

## Movement and habitat use of the snapping turtle in an urban landscape

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**Abstract** In order to effectively manage urban habitats, it is important to incorporate the spatial ecology and habitat use of the species utilizing them. Our previous studies have shown that the distribution of upland habitats surrounding a highly urbanized wetland habitat, the Central Canal (Indianapolis, IN, USA) influences the distribution of map turtles (*Graptemys geographica*) and red-eared sliders (*Trachemys scripta*) during both the active season and hibernation. In this study we detail the movements and habitat use of another prominent member of the Central Canal turtle assemblage, the common snapping turtle, *Chelydra serpentina*. We find the same major upland habitat associations for *C. serpentina* as for *G. geographica* and *T. scripta*, despite major differences in their activity (e.g., *C. serpentina* do not regularly engage in aerial basking). These results reinforce the importance of recognizing the connection between aquatic and surrounding terrestrial habitats, especially in urban ecosystems.

**Keywords** *Chelydra serpentina* · Radiotelemetry · Riparian · Snapping turtle · Spatial ecology · Urbanization

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## Introduction

Over the last century, human populations have continued to grow in numbers, increasing the amount of urbanization. The subsequent conversion of habitat has lasting impacts on biodiversity, including the homogenizing of flora and fauna (McKinney 2006; Pickett et al. 2001). The persistent land use and land cover changes in urban areas, which are made to meet the demands of increasing populations, have broad impacts on already diminished habitat (Grimm et al. 2008). Riparian systems have been particularly susceptible to urbanization through changes in stormwater runoff, hydrology, and biological diversity (Grimm et al. 2008). These changes have dramatic consequences for urban wildlife, such as birds, amphibians, reptiles and mammals, which utilize riparian areas for at least part of their life history (Naiman et al. 2005). In order to effectively manage urban habitats, it is important to incorporate the spatial ecology and habitat use of the species utilizing them (Soule 1991). Determining how human activities impact wildlife ecology and ecosystem function has been paramount to the rise of urban ecology (Grimm et al. 2000; Pickett et al. 2001).

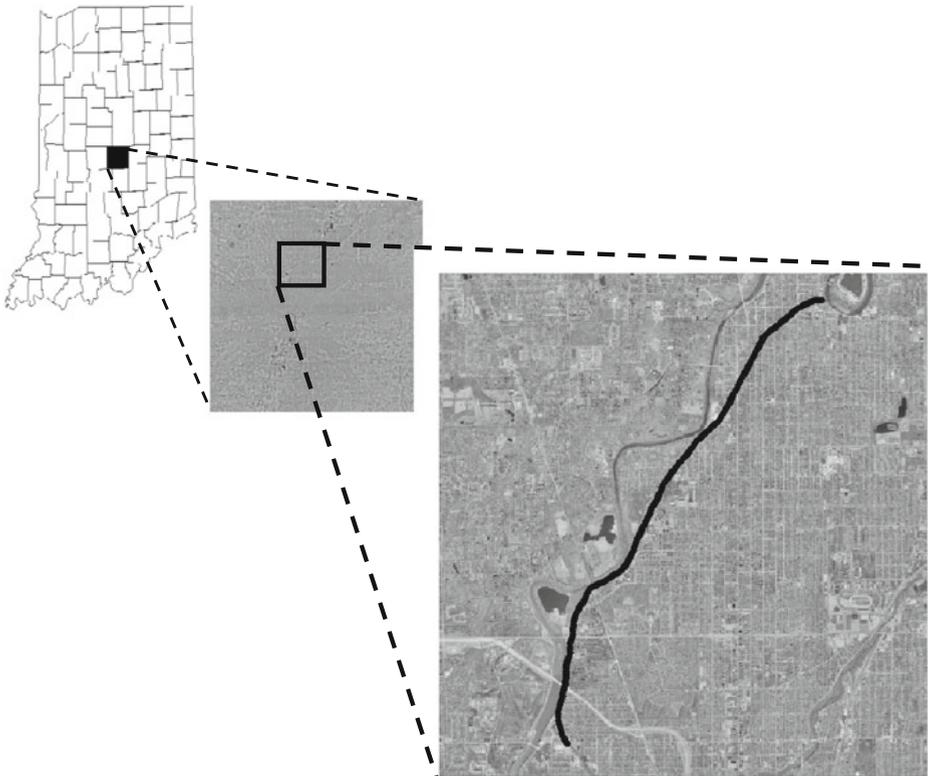
Freshwater turtles are hearty constituents of urban landscapes (Conner et al. 2005; Mitchell 1988; Souza and Abe 2000) and some species are able to acclimate and thrive in harsh conditions (Hays and Mcbee 2010; Souza and Abe 2000). However, the potential negative impacts of urbanization on the biology and population structure of turtle communities can be profound and diverse (Marchand and Litvaitis 2004a; Ryan et al. 2008; Steen and Gibbs 2004). Altered features common to urban areas such as roads, increased land use, and subsidized predators are known to impact the distribution, population demographics, and spatial ecology of turtle communities (Marchand and Litvaitis 2004b; Steen and Gibbs 2004; Sterrett et al. 2011). Previously, we have shown that the distribution of upland habitats surrounding a highly urbanized wetland habitat in Indianapolis, Indiana, USA influences the distribution of red-eared sliders (*Trachemys scripta*) and map turtles (*Graptemys geographica*) during both the active season and during hibernation (Ryan et al. 2008). Within urban landscapes, the suitability of habitats for wildlife often changes with the distribution and extent of built environments. For example, commercial districts, neighborhoods and housing complexes, and tracts of largely wooded or open areas frequently surround urban riparian areas. Because of the complex matrix of terrestrial habitats surrounding it, the Central Canal is an ideal study system to assess how turtle species respond to the urban terrestrial landscape.

