

UC Santa Cruz

UC Santa Cruz Previously Published Works

Title

Richness and composition of spiders in urban green spaces in Toledo, Ohio

Permalink

<https://escholarship.org/uc/item/8g90w6xf>

Journal

Journal of Arachnology, 41(3)

ISSN

0161-8202

Authors

Moorhead, Leigh C
Philpott, Stacy M

Publication Date

2013-11-01

DOI

10.1636/p12-44

Peer reviewed

Richness and composition of spiders in urban green spaces in Toledo, Ohio

Author(s): Leigh C. Moorhead and Stacy M. Philpott

Source: Journal of Arachnology, 41(3):356-363. 2013.

Published By: American Arachnological Society

DOI: <http://dx.doi.org/10.1636/P12-44.1>

URL: <http://www.bioone.org/doi/full/10.1636/P12-44.1>

BioOne (www.bioone.org) is a nonprofit, online aggregation of core research in the biological, ecological, and environmental sciences. BioOne provides a sustainable online platform for over 170 journals and books published by nonprofit societies, associations, museums, institutions, and presses.

Your use of this PDF, the BioOne Web site, and all posted and associated content indicates your acceptance of BioOne's Terms of Use, available at www.bioone.org/page/terms_of_use.

Usage of BioOne content is strictly limited to personal, educational, and non-commercial use. Commercial inquiries or rights and permissions requests should be directed to the individual publisher as copyright holder.

Richness and composition of spiders in urban green spaces in Toledo, Ohio

Leigh C. Moorhead¹ and Stacy M. Philpott²: Department of Environmental Sciences, University of Toledo, 2801 W. Bancroft St., Toledo, Ohio 43606-3390 USA. E-mail: lmoorhea@utk.edu

Abstract. Urbanization negatively affects biodiversity by increasing disturbance and habitat fragmentation. We compared three different urban habitats (vacant lots, gardens and forests) to examine differences in spider communities. We selected four sites of each habitat type and sampled spiders with pitfall traps. We collected a total of 547 individuals from 19 families. The most common families were Lycosidae, Corinnidae, Liocranidae, Cybaeidae, and Dictynidae. Spider activity-density overall and for males and females was higher in vacant lots than in forests, and female spiders had greater activity-density in gardens than in forests. Observed species richness did not differ with habitat type. Spider family composition differed significantly between urban habitat types, female morphospecies composition differed in forests and gardens and male morphospecies composition differed in forests and lots. The site characteristics differed significantly with habitat, and these habitat differences explained a large fraction (53.3% to 90.9%) of the variation in composition and richness. Yet, bare ground was the only factor that significantly correlated with declines in female richness. Thus, spider communities, aspects of specifically activity-density and composition, differ between habitats in urban green spaces with potentially important implications for conservation and trophic interactions within urban areas.

Keywords: Araneae, biodiversity, habitat fragmentation, urbanization

Urbanization leads to habitat loss and fragmentation, both serious threats to biodiversity. Along with the spread of invasive species, habitat loss is considered the greatest threat to biodiversity (Wilcove et al. 1998). Currently, 3 billion people, 48% of the world's human population, live in urban settings, and urban population size is projected to reach 6 billion (a 200% increase) by 2030, while rural populations are projected to decrease by only 3% (United Nations Information Service 2004). With this projected doubling of urban population an even greater proportion of land will become fragmented. Wildlife has responded to urbanization and fragmentation by adapting, moving, or experiencing population crashes (Markovchick-Nicholls et al. 2008). Although other human activities, such as road building and development of infrastructure fragment habitat, urban development results in local mass extinctions, leading to elimination of many native species (McKinney 2002).

Until recently, the importance of urban habitats for arthropod communities was largely ignored (Miller & Hobbs 2002). However, some studies examined urban to rural gradients as early as 1998, finding that overall carabid beetle diversity did not decline with increasing urbanization along a forested habitat (Magura et al. 2010a). A recent surge of studies has investigated how differences among urban habitat types, differences along an urban to rural gradient, and the landscape in which urban habitats are embedded, affect different arthropod communities (e.g., Turner et al. 2004; Carpaneto et al. 2005; Shochat et al. 2006; Elek & Lövei 2007; Pacheco & Vasconcelos 2007; McKinney 2008; Christie & Hochuli 2009; Uno et al. 2010; Fattorini 2011; Tóthmérész et al. 2011). Most studies have examined arthropod communities

across rural-urban gradients (Vilisics et al. 2007; Hornung et al. 2007; Tonietto et al. 2011; Varet et al. 2011), but relatively few have compared arthropod communities in more than one habitat type exclusively within urban settings (Yamaguchi 2004; Rango 2005; Sadler et al. 2006; Smith et al. 2006; Thompson & McLachlan 2007; Cárdenas & Buddle 2009; Uno et al. 2010). As such, there is still a need for more invertebrate studies from within cities.

Spiders are important predatory arthropods and are excellent indicators of habitat modifications and disturbance. Spider communities have been well examined in forest ecosystems (Miyashita et al. 1998; Dias et al. 2006), in agricultural settings (Riechert & Bishop 1990; Landis et al. 2000; McIntyre 2000; Öberg 2007) and on islands (e.g., Schoener & Spiller 2006), and it is evident that both natural and human disturbances strongly affect spider abundance and richness. Spiders are also affected by changes in habitat structure including changes to plant richness, architecture, and plant density (Wise 1993). Shochat et al. (2004) found that although spider abundance increased in disturbed areas, spider diversity decreased. They related these changes to the increased abundance of Lycosidae and Linyphiidae individuals in more disturbed and highly productive habitats, contrasting with the drastic decreases in abundance of Clubonidae and Oxyopidae, and thus suggest that rarer species are more susceptible to habitat disturbance. Because spiders are abundant and dominant predators, Shochat et al. (2004) predicted that spiders should be strongly influenced by habitat fragmentation and other anthropogenic changes such as urbanization. In support, a study by Magura et al. (2010b) found that spider diversity increased in disturbed areas due to increased alteration of habitat, leading to a wider variety of niches and, consequently, spider diversity. In contrast, Alaruiikka et al. (2002) investigated changes in spider abundance and richness along an urban to rural gradient in Finland, but did not find any significant differences. Nonetheless, potential losses of spider diversity and changes in species composition with urbanization may have practical

¹ Current Address. Department of Ecology and Evolutionary Biology, University of Tennessee: Knoxville, 1416 Circle Dr., Knoxville, Tennessee 37996-1610 USA.

