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Effects of Urbanization on Small Mammal Occupancy in Kirksville, MO: A Pilot Study

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Abstract: *Urbanization has caused large-scale changes in wildlife distributions. Populations and communities of small mammals can be good indicators of ecosystem health as they indicate change in vegetation diversity and structure. We surveyed small mammals in Kirksville, Missouri – a small isolated city within a landscape matrix of savanna and oak-hickory woodlands (*Quercus *spp. and* Carya *spp.). We trapped thirteen* Peromyscus *spp. and three* Blarina brevicauda*. Overall small mammal occupancy (95% CI) was 0.318 (0.131-0.589). Our results indicated that occupancy was constant across all variables and locations; however, future research is needed to better understand if there are indeed habitat covariates that have an effect on* Peromyscus *spp. occupancy, such as distance to green space or number of dumpsters in the area. Urban planners should be aware of the long-term effects of drought and of the isolation of small mammal populations. Future research should consider what urban variables may keep these small mammals in these isolated areas (i.e., nutrition, habitat requirements, and barriers of migration). This information will help improve management programs aimed at regulating small mammal populations and distributions in cities.*

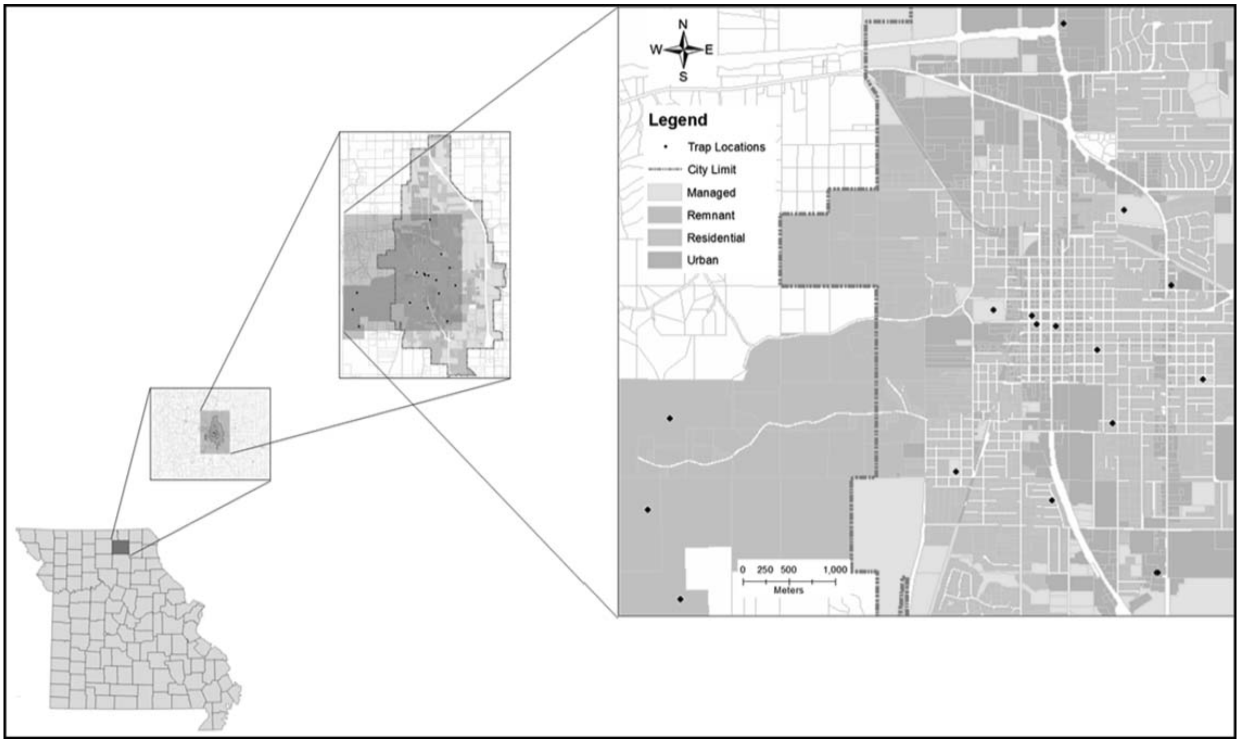
Introduction

Urbanization can be defined as habitat simplification via the conversion of complex natural habitats to anthropogenic spaces/structures such as buildings and parking lots (Beissinger and Osborne 1982, Adams et al. 2006). This activity tends to result in habitat fragmentation at both landscape and microhabitat scales, resulting in increased habitat heterogeneity (i.e., patchiness) in cities (Medley et al. 1995). These patchy urban landscapes often result in species assemblages that are very different from those found in more rural or natural areas. It is important to understand urban habitat use by wildlife in order to inform future conservation programs.