The snapping turtle (*Chelydra serpentina*) is one of the most widely-distributed and well-studied freshwater turtle species in North America (Steyermark et al. 2008). *Chelydra serpentina* inhabits still or slow-moving aquatic habitats and moves through the surrounding landscape when nesting or relocating (Ernst and Lovich 2009; Obbard and Brooks 1980). Extensive nesting migrations and overland movements between wetlands in response to environmental extremes, such as drought, have been reported for *C. serpentina* across its range (Obbard and Brooks 1980; Steen et al. 2010). While recent work suggests that phenomena associated with urbanization, such as road mortality, can impact population demographics of *C. serpentina* (Steen and Gibbs 2004), there is a lack of understanding of their spatial ecology in urban areas where these threats are the greatest. Conner et al. (2005) reported that *C. serpentina* is a prominent member of the turtle assemblage in the Central Canal. The objective of the current study is to evaluate the movements and habitat use of *C. serpentina* in the Central Canal, which bisects Indianapolis, and is bordered by a variety of terrestrial habitats with varying degrees of human influence. By studying the manner in which the varied environment surrounding the Central Canal shapes movement and habitat associations of *C. serpentina*, we gain an understanding that will be vital for long-term habitat planning to ensure the persistence of this species within this and other urbanized aquatic habitats.

## Methods

The Central Canal is a man-made riverine habitat constructed more than 180 years ago originating from the White River and flowing for 11.2 km through commercial, residential, recreational, and upland wooded areas where it is crossed by more than a dozen roads (Fig. 1; for more details regarding the study site, please see Conner et al. 2005; Peterman and Ryan 2009; Ryan et al. 2008). In 2003 and 2004, 23 *C. serpentina* adults (12 female, 11 male; Table 1) were radiotracked through the majority of the active season (roughly 15 May through 30 September) and selectively during the winters to understand movement patterns and habitat use. Turtles were collected using baited 0.76-m hoop traps (Conner et al. 2005). Radiotransmitters (ATS Inc., Isanti, MI, USA) set on an 18-h duty cycle (active between 06:00 and 24:00) were attached to the posterior region of the carapace with aluminum machine bolts and plumber's epoxy (Ryan et al. 2008). During the active season, we searched each transmitted frequency every 24–72 h and recorded locations (with 5 m accuracy) using handheld global positioning system (GPS) units (Garmin V+).