² Current Address. Environmental Studies Department, University of California, Santa Cruz, 1156 High Street, Santa Cruz, California 95060 USA.

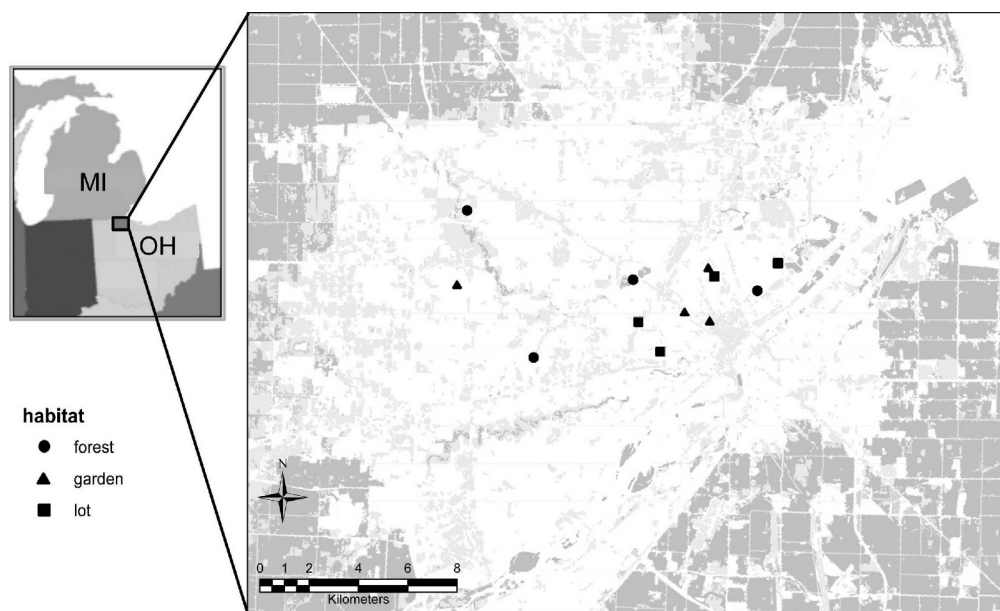


Figure 1.—Location of urban study sites in Toledo, Ohio. Sites sampled included natural forests (F), community gardens (G) and vacant lots (V).

importance in urban habitats because spiders are natural predators and valuable as naturally occurring pest control agents (Marc et al. 1999).

We examined spider activity-density (a measure of both abundance within a habitat and degree of movement), species richness and species composition in three different habitat types in an urban area. Specifically, we examined spider communities collected from community gardens, vacant lots and small forest fragments across a four-month period to examine 1) differences in richness, activity-density, and composition of ground-dwelling spiders in different urban habitat types; 2) differences in richness, activity-density, and composition of ground-dwelling spiders in different sample months and 3) the specific habitat characteristics that correlate with changes in spider communities in urban habitats. Based on previous studies of spiders in urban and agricultural habitats, we hypothesized that gardens and lots would have higher spider activity-density and lower richness than forest fragments.

METHODS

Study sites.—We conducted our study in Toledo, Ohio (41°39'56"N, 83°34'31"W), a city with a population of 295,614 that covers roughly 208 km² (United States Census Bureau 2006–2008). We sampled spiders in three urban habitat types: community gardens (gardens), vacant lots (lots), and forest fragments (forests). We established four replicate sites of each habitat type distributed throughout the city for a total of 12 study sites (Fig. 1). Study sites were located between 0.5–13.1 km apart, with no significant difference in the mean distance between gardens (5.8 ± 1.9 km (SE)), lots (3.9 ± 0.8 km) and forests (7.7 ± 1.1 km) ($F_{2,15} = 2.0$, $P = 0.18$). Sites were chosen to be as similar as possible in terms of the surrounding landscape condition and the habitat extent (e.g. patch size). The forest fragments were located within Toledo

City Parks, and ranged from 30,750–85,000 m². Gardens were all facilitated by an urban gardening outreach program, Toledo Grows of the Toledo Botanical Garden, had been in vegetable production for at least five years prior to the study, and were between 420–2688 m². The vacant lots ranged in size from 1299–8262 m², were all managed (and owned) by the city of Toledo and were vacant for at least nine years prior to the study. Vacant lots are a significant habitat type in Toledo, with more than 1000 vacant lots distributed throughout the city (Uno et al. 2010).

Spider sampling and identification.—We sampled spiders with pitfall traps. At each site, we placed 6 pitfall traps in a 5 × 10 m grid with traps placed 5 m apart. The traps consisted of two 473mL (16 oz.) cups, 11.4 cm in diameter and 7.6 cm in depth. One cup was a placeholder put just below ground level and sealed when not in use. Inside these cups we placed a second cup, flush with the surface to capture ground-dwelling arthropods. During trap days, we placed 200 ml of a saturated saline solution with a small amount of detergent to break surface tension in the cups. We then placed green plastic plates held up with small nails over the traps (~ 8 cm above ground level) to exclude rainwater. Every month from May to August, traps were left open for three days. Trap dates during 2007 were as follows: May 6–10, June 4–7, July 2–5, and July 30–August 2. Within each site, we placed traps toward the center of the habitat patch to limit edge effects. After three days, we retrieved the traps, rinsed the contents with deionized water to remove the salt solution and stored arthropods in 70% ethyl alcohol. During non-trap days, traps remained in the exact same locations within the soil, and we covered all traps with Tupperware lids when not in use.

