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URBAN DITCH CHARACTERISTICS ASSOCIATED WITH TURTLE ABUNDANCE AND SPECIES RICHNESS

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***Abstract.*—Although urbanization has contributed to wildlife population declines, urban ditches may present some of the last remaining refugia in expanding cities where turtles have persisted. To determine effective and easy-to-implement conservation measures, it is crucial to better understand the ecology of these urban turtle populations. Here, we assessed the influence of six easy-to-understand ditch characteristics on turtle abundance and richness using generalized linear mixed models. We based our study on capture and habitat data collected from May to August of 2011 and 2012, in seven ditches of Jonesboro, Craighead County, Arkansas, USA. Over these two years, we captured 452 turtles of six different species. Abundance and species richness were higher in ditches that were wider, longer, deeper, and had a wider buffer zone than ditches without these characteristics. No other variables (e.g., substrate type) were associated with variation in abundance or richness. Our results highlight the importance of habitat size for the persistence of turtle populations. Although other factors (e.g., water quality, food abundance) might be more ecologically relevant to urban turtles, ditch dimensions, being easy to manipulate, should be strongly considered when building or modifying a ditch system to minimize impact on turtle populations.**

Key Words.—buffer zone composition; buffer zone width; ditch depth; ditch length; ditch width; habitat; GLMM; substrate

INTRODUCTION

There are 328 recognized species of turtles in the world, 141 (43%) of which are listed as vulnerable, threatened, or endangered (Rhodin et al. 2011; IUCN Red List 2012). Anthropogenic activities such as turtle harvesting and habitat loss have contributed significantly to reductions in turtle numbers (Gibbons et al. 2000; Revenga and Kura 2003). As riparian areas are continually drained and reduced, urban habitat may offer some of the last remaining refugia in some places. Recent studies have begun to investigate wildlife usage of drainage ditches as habitat, and although biodiversity is typically lower in these areas, they do provide suitable habitat for some species (Williams et al. 2003; Moore et al. 2005; Vermonden et al. 2010; Verdonschot et al. 2011). However, most of these urban aquatic studies have focused on fish and macroinvertebrates. Turtles possess equal if not greater biomass in many freshwater systems (Congdon et al. 1986; Aresco 2009), and despite rising interest in urban turtle ecology, relatively few studies have investigated habitat associations in urban areas.

Here we studied six habitat components that play important roles in turtle biology in natural systems and examined their influence on turtle abundance and species richness in urban systems. These habitat components were stream length, width, depth, substrate type, and buffer zone width and composition. Maintaining certain uninterrupted stream lengths can provide foraging habitat, dispersal corridors, and can allow turtles to escape short-term disturbances (Bodie and Semlitsch 2000; Plummer and Mills 2008). Stream width may also increase availability of resources such as basking spots and foraging opportunities (Shively and Jackson 1985; DonnerWright et al. 1999). Various substrate types and ranges of stream depth preference accommodate different requirements for thermal regulation, foraging, and predator avoidance (Fuselier and Edds 1994; Reese and Welsh 1998; DonnerWright et al. 1999; Trauth et al. 2004; Aresco 2009).

In addition to the stream itself, turtles also use the bank and adjacent terrestrial habitat for foraging, basking, nesting, and overwintering (Ernst et al. 1994; Bodie 2001; Trauth et al. 2004). A buffer zone encompasses and protects this riparian zone from significant alteration or destruction. The width of this buffer zone used for nesting and overwintering can vary greatly amongst turtle species. Bodie (2001) reported that nest sites of 10 species studied in four countries, including the US, averaged 19.7 m away from the shore line (range 0.3–320 m). Overwintering sites for these species averaged 168 m from the shore (range 39–423 m). Preferences for composition of these buffer zones can also differ between species, varying from sandy banks to dense trees (Fuselier and Edds 1994; Reese and Welsh 1998; DonnerWright et al. 1999).