We characterized the upland habitat (the land immediately adjacent to the canal edge) surrounding the canal at 50 m intervals from its origin to its end as either woodlot, road, river, residential, commercial, or open (described further in Ryan et al. 2008). We plotted each individual's locations on a 2004 digital orthophoto using ArcGIS 9.1 software (ESRI,



**Fig. 1** The location of the Central Canal within Indianapolis (the 13th largest city in the United States), Marion County, and Indiana

**Table 1** Descriptive statistics of *C. serpentina* used in habitat use and movement calculations

	Male		Female	
Body mass (g)				
Mean, SE	4357, 657		6632, 714	
Range	2720–10200		3280–11160	
Locations per Individual	2003	2004	2003	2004
Mean, SE	25.82, 2.29		27.25, 2.07	
Min-Max	7–33	6–11	11–39	3–11
N turtles tracked	11	11	12	9

Redlands, CA, USA). For each individual, we recorded the total range of movement (range, hereafter) as the straight-line distance between the two farthest locations. Mean movement was calculated as the total cumulative straight-line distance between successive locations divided by the number of movements, regardless of the number of days between locations. We calculated daily movement as the straight-line distance between successive locations recorded within a 24 h period for each individual. One-way analysis of variance (ANOVA) was used to determine significant differences between sexes and years for range, mean movement, and daily movement. We recorded each turtle's modal center of activity (MCA), designated as the 300-m stretch of canal with the most locations for any given individual (see Ryan et al. 2008 for details). For each individual we calculated a skewness index, a relative measure for the evenness of the spread of an individual's locations throughout its range (Ryan et al. 2008). Locations of hibernacula were determined by locating individuals on successive days during the winter when temperatures were below 0 °C; a lack of movement under these conditions was interpreted as indicative of hibernation. To determine whether the location of MCAs and hibernacula differed significantly from a random assortment along the length of the canal, we used *G*-tests for goodness-of-fit.

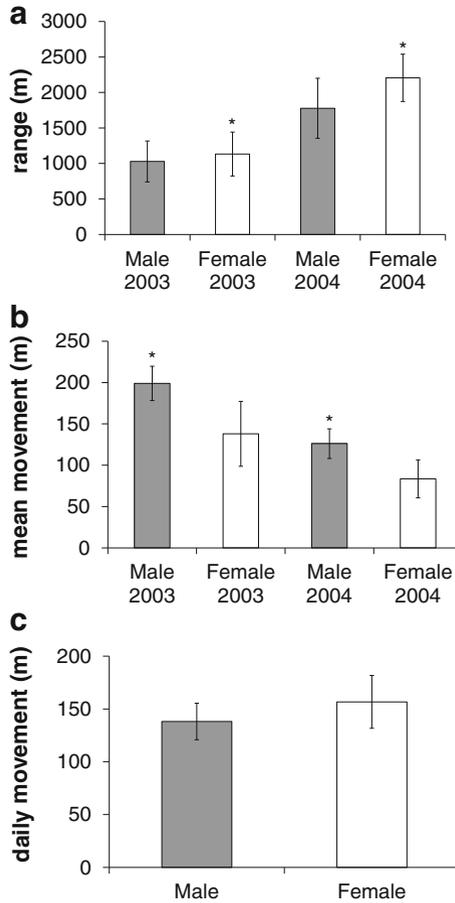
## Results

### Movements

We located the tagged turtles more than 850 times over the course of this study (Table 1). The range, mean movement, and daily movement did not differ between sexes within each year sampled ( $P > 0.05$  for all; Fig. 2). Range differed significantly among years for females ( $F_{1,21}=7.23$ ,  $P=0.015$ ), but not for males (Fig. 2a), whereas mean movements differed significantly among years for males ( $F_{1,20}=5.76$ ,  $P=0.026$ ), but not for females (Fig. 2b). There was no difference in daily movement between the sexes (Fig. 2c).

### Habitat use

We found that *C. serpentina* locations were not equally distributed within the canal (skewness  $> 0$ ;  $t=6.78$ ,  $df=22$ ,  $P < 0.001$ ), demonstrating an unequal distribution of locations for each individual within its range. There were no differences between sexes nor between the years ( $P > 0.05$ ). The MCAs were not distributed randomly relative to the terrestrial habitat types surrounding the canal ( $G=22.757$ ,  $df=5$ ,  $P < 0.001$ ; Fig. 3). Areas associated with residential habitat were used than less expected and woodlot habitat were used more than



