and canopy basal area impact urban wildlife.

Despite the limitations of our study, our findings suggest that urban generalist mammals do not require high quality sites, which are not abundant in urban areas anyway. In fact, the generalist mammals in our study seem to prefer lower quality forests that have fewer native plants. These lower quality sites likely harbor dense shrubs that promote prey abundance.

Our data investigating the relationships between wildlife richness and plant diversity/quality suggest that animals do not inhabit particular areas solely based on the type of native vegetation present. Other factors such as food supplies, location of the site within the landscape and the overall structure of a site may be influencing the distribution of animals throughout the Chicago area.

ACKNOWLEDGEMENTS

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