The fragmentation of landscapes due to urbanization makes the landscape more heterogeneous (i.e., patchy; Medley et al. 1995). Consequently, overall species richness and diversity across the urban landscape tends to increase. Species composition of urban areas tends to become dominated by generalists. Most generalists are opportunistic and thus can modify their requirements based on their surroundings (Futuyma and Moreno 1988, Kassen 2002, Marvier et al. 2004, Östergård and Ehrlén 2005). Specialists tend to do very poorly in fragmented landscapes (Crooks et al. 2004, Levins 1968). This is mainly because they are specialized for certain conditions that may no longer be available, due to urbanization. Ultimately, this increase in species diversity may not reflect an increase in ecosystem health because of the loss of most specialists.

Many studies have been done on the effects of urbanization on wildlife in cities with human populations $>$100,000 (Marzluff et al 2001, Spellerberg 1998); however, few studies have been done on the effects of small-scale urbanization (e.g., $<$20,000 humans) on wildlife. This is important to understand because these effects on native wildlife may be more pronounced in small isolated cities because of the proximity of the urban core to the surrounding natural habitats. For conservation efforts of future biodiversity in an increasingly urbanized landscape, it is imperative to understand how wildlife populations and diversity respond to these ecological changes brought on by all levels of urbanization. Our objective was to evaluate the distribution, abundance, and diversity of small mammals in urban (the city of Kirksville) and non-urban habitats (Thousand Hills State Park and Big Creek Conservation Area) in northeastern Missouri. Populations and communities of small mammals can be good indicators of ecosystem

Figure 1. Study site and trapping locations. Urban habitat includes both highly-urbanized and commercial areas.



health as they indicate change in vegetation diversity and structure (Medellín et al. 2000). To our knowledge, there have not been any other studies regarding the effects of small-scale urbanization on the dynamics of small mammals.

Field-Site Description

Kirksville (15 N 0556247 m E 4440175 m N) is a small isolated city of 17,522 people located in Adair County in northern Missouri, USA. Columbia, Missouri is the nearest city of over 100,000 people and is 145 km to the south. Kirksville is 37.37 km^2 in area set within a landscape matrix of agriculture, oak savanna, and oak-hickory woodlands (*Quercus* spp. and *Carya* spp.).

We surveyed small mammals in five habitat types throughout Kirksville (Figure 1). ***highly urbanized areas*** (very little vegetation, buildings, parking lots, sidewalks, alleys, and roads), 2.) ***commercial areas*** (spare vegetation, large parking lots, and a high level of human activity; e.g., McDonald's© restaurant, a chiropractor's office, Orscheln Farm and Home©), 3.) ***residential areas*** (grassy lawns, sparsely distributed trees, and landscaped gardens), 4.) ***managed habitat patches*** (scattered trees throughout groomed open spaces; e.g., cemeteries, golf courses, and city parks), and 5.) ***remnant habitat patches*** (areas not managed by humans, e.g., Thousand Hills State Park and Big Creek Conservation Area). Dominant tree species throughout the city included sweetgum (*Liquidambar styraciflua* L.), sugar maple (*Acer saccharum* Marshall), ash (*Fraxinus* spp. L.), pin oak (*Quercus palustris* Münchh.), willow oak (*Q. phellos* L.), river birch (*Betula nigra* L.), sycamore (*Platanus occidentalis* L.), red maple (*Acer rubrum* L.), honeylocust (*Gleditsia triacanthos* L.), hackberry (*Celtis occidentalis* L.), white pine (*Pinus strobus* L.), and crab apple (*Malus* spp.) (City of Kirksville Parks and Recreation 2014).

Methods

Sampling design

We surveyed three locations per habitat type (i.e., totaling 15 locations) from 18 March to 20 April 2013. We strategically placed twelve to fifteen Sherman live traps ($7.62 \times 8.89 \times 22.86$ cm) at each location. Traps were baited with a mixture of peanut butter and oats (Bookhout 1996). The variation in trap numbers and placement was because some traps were vandalized and we obtained additional traps partway through the survey period. Trap nights and number of traps set up across all locations during the entire study period were maximized in order to get a large sample size for data analysis. Upon animal capture, we recorded date, species, mass, length from nose to urogenital opening, tail length, and right hind foot length. We also marked the mammal in order to identify individuals for estimating population size. We used red, blue, and black Sharpie© non-toxic

Table 1. The relative fit[a] of occupancy models (Ψ) that estimate the proportion of survey sites with at least one *Peromyscus* spp. Models included the intercept only (.) and various combinations of habitat covariates[b].