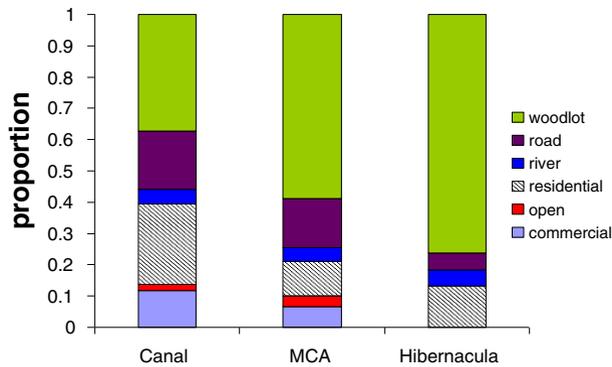
**Fig. 2** Mean ( $\pm 1$  SE) **a** range, **b** mean movement, **c** and daily movement for male and female *C. serpentina*. An asterisk (\*) denotes that values differed significantly within sex among years

more than expected. Furthermore, hibernacula were even more strongly associated with woodlots ( $G=27.669$ ,  $df=5$ ,  $P<0.001$ ). The locations of hibernacula differed significantly from summer MCAs ( $G=13.068$ ,  $df=5$ ,  $P=0.023$ ) with a more pronounced movement towards the woodlots during hibernation. The MCAs for each turtle did not differ between years, with a mean difference in distance between MCAs for individuals in 2003 and 2004 of less than 50 m (mean= $47.6 \text{ m} \pm 30.2$ );  $t=0.21$ ,  $df=19$ ,  $P=0.582$ ).

## Discussion

### Range and movement

Within-year observations of *C. serpentina* movement within the Central Canal revealed that range, mean movement, and daily movement over the course of the active season did not differ between sexes. Furthermore, these similarities in movement behavior between sexes also extended to year comparisons (2003 to 2004). Because previous studies have focused



**Fig. 3** Habitat use of snapping turtles in the Central Canal. Bars represent proportion of MCAs during the active season, and hibernacula during the winter. Canal represents the proportion of each habitat surrounding the canal

on non-linear aquatic systems (e.g., lakes and wetland complexes) comparisons to this very linear system may be difficult. Quantification of movement using home range analyses, be it via minimum complex polygon (e.g., Obbard and Brooks 1981) or kernel density (e.g., Kobayashi et al. 2006) methods, is standard practice in non-linear habitats. There have been conflicting results of home range analyses for *C. serpentina* in non-linear systems, with some reporting similarities in range sizes between sexes (Brown 1992; Kobayashi et al. 2006; Obbard and Brooks 1981) and others suggesting differences between sexes (Pettit et al. 1995). These contrasting results may be, in part, attributed to methods (i.e. mark-recapture vs. telemetry) and/or type of aquatic habitat across studies (i.e. lakes, ponds, streams). Therefore, comparisons of our spatial patterns with others may not be indicative of any general trend. Future comparisons of *C. serpentina* movement in other urban habitats – in both riparian and lentic systems – will provide further insight into possible variation between sexes within this species.

While there were no differences between sexes, there were notable differences between years for each sex. Mean movements of males was greater in 2003 relative to 2004 and females had a larger range in 2004 relative to 2003 while males did not vary. Among years, males may increase the average distance between locations while the overall range stays constant. Females, on the other hand, tend to be consistent with distance between locations, but range may change depending on the year. In either case, daily movements were not different between years or sexes. The reduced mean movement from 2003 to 2004 in males may be due to the reduced frequency of locating, but this explanation does not square with the observed significant increase in range observed in females in 2004. These results are difficult to put into context given the paucity of spatial ecology studies conducted on *C. serpentina* using radiotelemetry. Other studies using mark-recapture information have found that *C. serpentina* tends to be wide-ranging (Minton 2001) and can migrate several kilometers (Haxton 2000; Pettit et al. 1995). We found individual *C. serpentina* to utilize between 1 and 2.5 km of the available 11 km linear canal habitat, which is comparable to previously reported mean movements (approximately 1.1 km; Hammer 1969). Our results suggest that while the linear nature of the aquatic habitat restricts movement directionally, it does not necessarily constrict movement of *C. serpentina* within the aquatic habitat.