We first sorted arthropods in order to separate the spiders from the collection. Then we identified spiders to family using Ubick et al. (2005) and Bradley (2004). We then sorted all adult spiders to genus where possible, and, subsequently, to

morphospecies. Identification to at least the family level allows for comparison between different habitats (Shochat et al. 2004). We recorded sex for each spider and only included adult spiders in data analyses. We stored specimens in 70% ethyl alcohol. Specimens are now stored at the Environmental Studies Department at the University of California, Santa Cruz.

Habitat characteristics.—We quantified 24 site characteristics of the urban habitats surrounding the pitfall traps at three spatial scales. We first measured the extent of habitat patch (e.g., contiguous garden, lot or forest habitat) surrounding pitfall traps. We then established 100×100 m plots centered on pitfall traps within which we quantified percent area covered with a) concrete, b) buildings, c) bare ground, d) grass or herbs and e) shrubs. Within 100×100 m plots, we also counted the number of trees >30 cm circumference at breast height (cbh). We also established 20×20 m plots centered on the spider sampling area. In the 20×20 m area we sampled canopy cover with a concave vertical densiometer at each corner and the center of each plot. We also counted and identified all trees >30 cm cbh, measured tree circumference at 1.37 m above the ground, and estimated tree height. We identified and measured height and circumference (at 1 cm above ground) of all tree seedlings and shrubs < 2 m tall and calculated total woody plant richness per site. Finally, within the 20×20 m plots, we randomly placed four 1×1 m plots to examine herbaceous vegetation and ground cover. Within each 1×1 m plot, we estimated percent cover of a) bare ground, b) grasses, c) forbs and herbs, d) rocks/wood panels, e) leaf litter and f) fallen branches. We recorded a) height of the tallest non-woody vegetation, b) number of forbs and herbs and c) richness of forbs, herbs, and grasses.

Data analysis.—To examine spider richness, we plotted species accumulation curves for each habitat type and each sample date with EstimateS (Colwell 2005) and determined significant differences between habitat types and sample dates by comparing overlap in 95% confidence intervals (CIs). We plotted curves for males and females separately due to use of morphospecies and common sexual dimorphism for spiders. We assessed spider activity-density data and treated each site on each date as a sample, summing across the 6 pitfall traps. We used sample-based rarefaction curves standardized to the number of individuals to compare species richness (Gotelli & Colwell 2001).

We compared spider activity-density between habitats and between sampling dates using a repeated measures analysis of variance (ANOVA). We summed activity-density across all pitfall traps in a site and then examined activity-density of all spiders, of males or of females as the dependent variable and sampling date and habitat type as main factors. We natural log (+1) transformed activity-density data for all and male spiders to meet conditions of normality. We used Tukey's tests to distinguish significant differences between pairs of habitat types and between sample dates. We also compared the activity-density of the five most common families encountered with multivariate ANOVA with number of spiders of each family captured as the dependent variables and habitat type, date, and gender as the main factors. We conducted all activity-density analyses with SPSS v. 17.

We compared family and morphospecies composition of spiders in the three urban habitats and four sample dates with

three methods. First, we used non-metric multi-dimensional scaling (NMDS) and analysis of similarities (ANOSIM) to visually and statistically compare composition of spiders. We considered each site as a replicate, summed all occurrences of each species over four sample months, and compared similarity with the Bray-Curtis similarity index. ANOSIM produces a global P-value to indicate any differences in composition and also reports pair-wise comparisons between particular sites. Third, we used a non-parametric MANOVA (NPMANOVA) to compare the relative differences in family and morphospecies composition in sites of the same habitat type or sampled on the same date (e.g., spread of the points). All composition analyses were conducted with PAST (Hämer et al. 2001).

We examined differences in site characteristics measured in each habitat type and then examined which characteristics best correlated with changes in spider communities. To examine differences in site characteristics in the three different habitats, we used a multivariate ANOVA with each of the 24 site variables as dependent variables and habitat type as the main factor. To examine relationships between the site characteristics and spider communities, we first used a Principal Components Analysis (PCA) to reduce the 24 possible explanatory variables into principal components. Then we correlated PCA axis 1 and axis 2 with individual vegetation variables with Pearson's correlations to determine which variables were significantly explained by the two principal components, and thus which biological factors were explained by each component. Then, we used multivariate regressions to examine whether PCA axes 1 and 2 and other remaining variables (e.g., those not significantly correlated with PCA axis 1 or 2) predicted total observed spider richness, or NMDS dimensions 1 and 2 for spider family and morphospecies composition. Variables representing percent ground cover at the 100×100 m and 1×1 m scale were arcsine-root transformed; counts of trees, shrubs and herbs were log (ln+1) transformed and habitat size was square-root transformed to meet conditions of normality before any analysis. All vegetation, PCA, and regression analyses were conducted with SPSS v. 17.0.

RESULTS

Spider activity-density.—We collected 547 adult spiders from pitfall traps from 19 families across all habitats. Overall, more male (328) than female (219) spiders were collected. On average, across the summer, spider activity-density was higher in lots than in forests (Table 1). There were also differences in activity-density of female and male spiders with habitat type (Table 1). Female spider activity-density was higher in lots than in gardens, and higher in gardens than in forests. Male spider activity density was higher in lots than in forests. Spider activity-density was relatively constant over the summer, with 8.9 ± 1.3 individuals per site in May, 10.0 ± 1.5 individuals in June, 11.2 ± 2.3 individuals in July and 15.5 ± 2.7 individuals in August (ANOVA, $F_{3, 27} = 2.2$, $P = 0.10$). Further, there was no significant interaction between habitat type and sampling date (ANOVA, $F_{6, 27} = 1.8$, $P = 0.15$).

The most common families encountered were ground-foraging families: Lycosidae (34.37% of individuals), Corinnidae (8.78%), Liocranidae (8.23%), Cybaeidae (7.68%) and

Table 1.—Activity density of spiders in three urban habitats in forests, gardens and vacant lots in Toledo, Ohio. Values for forests, gardens and lots show mean $\pm$ standard error, and different superscript letters designate significant differences between habitats (Tukey's test, $P < 0.05$). Statistical results are from univariate ANOVA tests.