Previous studies have indicated that all six habitat components described above are vital constituents of turtle life cycles, but were all conducted primarily on

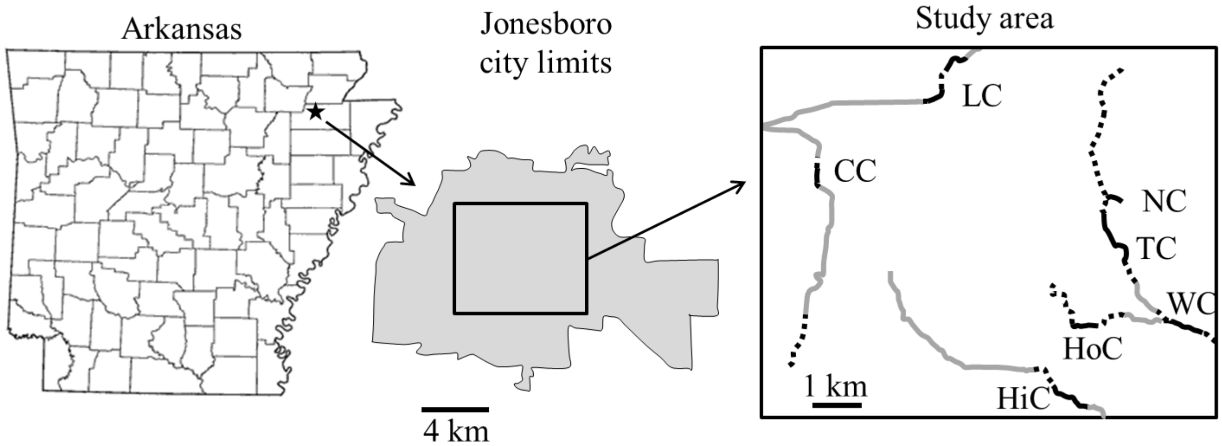

FIGURE 1. Location of studied ditches in Jonesboro, Arkansas, USA. Turtle traps were placed on accessible and authorized ditch segments (black solid lines; see Fig, 2 for details) of each studied ditch (TC: Turtle Creek; LC: Lost Creek; HiC: Higginbottom Creek; HoC: Hotel Creek; NC: Neil Creek; CC: Christian Creek; and WC: Whiteman's Creek). Solid gray lines represent ditch sections where accessibility was not authorized, and dashed lines are sections that were dry bed or underground.

non-urban streams (excluding stream length investigations from Plummer and Mills 2008). Our objective was to determine which components were associated with turtle abundance and species richness in urban ditch habitats. Unlike factors such as food abundance or connectivity, each proposed component is easy for builders, land owners, and maintenance crews to comprehend, modify, and replicate. Therefore, any association with one or more of these components would make conservation more likely to be implemented.

MATERIALS AND METHODS

Study site.—We conducted turtle trapping and habitat assessments for seven ditches in Jonesboro, Craighead County, Arkansas, USA (Fig.1), over two field seasons. Turtle populations can be considered residents of these ditches as the closest major body of water, the St. Francis River, is about 28 km away. We explored each of the seven studied ditches to fullest extent legally and safely possible. For private segments, we accessed only ditches for which we obtained permission from the property owners in this study. We set traps at each ditch on four separate occasions per field season, approximately three weeks apart. We trapped Turtle Creek, Higginbottom Creek, Lost Creek, and Hotel Creek (Fig. 2) in 2011 and 2012, whereas we trapped Whiteman's Creek at Nettleton High School, Christian Creek, and Neil Creek (Fig. 2) only in 2012.

We placed four traps in each ditch during every trapping occasion. The exceptions were Christian Creek and Neil Creek, in which we used only two hoop nets due to the very short stream segment length available. Because water levels changed, we reset traps at each trapping occasion, ideally placing them in areas of the ditch that submerged at least half of the trap. For < 10% of the traps, only the bait could be submerged, due to water levels being too low. When a trap was completely submerged, we provided empty plastic bottles as buoys to allow captured turtles to come up for air.