The range of *C. serpentina* is relatively small when compared to female *Graptemys geographica* and both sexes of *Trachemys scripta* in the Central Canal. Whereas *C. serpentina* had an average range of about 1.5 km (averaged across sexes and years), *T.*

*scripta* had a range of 2.25 km and *G. geographica* (females only) had a range of approximately 3 km (Ryan et al. 2008). Likewise, mean movement and daily movement for *T. scripta* and *G. geographica* were on average about twice as large as *C. serpentina* (Ryan et al. 2008). Differences in basking and feeding behavior likely explain the dissimilarity among these species. The diet of *G. geographica* largely consists of mollusks (Gordon and MacColluch 1980; Vogt 1981; White and Moll 1992; J. D. Stephens and T. J. Ryan, unpublished) which suggests foraging for prey as a cause for the greater range and mean movement (Pluto and Bellis 1988; Ryan et al. 2008). While *T. scripta* is omnivorous and less susceptible to local food scarcity and thus would have less need for long ranging movements to obtain food, this species, like *G. geographica*, actively pursues quality basking sites daily (Peterman and Ryan 2009). There may be intense competition for basking sites (Cadi and Joly 2003; Ernst and Lovich 2009; Lindeman 1999) which would necessitate increased rates of movement. *Chelydra serpentina*, on the other hand, does not exhibit a propensity for aerial basking and it is considered an ambush predator (Feuer 1971; Punzo 1975), often preferring areas of cover likely associated with their feeding habits (Froese 1974). These differences in behavior most likely account for the smaller range and scope of movements of *C. serpentina* relative to *T. scripta* and *G. geographica* in the Central Canal.

#### Habitat associations

Our results indicate that the distribution of *C. serpentina* in the Central Canal is non-random, with terrestrial woodland habitat being used more frequently and residential habitat used less frequently than expected. There was no significant difference in habitat association between sexes or years. Over 50 % of the MCA association was with terrestrial woodlots, emphasizing the importance of this habitat type for *C. serpentina*. This result corroborates previous studies assessing general habitat preference of *C. serpentina* (DonnerWright et al. 1999; Ernst and Lovich 2009; Froese and Burghardt 1975; Major 1975,). These studies found *C. serpentina* has a predilection for habitats containing slow-moving waters, muddy substrates, abundant vegetation, and submerged logs. In addition, *C. serpentina* densities tend to increase where there is a higher productivity of aquatic macrophytes (Galbraith et al. 1988). The water flow and height in the Central Canal is controlled by the Indianapolis Water Company, but the abundance of allochthonous input from overhanging trees and deadwood varies spatially along the Canal, with higher abundances of both found along the banks associated with terrestrial woodlot habitat type (T. Ryan, personal observation).

The preference of woodlots by *C. serpentina* is very similar to the habitat preferences of *T. scripta* and *G. geographica* in the Central Canal (Ryan et al. 2008). All of these species used woodlot-associated sections of the canal more than expected and residential and road areas less frequently. For *T. scripta* and *G. geographica* these trends were attributed to number of basking sites and food preference (Peterman and Ryan 2009; Ryan et al. 2008). While *C. serpentina* does not use logs for basking, they are known to use these locations to hide and bury themselves under the softer substrate created by logs (Ernst and Lovich 2009). In addition, *C. serpentina* has been found to prefer areas with adequate vegetative cover (Obbard and Brooks 1981) which would provide sites from which prey could be ambushed (Feuer 1971; Punzo 1975).

Hibernacula differed significantly from summer MCAs, demonstrating that *C. serpentina* changes habitat association between the active season and overwintering period. It appears that terrestrial woodlots serve a vital function for hibernation, because overwintering individuals were associated with this habitat type over 70 % of the time. This trend was also consistent with *T. scripta* and *G. geographica* in the Central Canal (Ryan et al. 2008). We

believe that the root system associated with woodlots likewise plays an important role in *C. serpentina* hibernaculum choice. Specifically, *C. serpentina* is known to use overhanging banks that are maintained by root systems, as well as muddy substrates for burrowing (Ernst and Lovich 2009). In addition, the use of logs, plant debris, and muskrat burrows and lodges (Meeks and Ultsch 1990) is commonly associated with woodlot areas found in the Central Canal. In contrast, commercial, open, and road areas surrounding the canal tend to have steep embankments that are reinforced by large rocks (rip-rap) creating less than ideal hibernaculum sites.