	Garden	Lot	Forest	$F_{2,9}$	P
All spiders	39.75 $\pm$ 5.67 ^{a,b}	70.75 $\pm$ 4.49 ^a	26.25 $\pm$ 6.37 ^b	9.4	0.006
Male spiders	21.50 $\pm$ 2.90 ^{a,b}	43.00 $\pm$ 6.61 ^a	17.50 $\pm$ 5.30 ^b	4.8	0.039
Female spiders	18.25 $\pm$ 3.12 ^b	27.75 $\pm$ 2.46 ^a	8.75 $\pm$ 2.18 ^c	17.6	0.001

Dictynidae (7.31%). Activity-density of different families differed with habitat type (ANOVA, $F_{10,138} = 11.1$, $P < 0.001$; Fig. 3) and gender (ANOVA, $F_{5,68} = 4.4$, $P = 0.002$). Specifically, activity-density of Corinnidae was higher in forests than in lots (ANOVA, $F_{2,72} = 4.2$, $P = 0.014$), activity-density of Dictynidae was higher in lots than in forests (ANOVA, $F_{2,72} = 39.9$, $P < 0.001$) and than in gardens (ANOVA, $F_{2,72} = 39.9$, $P < 0.001$), and Lycosidae were encountered at least twice as often in lots and in gardens as in forests (ANOVA, $F_{2,72} = 29.9$, $P < 0.001$). Activity-density of males was higher for Corinnidae (ANOVA, $F_{1,72} = 6.3$, $P = 0.011$) and Dictynidae (ANOVA, $F_{1,72} = 9.6$, $P = 0.003$). There were significant interactions between habitat type and gender (ANOVA, $F_{10,138} = 2.7$, $P = 0.005$).

Spider richness and composition.—Overall we collected 62 female morphospecies and 52 male morphospecies of spiders. According to species accumulation curves and 95% CI for female and male spiders, there were no significant differences in richness in the three habitat types; however, for both females and males, richness tended to be highest in vacant lots and lowest in forests (Fig. 3a, b). None of the accumulation curves reached asymptotes, indicating that spiders were not completely sampled in any habitat.

According to NMDS and ANOSIM, composition of spider families differed with habitat type (ANOSIM, $P = 0.002$, Fig. 4a). Spider families found in forests differed from those in lots (ANOSIM, $P = 0.029$) and tended to differ from those in gardens (ANOSIM, $P = 0.06$). Similarly, at the level of morphospecies, spider composition differed with habitat type both for females (ANOSIM, $P = 0.002$, Fig. 3b) and males (ANOSIM, $P = 0.008$, Fig. 4c). Female morphospecies composition differed in forests and gardens (ANOSIM, $P =$

0.029), and male morphospecies composition tended to differ in forests and lots (ANOSIM, $P = 0.057$). Spider family composition was more dissimilar in individual forest sites (e.g., composition of forest spiders was more widely distributed) than in gardens (ANOSIM, $P = 0.06$) or in lots (ANOSIM, $P = 0.031$) (NPMANOVA, $F = 2.3$, $P = 0.005$). Female morphospecies composition was more dissimilar in forest sites than in lots (NPMANOVA, $P = 0.029$) and more dissimilar in forest sites than in gardens (NPMANOVA, $P = 0.025$) (NPMANOVA, $F = 1.8$, $P = 0.002$). Male morphospecies composition tended to be more dissimilar in forest sites than in lots (NPMANOVA, $F = 2.3$, $P = 0.005$).

Habitat characteristics and spider richness and composition.—Several site characteristics differed with habitat (MANOVA, $F_{4,18} = 9.6$, $P = 0.004$, Table S1 [Supplemental materials are available online at <http://www.bioone.org/doi/suppl/10.1636/P12-44>]). Forests were larger, had more and larger shrubs and trees, higher richness of woody plants, more canopy cover, and more fallen branches (Table S1). Lots and gardens were more surrounded by buildings and concrete (Table S1). Vacant lots had taller non-woody vegetation than forests, and more grass cover, and gardens had more rock and wood cover, more forb cover and higher herb richness (Table S1). The PCA predicted a large fraction of the variation in habitat characteristics and reduced the site characteristics from 24 to 6. PC1 explained 48.2%, PC2 explained 17.6% and PC1-5 explained 89.5% of the variation in the habitat characteristic data. Sixteen factors correlated with PC1 and four factors correlated with PC2 (Table S2 [Supplemental materials are available online at <http://www.bioone.org/doi/suppl/10.1636/P12-44>]). PC1 positively correlated with amount of concrete, buildings, and grass cover and negatively correlated with % cover of herbs, shrubs,

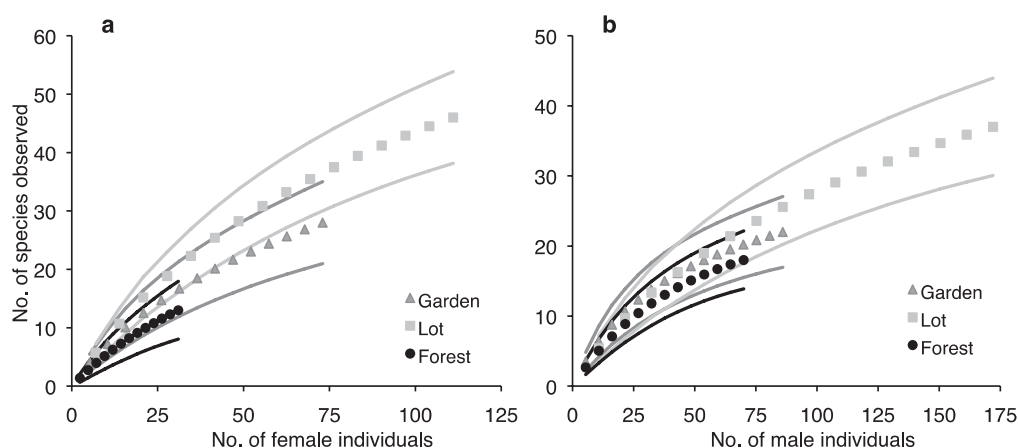


Figure 2.—Species accumulation curves for observed spider species richness for a) females and b) males observed in urban forests, community gardens and vacant lots sampled in Toledo, Ohio. Thin lines show upper and lower 95% confidence intervals for symbols of the same shading.