Model	*-2L*	*K*	ΔAIC_c	w_i
Ψ (.)	95.13	2	0.00	0.3474
Ψ(DistGreen)	91.95	3	0.29	0.3005
Ψ (No.Dump)	92.51	3	0.85	0.2271
Ψ (DistDump)	94.40	3	2.74	0.0883
Ψ (HabType)	91.82	4	4.49	0.0368

[a]Compared by -2log likelihood (-2*L*) adjusted for number of parameters in the model (*K*) and small sample size (AIC_c). AIC_c values were rescaled by subtracting the lowest AIC_c value within the season (ΔAIC_c) and are expressed as model probabilities (w_i). The minimum value of AIC_c was 100.33.

[b]Habitat covariates included were number of dumpsters within a 50m radius (No.Dump), distance to nearest dumpster (DistDump), distance to nearest green space greater than $50m^2$ (DistGreen), and variation among five urban habitat types (HabType).

permanent markers on the ventral side of the mammals (Root et al. 1999). The marks were small lines with various combinations of colors to denote individuals. We then released the animal at the site of capture.

Data analysis

Due to an overall low number of captures, we used presence/absence data to estimate site occupancy. Occupancy is a measure of the proportion of sites used by a species (e.g., if 100 sites are surveyed and a species is present at 50 sites, then occupancy would be 50%). Occupancy estimation is not data hungry and thus was the most suitable parameter for our study (MacKenzie et al. 2006). However, some absences may just be non-captures (i.e., small mammals may have been present but we may failed to trap them). To account for this, we used program PRESENCE to estimate occupancy corrected for imperfect detectability (Hines 2006). Because *Peromyscus leucopous* (white-footed mouse) and *Peromyscus maniculatus* (deer mouse) are difficult to distinguish, data for these two species were pooled for analysis (and hereafter we refer to these two species together as "mice"). We did not analyze data for *Blarina brevicauda* (short-tailed shrew; hereafter referred to as "shrews") because of too few captures. We did not think it made sense to pool mice and shrews together for analyses as these two groups of small mammals differe substantially in their ecological requirements.

For evaluating the effects of urban habitat variables, we used Akaike's information criterion corrected for small sample size (AIC_c) to rank the fit of candidate models describing small mammal occupancy. These models incorporated effects from distance to nearest green space greater than 50 m^2, number of dumpsters within a 50-m radius, distance to nearest dumpster, and habitat type. Models are ranked in order of lowest (i.e., top-ranked) to highest AIC_c value (bottom-ranked). Models within 2 AIC_c of each other were considered equally plausible given the data. Specifically, all models with $\Delta AIC_c < 2.0$ in comparison to the top model are considered top-ranked (Burnham and Anderson 2002). Models with $\Delta AIC_c > 2.0$ are considered less plausible. We also estimated the relative probability of each model as model weights (w_i). To account for uncertainty in the model selection process, we used model averaging (with these estimated w_i's) to estimate overall occupancy levels. We evaluated the magnitude of the effect of each habitat variable by evaluating the estimated betas associated with each variable.

Results

Sixteen total captures were made with no recaptures over the course of 1209 trap nights. We did not trap any introduced species. We trapped thirteen mice and three shrews. Eight mice were captured in a commercial habitat at McDonald's©, four were captured in remnant habitat at Thousand Hills State Park, and one was captured at a highly-urbanized alleyway site behind the Kirksville Police Station. All three shrews were trapped at a single location in the residential habitat type.

Our model-selection results indicated no clear top model (i.e., all models were within 2 AIC_c of each other) for explaining the effects of certain habitat variables on occupancy (Table 1). The two variables with $\Delta AIC_c < 2.0$ were distance to nearest green space and the number of dumpsters within a 50-m radius. The estimated effect of distance to nearest green space greater than $50m^2$ ($\beta_{DistGreen}$) on occupancy was -0.007 (SE = 0.004). The estimated $\beta_{No.Dump}$ on occupancy was -0.275 (SE = 0.196). Mouse detectability was found to be 0.175 (0.071) and was constant across all sites. The model-averaged estimate of occupancy over all sites was 0.318 (SE = 0.125) with a 95% confidence interval of 0.131-0.589.