We found MCAs associated with roads were less frequent than expected by chance, which is similar to *T. scripta* and *G. geographica* (Ryan et al. 2008). While *T. scripta* and *G. geographica* had a positive association with commercial areas which are tied to high vehicle density, owing to the increased availability of basking sites (Peterman and Ryan 2009; Ryan et al. 2008), *C. serpentina* did not. In many previous studies, vehicular-based mortality rates for snapping turtles were found to be extremely high (Haxton 2000; Pettit et al. 1995; Rizkalla and Swihart 2006), and vehicular mortality has been shown to adversely affect the sex ratio of turtle populations (Gibbs and Steen 2005; Steen and Gibbs 2004). Our results showed habitat use of *C. serpentina* negatively associated with commercial and residential areas. While aquatic habitat characteristics (e.g., the availability of roots) likely shape this pattern in part, an avoidance of areas where vehicular-based mortality is an additional viable hypothesis.

#### Conservation and management implications in urban landscapes

Species that inhabit urban areas are referred to as ‘urbanophiles’ (see McKinney 2006); Grant et al. (2011) however, use the term ‘temporally urbanoblivious’ for species that are generally oblivious to urbanization. The persistence of these species is tied to long life spans and successful recruitment from within populations and Grant et al. (2011) hold up *C. serpentina* as a prime example of this classification. The multiplicity of habitats within cities varies widely with regards to suitability for particular species; temporally urbanoblivious species are more reliant on cryptic habitats within this matrix than are true urbanophiles who thrive in the city at large. Therefore, urban landscapes present challenges to the species that require particular elements within urban green spaces. For semi-aquatic species, such as freshwater turtles, these problems are two-fold, as not only are they reliant on aquatic habitats, but they also require upland terrestrial landscapes for nesting sites, dispersal, and/or hibernacula. For example, turtles are continually susceptible to stormwater runoff, hydrology, and water quality (Grimm et al. 2008), as well as, forest cover and road density (DonnerWright et al. 1999; Steen and Gibbs 2004). The effects of habitat alteration may be more apparent for turtle species because their life history consists of delayed sexual maturity and low reproductive success (Brooks et al. 1991; Congdon et al. 1993, 1994; Lovich 1995). However, elements of human-altered landscapes, such as lawns and gardens in residential and commercial areas, can be productive nesting habitats (Joyal et al. 2001; Klemens 1993; Linck et al. 1989; Marchand and Litvaitis 2004b). Taken together, these characteristics can influence population structure of turtle communities found in urban landscapes (Bodie 2001; Ryan et al. 2008; Steen and Gibbs 2004). An understanding of spatial ecology and habitat use is therefore essential for the long-term persistence of these species in highly managed, urban ecosystems (Soule 1991).

Previous urban studies focused on freshwater turtle species have found distinct patterns in habitat association use (Saumure and Bider 1998; Marchand and Litvaitis 2004a) and earlier research on the Central Canal found non-random habitat associations for both *T. scripta* and

*G. geographica* (Ryan et al. 2008). Similar to *T. scripta* and *G. geographica*, our results indicated the importance of upland woodlot habitat in the spatial ecology of *C. serpentina* in an urban landscape. In addition, there is reason to suspect that road density near the Central Canal may be playing an important role in shaping community structure and distribution (Conner et al. 2005; Ryan et al. 2008). Collectively, these results emphasize the influence of human activities on the habitat use and movement of these turtle species in the Central Canal and highlight the significance of considering spatial ecology and habitat use of various riparian species in urban management designs. Management techniques incorporating connectivity of wetlands and large riparian buffer zones are ideal (Bodie 2001; Burke and Gibbons 1995; Marchand and Litvaitis 2004a, b; Rees et al. 2009; Roe and Georges 2007; Semlitsch and Bodie 2003) and while many urban areas have instituted such provisions, the question remains how useful these practices are at maintaining and promoting species habitat association. Further research investigating life history and spatial use of turtles and other riparian species within an urban landscape is warranted in order to maintain and conserve these populations.

**Acknowledgments** We would like to thank C. Conner, B. Douthitt, and A. Stachniw, for their assistance with data collection. This research was supported by funds from the Butler University Holcomb Awards Committee and the Butler Summer Institute. This is a publication of the Center for Urban Ecology at Butler University (<http://www.butler.edu/urban-ecology/>).

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