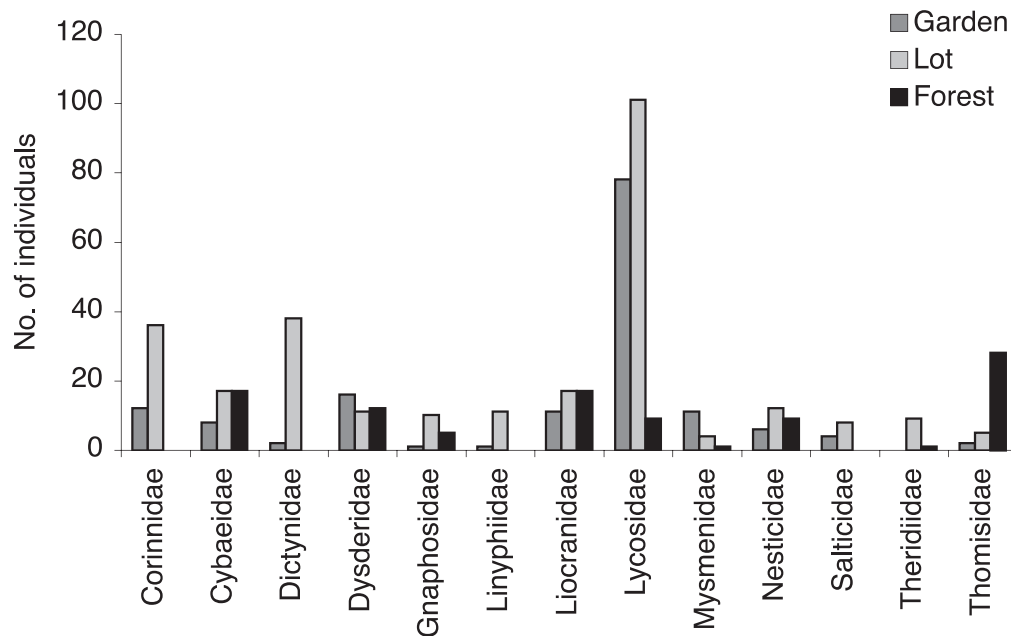


Figure 3.—Rank abundance curves for spider families collected in community gardens, vacant lots, and forest fragments in Toledo, Ohio. All families shown were represented by at least 10 individuals across all habitat types and are arranged alphabetically.

trees, and tree size. Other components (PC3, PC4, PC5) did not correlate with other site characteristics.

Spider composition was not well predicted by the measured site characteristics; richness correlated with some habitat changes. PC1, PC2 and four remaining vegetation factors explained >70% of the variation in composition of different spider groups, yet were not significant predictors of female morphospecies composition (NMDS 1, $F_{6,11} = 2.0$, $P = 0.24$; NMDS 2, $F_{6,11} = 2.9$, $P = 0.13$), male morphospecies composition (NMDS 1, $F_{6,11} = 2.3$, $P = 0.19$; NMDS 2, $F_{6,11} = 3.5$, $P = 0.09$), or spider family composition (NMDS 1, $F_{6,11} = 1.4$, $P = 0.38$; NMDS 2, $F_{6,11} = 6.2$, $P = 0.032$; spider family composition did not correlate with any individual site characteristics ($P > 0.05$). Site characteristics explained 90.9% of the variation in observed species richness of females (Multivariate regression, $F_{6,11} = 8.4$, $P = 0.017$), and female richness decreased with increased bare ground ($t = -2.7$, $P = 0.043$), but did not correlate with other factors. Site characteristics explained 53.3% of the variation in male spider richness, but were not significantly correlated (Multivariate regression, $F_{6,11} = 1.0$, $P = 0.53$).

DISCUSSION

Spider activity-density differed with habitat but did not significantly vary with sampling date. Overall, the activity-density that we observed for spiders (22.7 spiders per trap per month) was consistent with what others have found in urban and agricultural habitats (between 0.4 and 15.9 spiders per trap per month: Shochat et al. 2004; Dias et al. 2006; Magura et al. 2010b). We collected more spiders in lots than in forests for all, and male spiders and female activity-density was greater in lots than in gardens and greater in gardens than in forests. These results are consistent with other studies that have found greater spider activity-density in more disturbed habitats (Samu et al. 1999; Bolger et al. 2000; Pinkus-Rendón

et al. 2006). We did not directly measure habitat disturbance, but forest fragments were relatively undisturbed, whereas the lots experienced mowing, and gardens were tilled, planted, and experienced heavy human activity during the summer. Several characteristics of the sampled habitats may have influenced spider activity-density. For instance, higher prey activity-density may support higher predator activity-density (Bultman & Uetz 1982; Miyashita et al. 1998) and more active foraging of spiders (Bradley 1993). Yet prey activity-density may not be as important in determining activity-density and composition patterns as other habitat characteristics, especially during mid-summer (Bultman & Uetz 1982). Spider prey may be more abundant in areas with high amounts of grass cover (Bolger et al. 2000), and vacant lots had higher grass cover at the smallest scale measured. Spider activity-density, especially of some lycosids, one commonly encountered group, also increases with the amount of thatch (Döbel et al. 1990; Denno et al. 2002). We did not measure thatch cover, but this may be correlated with grass cover, which was higher in vacant lots.