Discussion

Overall, small mammal populations throughout the city of Kirksville seem to be not randomly distributed given our successful trapping locations and our imprecise estimates of occupancy. Most captures of mice were near a dumpster at McDonald's©. A large green space is also in close proximity to McDonald's©, providing good habitat for *Peromyscus* spp. Four *Peromyscus* individuals were captured at Thousand Hills State Park. This remnant site provides forested habitat that is known to be preferential to mice (Schwartz and Schwartz 2002). It is surprising that more mice were not captured in this remnant area. One mouse was captured in highly urbanized habitat downtown in an alleyway. This location had a large number of dumpsters in proximity to the capture site, but no green spaces. The only shrews were trapped in a residential habitat that contained a high density of seeds from bird feeders, and shrews are known to consume seed (Schwartz and Schwartz 2002).

There was a negative relationship between number of dumpsters and occupancy, although this relationship was weak given the magnitude and the imprecision of the estimated effect. If this relationship was true, it would suggest that more dumpsters in an area would mean fewer mice occupy that area. Overall this result contradicts our raw data and seems counterintuitive as dumpsters provide a potential food source. However, dumpsters tend to attract mid-sized scavengers and potential predators, which could result in avoidance by mice. Additionally, the results indicated that the model suggesting occupancy would vary by habitat type was the worst indicator of mouse occupancy. This also seems counterintuitive as most mice were found primarily in a commercial area and remnant area as opposed to residential, managed, and highly-urbanized areas.

Mice are known to inhabit grassy fields or forested areas (Schwartz and Schwartz 2002, Dice 1925, Blair 1940). This supports the fact that mice were found near a grassy field at McDonald's and at a forested area within Thousand Hills State Park. More mice were found near a dumpster at McDonald's© than at Thousand Hills State Park presumably because the commercial area had a readily available food source (dumpster) and habitat (grassy field). This is supported by Nupp and Swihart (2000) who found that *Peromyscus leucopus* are generalists in their habitat requirements. This would also explain why a mouse was found in a highly urbanized area (alleyway). Our results indicated that mouse occupancy was generally constant across all of our habitat types and variables. This is supported by Nupp and Swihart (2000) who also found that mouse occupancy was constant across a fragmented landscape.

Additionally, Krohne and Hoch (1999) found that emigration and immigration among *Peromyscus* spp. populations is minimal due to factors such as natural, and man-made, barriers. If migration is rare in a fragmented landscape, then there are likely isolated populations within the urban landscape, such as the population at the McDonald's© dumpster. We may have had our highest capture rate at McDonald's© precisely because we found an isolated population. The reason we did not see thriving populations of mice across the fragmented landscape of Kirksville, as predicted by Nupp and Swihart (2000), may be because we failed to find isolated populations at our other trapping locations. Our other trapping locations may have been inaccessible by mice or did not have sufficient nutritional incentives to drive immigration.

It is important to note that the AIC_c values for distance to nearest green space greater than $50m^2$ and number of dumpsters within a 50m radius were very close (within 2 AIC_c) to the model with only the intercept, indicating these may not actually be good predictor variables. It is clear that there were not enough captures to accurately model occupancy or make any other major conclusions. Another limitation of this study was the lack of a pilot season to gain an informed and effective sampling design. We only had 16 captures out of 1209 trap nights, representing a 1.3% capture rate and consequently low detectability. This may be due to many factors such as poor placement of traps, low activity by small mammals, or there is simply a low abundance of small mammals in Kirksville. The sampling area experienced a major drought during the year of 2012 (NOAA 2014). This may be the most plausible reason why our capture rate was extremely low, as droughts tend to deplete small mammal populations (Yahner 1992). Furthermore, a large capture effort was made during October 2013 to increase our sample size but resulted in a 0% capture rate (135 trap nights), showing that the results of drought may be long lasting on small mammal populations.

This study can be used as a pilot study for a more focused and informed sampling design in the future. The results of this future study could be used as a report of the effects from urbanization on mammals in northern Missouri. This information is important for planning conservation strategies for future small mammal populations. Additionally, this future study could also help inform on feral cat activity by tracking both small mammal populations and feral cat populations to see if feral cats do indeed deplete small mammal populations (Woods et al. 2003). This study also highlights the fact that future research needs to investigate how drought impacts small mammal populations in an urban setting. Droughts may cause increased isolation of *Peromyscus* populations. If this is the case, it may aid future surveyors to locate these isolated populations and monitor only these areas as migration is relatively rare.

Management implications

For anyone wishing to manage populations of *Peromyscus* spp. it would help to be aware of the long-term effects of drought. They should also be aware of the isolation of small mammal populations and consider what factors keep these small mammals in these isolated areas (i.e. nutrition, habitat requirements, and barriers of migration). This will help managers keep *Peromyscus* spp. away from certain areas or attract them towards other areas.

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