Many factors at both local and landscape scales likely influence spider richness. For example, vegetation complexity can influence spiders by altering temperature, humidity, prey activity-density and richness, and number of prey refuges (Bultman & Uetz 1982; Wise 1993; Samu et al. 1999; Denno et al. 2002). Here, observed richness showed no significant differences between habitats. Spider diversity can differ with agricultural or urban habitat differences (Miyashita et al. 1998; Shochat et al. 2004; McKinney 2008) or along rural to urban gradients (Magura et al. 2010b). However, as in this study, others have found limited or no differences in richness among different urban and agricultural habitats (Alarukka et al. 2002). McKinney (2008) reported declines in spider diversity with increasing amounts of impervious surface and declines in vegetation complexity; yet for some situations, spider richness was not affected or even increased with

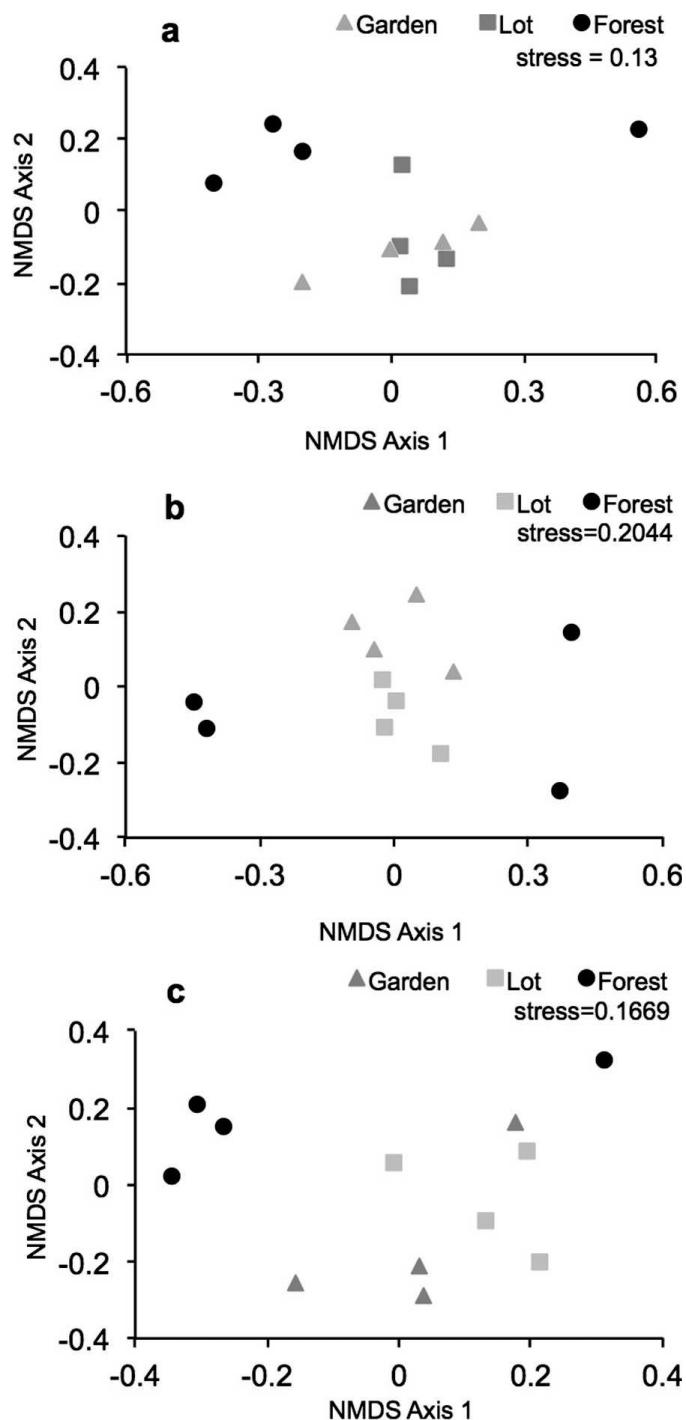


Figure 4.—Non-metric multi-dimensional scaling analysis of spiders collected in urban habitats in Toledo, Ohio showing a) family composition and b) morphospecies composition of females and c) morphospecies composition of males in different habitat types.

urbanization. Similarly, Magura et al. (2010b) did not find differences in richness of ground-dwelling spiders in urban, suburban and rural habitats. Further, Clough et al. (2005) and Pinkus-Rendón et al. (2006) found similar spider richness in organic vs. conventional farms, and Pinkus-Rendón et al. (2006) also found no clear diversity gradient in coffee farms managed with a more or less complex shade tree canopy. Thus

our results, showing minor differences in spider richness with changes in habitat are not unusual.

Spider composition also differed with habitat type at the level of family and for female and male morphospecies. Composition was generally more similar in the two open habitats: lots and gardens. Since the vegetation differed with habitat type, it is not surprising that the community differed in different habitats. In fact, spider species composition differs in disturbed and undisturbed habitats (Bolger et al. 2000; Bonte et al. 2002; Öberg 2007), or in urban forests and heaths differing in fragment size (Gibb & Hochuli 2002). Further, different forest types, including a highly disturbed clear-cut forest, differ dramatically in terms of species composition (e.g., Pearce et al. 2004). However, we did not find strong correlations between vegetation variables examined or changes in spider richness and composition, indicating that other factors may be more important for spider communities. For example, landscape factors, such as habitat edges, landscape heterogeneity and habitat fragment size may influence spiders in agricultural landscapes (Bolger et al. 2000; Clough et al. 2005; Drapela et al. 2008). Spider diversity may vary with distance to habitat edges, and both landscape heterogeneity and location of the fields within the landscape may affect diversity and activity-density of spiders (Clough et al. 2005). Both habitat fragment size and age may also influence spider richness, especially for spiders with larger body size (Miyashita et al. 1998; Bolger et al. 2000). We did not examine the landscape surrounding our study sites. Thus, possibly the landscape surrounding our study sites differs, potentially masking effects of local scale vegetation or site differences on spider diversity.

Spiders tended to be more abundant and species-rich in lots than in the other habitat types, and composition strongly varied in the different urban green space habitats. One aim of this study was to examine the potential of different urban green habitats to conserve biodiversity, thus a comparison to nearby natural areas is important. Bradley and Hickman (2009) recently examined spider communities in several habitats within the Glen Helen Nature Preserve in Greene County (central Ohio). They used several methods, including pitfalls, to sample spiders, making direct comparisons difficult. Nonetheless, they sampled upland forests (77 species collected) and old fields (41 species found). Overall, 26% of the species they captured were with pitfall traps, but they did not report exact values for each habitat type. We collected 13 female and 18 male species in forests, and 46 female and 37 male species in lots; thus, values at least for the open habitats are relatively comparable with natural habitats in the region. In sum, vacant lots support slightly higher richness and greater spider activity-density than other urban habitats examined, and appear comparable to spider richness from nearby natural locations. Because spider composition differs with urban green space habitat, maintaining a variety of habitat types may be most beneficial for spider conservation in urban landscapes.

ACKNOWLEDGMENTS

The University Research Award and Fellowship Program of the University of Toledo funded this study. We thank P. Bichier, A. Bobak, R. Friedrich, and S. Uno for assisting with field and laboratory work. We thank J. Cotton for assistance

with developing the project and L. Marin-Rivera for comments on the manuscript. We thank the City of Toledo for access to sample sites, and M. Szuberla and Toledo Grows, a community garden outreach program of the Toledo Botanical Garden for help with selecting study sites.

LITERATURE CITED

- Alaruikka, D., D.J. Kotze, K. Matveinen & J. Niemelä. 2002. Carabid beetle and spider assemblages along a forested urban-rural gradient in southern Finland. *Journal of Insect Conservation* 6:195–206.
- Bolger, D.T., A. Suarez, K. Crooks, S. Morrison & T. Case. 2000. Arthropods in urban habitat fragments in southern California: Area, age, and edge effects. *Ecological Applications* 10:1230–1248.
- Bonte, D., L. Baert & J. Maelfait. 2002. Spider assemblage structure and stability in a heterogeneous coastal dune system (Belgium). *Journal of Arachnology* 30:331–343.
- Bradley, R.A. 1993. The influence of prey availability and habitat on activity patterns and abundance of *Argiope keyserlingi* (Araneae: Araneidae). *Journal of Arachnology* 21:91–106.
- Bradley, R.A. 2004. In Ohio's Backyard: Spiders. Ohio Biological Survey Backyard Series No. 4. Columbus, Ohio.
- Bradley, R.A. & W.L. Hickman. 2009. Spiders (Araneae) of the Glen Helen Nature Preserve, Greene County, OH. *Ohio Journal of Science* 109:3–14.
- Bultman, T.L. & G.W. Uetz. 1982. Abundance and community structure of forest floor spiders following litter manipulation. *Oecologia* 55:34–41.
- Cárdenas, A.M. & C.M. Buddle. 2009. Introduced and native ground beetle assemblages (Coleoptera: Carabidae) along a successional gradient in an urban landscape. *Journal of Insect Conservation* 13:151–163.
- Carpaneto, G.M., A. Mazziotta & E. Piatella. 2005. Changes in food resources and conservation of scarab beetles: from sheep to dog dung in a green urban area of Rome (Coleoptera, Scarabaeoidea). *Biological Conservation* 123:547–556.
- Christie, F.J. & D.F. Hochuli. 2009. Responses of wasp communities to urbanization: effects on community resilience and species diversity. *Journal of Insect Conservation* 13:213–221.
- Clough, Y., A. Kruess, D. Kleijn & T. Tschardt. 2005. Spider diversity in cereal fields: comparing factors and local, landscape, and regional scales. *Journal of Biogeography* 32:2007–2014.
- Colwell, R.K. 2005. EstimateS: Statistical estimation of species richness and shared species from samples. Version 8.0.0. Online at <http://viceroy.eeb.uconn.edu/estimates>.
- Dias, S.D., A. Brescovit, E. Couto & C. Martins. 2006. Species richness and seasonality of spiders (Arachnida: Araneae) in an urban Atlantic Forest fragment in Northeastern Brazil. *Urban Ecosystems* 9:323–335.
- Denno, R.F., C. Gratton, M.A. Peterson, G.A. Langellotto, D.L. Finke & A.F. Huberty. 2002. Bottom-up forces mediate natural-enemy impact in a phytophagous insect community. *Ecology* 83:1443–1458.
- Döbel, H.G., R.F. Denno & J.A. Coddington. 1990. Spider (Araneae) community structure in an intertidal salt marsh: effects of vegetation structure and tidal flooding. *Environmental Entomology* 19:1356–1370.
- Drapela, T., D. Moser, J.G. Zaller & T. Frank. 2008. Spider assemblages in winter oilseed rape affected by landscape and site factors. *Ecography* 31:254–262.
- Elek, Z. & G.L. Lövei. 2007. Patterns in ground beetle (Coleoptera: Carabidae) assemblages along an urbanization gradient in Denmark. *Acta Oecologica* 32:104–111.
- Fattorini, S. 2011. Insect extinction by urbanization: A long term study in Rome. *Biological Conservation* 144:370–375.
- Gibb, H. & D. Hochuli. 2002. Habitat fragmentation in an urban environment: large and small fragments support different arthropod assemblages. *Biological Conservation* 106:91–100.
- Gotelli, N.J. & R.K. Colwell. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecology Letters* 4:379–391.
- Hämmer, Ø., D.A.T. Harper & P.D. Ryan. 2001. Past: paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4:1–9.
- Hornung, E., B. Tóthmérész, T. Magura & F. Vilisics. 2007. Changes of isopod assemblages along an urban-suburban-rural gradient in Hungary. *European Journal of Soil Biology* 44:158–165.
- Landis, D.A., S. Wratten & G. Gurr. 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. *Annual Review of Entomology* 45:175–201.
- Magura, T., G.L. Lövei & B. Tóthmérész. 2010a. Does urbanization decrease diversity in ground beetle (Carabidae) assemblages? *Global Ecology and Biogeography*, 19:16–26.
- Magura, T., R. Horváth & B. Tóthmérész. 2010b. Effect of urbanization on ground dwelling spiders in forest patches, in Hungary. *Landscape Ecology* 25:621–629.
- Marc, P., A. Canard & F. Ysnel. 1999. Spiders (Araneae) useful for pest limitation and bioindication. *Agriculture, Ecosystems & Environment* 74:229–273.
- Markovchick-Nicholls, L., H. Regan, D. Deutschman, A. Widyanata, B. Martin, L. Noreke & T. Hunt. 2008. Relationships between human disturbance and wildlife land use in urban habitat fragments. *Conservation Biology* 22:99–109.
- McIntyre, N.E. 2000. Ecology of urban arthropods: a review and a call to action. *Annals of the Entomological Society of America* 93:825–835.
- McKinney, M.L. 2002. Urbanization, biodiversity and conservation. *Bioscience* 52:883–890.
- McKinney, M.L. 2008. Effects of urbanization on species richness: A review of plants and animals. *Urban Ecosystems* 11:161–176.
- Miller, J.R. & R.J. Hobbs. 2002. Conservation where people live and work. *Conservation Biology* 16:330–337.
- Miyashita, T., A. Shinkai & T. Chida. 1998. The effects of forest fragmentation on web spider communities in urban areas. *Biological Conservation* 86:357–364.
- Öberg, S. 2007. Diversity of spiders after spring sowing – influence of farming system and habitat type. *Journal of Applied Entomology* 131:524–531.
- Pacheco, R. & H.L. Vasconcelos. 2007. Invertebrate conservation in urban areas: Ants in the Brazilian Cerrado. *Landscape and Urban Planning* 81:193–199.
- Pearce, J.L., L.A. Venier, G. Eccles, J. Pedlar & D. McKenney. 2004. Influence of habitat and microhabitat on epigeal spider (Araneae) assemblages in four stand types. *Biodiversity and Conservation* 13:1305–1334.
- Pinkus-Rendón, M.A., G. Ibarra-Núñez, V. Parra-Table & J.A. García-Ballinas. 2006. Spider diversity in coffee plantations with different management in Southeast Mexico. *Journal of Arachnology* 34:104–112.
- Rango, J.J. 2005. Arthropod communities on creosote bush (*Larrea tridentata*) in desert patches of varying degrees of urbanization. *Biodiversity and Conservation* 14:2185–2206.
- Riechert, S.E. & L. Bishop. 1990. Prey control by an assemblage of generalist predators: Spiders in garden test systems. *Ecology* 71:1441–1450.
- Sadler, J.P., E.C. Small, H. Fiszpan, M.G. Telfer & J. Niemelä. 2006. Investigating environmental variation and landscape characteristics of an urban-rural gradient using woodland carabid assemblages. *Journal of Biogeography* 33:1126–1138.
- Samu, F., K. Sunderland & C. Szinetár. 1999. Scale-dependent dispersal and distribution patterns of spiders in agricultural systems: A review. *Journal of Arachnology* 27:325–332.

- Schoener, T.W. & D.A. Spiller. 2006. Nonsynchronous recovery of community characteristics in island spiders after a catastrophic hurricane. *Proceedings of the National Academy of Sciences of the United States of America* 103:2220–2225.
- Shochat, E., W. Stefanov, M. Whitehouse & S. Faeth. 2004. Urbanization and spider diversity: Influences of human modification of habitat structure and productivity. *Ecological Applications* 14:268–280.
- Shochat, E., P.S. Warren, S.H. Faeth, N.E. McIntyre & D. Hope. 2006. From patterns to emerging processes in mechanistic urban ecology. *Trends in Ecology & Evolution* 21:186–191.
- Smith, R.M., P.H. Warren, K. Thompson & K.J. Gaston. 2006. Urban domestic gardens (VI): environmental correlates of invertebrate species richness. *Biodiversity and Conservation* 15:2415–2438.
- Thompson, B. & S. McLachlan. 2007. The effects of urbanization on ant communities and myrmecochory in Manitoba, Canada. *Urban Ecosystems* 10:43–52.
- Tonietto, R., J. Fant, J. Ascher, K. Ellis & D. Larkin. 2011. A comparison of bee communities of Chicago green roofs, parks, and prairies. *Landscape and Urban Planning* 103:102–108.
- Tóthmérész, B., I. Máthé, E. Balázs & T. Magura. 2011. Responses of carabid beetles to urbanization in Transylvania (Romania). *Landscape and Urban Planning* 101:330–337.
- Turner, W.R., T. Nakamura & M. Dinetti. 2004. Global urbanization and the separation of humans from nature. *Bioscience* 54:585–590.
- Ubick, D., P. Paquin, P.E. Cushing, & V. Roth (eds.). 2005. *Spiders of North America: an Identification Manual*. American Arachnological Society, Poughkeepsie, New York.
- United Nations Information Service. 2004. *World Urbanization Prospects: UN Report Says World Urban Population of 3 Billion Today Expected to Reach 5 Billion by 2030*. United Nations, New York.
- United States Census Bureau. 2006–2008. Toledo, OH Fact Sheet. Online at <http://factfinder.census.gov/servlet/> Accessed 26 February 2010.
- Uno, S., J. Cotton & S.M. Philpott. 2010. Diversity, abundance, and species composition of ants in urban green spaces. *Urban Ecosystems* 13:425–441.
- Varet, M., J. Pétilon & F. Burel. 2011. Comparative responses of spider and carabid beetle assemblages along an urban-rural boundary gradient. *Journal of Arachnology* 39:236–243.
- Vilisics, F., Z. Elek, G.L. Lövei & E. Hornung. 2007. Composition of terrestrial isopod assemblages along an urbanization gradient in Denmark. *Pedobiologia* 51:45–53.
- Wilcove, D.S., D. Rothstein, J. Dubow, A. Phillips & E. Losos. 1998. Quantifying threats to imperiled species in the United States. *Bioscience* 48:607–615.
- Wise, D.H. 1993. *Spiders in Ecological Webs*. Cambridge University Press, Cambridge, UK.
- Yamaguchi, T. 2004. Influence of urbanization on ant distribution in parks of Tokyo and Chiba City, Japan. *Ecological Research* 19:209–216.

Manuscript received 11 June 2012, revised 4 September 2013.