Trapping methods.—We conducted trapping from early May through the end of July in 2011 and 2012, using three-ringed 2.54-cm mesh hoop nets. The nets were 91.4 cm in diameter and 182.9 cm in length. The hoop nets are designed with a funnel leading into the trap that narrows as it extends toward the tail of the net. We baited hoop nets with Smallmouth Buffalo (*Ictiobus bubalus*) flanks, tied with tarred fisherman's string to the third ring at the tail of the net. We staked both the mouth and the tail of each trap in the water. We checked nets after approximately 24 h, and identified any captured turtles to species. We then marked them along marginal scutes using a three-letter notch filing system for future identification (Michael Dorcas, unpubl. report). We released each turtle back into the stream.

Habitat components.—At the time we checked each net (for each ditch and trap location), we measured various habitat components. We measured ditch length, which we defined as the length of continuous stream that has no significant blockage such as a dam (human constructed or non-human constructed), sewage pipe, construction runoff, gravel impoundment, adjacent levee or other human-made fabrication entering and occluding the stream. We did not trap sections of ditches that ran underground or were dry-bed. We recorded each trap location with a DNR Garmin handheld GPS unit

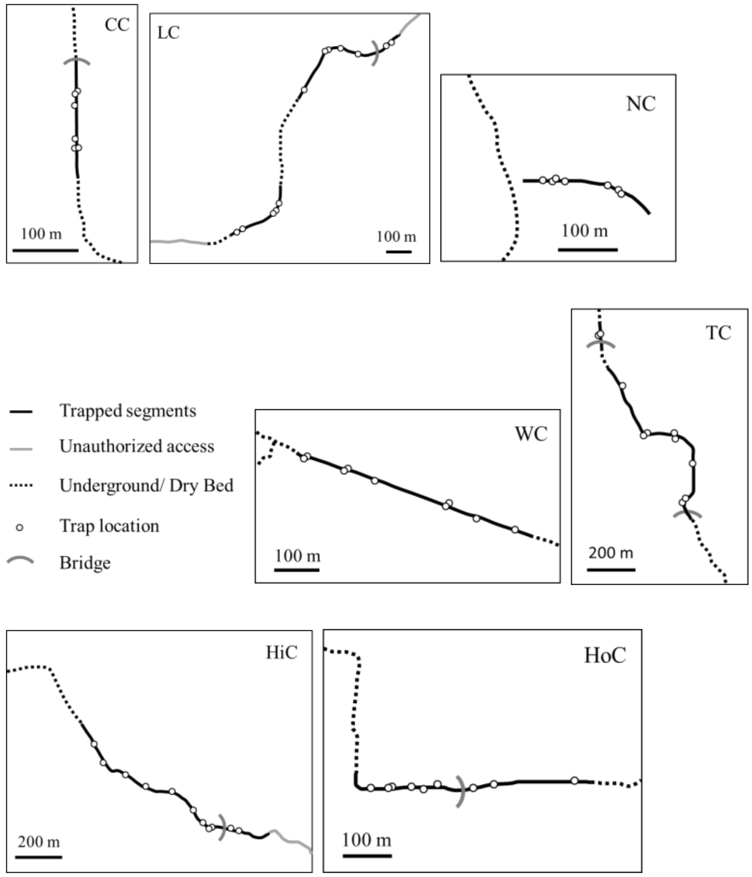

FIGURE 2. Ditch trapping sites for turtles in Jonesboro, Arkansas, USA. Ditch abbreviations are: TC (Turtle Creek); LC (Lost Creek); HiC (Higginbottom Creek); HoC (Hotel Creek); NC (Neil Creek); CC (Christian Creek); and WC (Whiteman's Creek).

(Garmin Ltd., Schaffhausen, Switzerland). We then calculated ditch length for each contiguous segment in ArcMap10 (ESRI, Redlands, California, USA). We measured ditch width and depth at each trap using a fiberglass open reel tape measure. Depth was measured at the mouth of the trap, whereas width was recorded from the edge of the water on one side of the trap, to the edge of the water on the other side.

We sampled substrate at four locations around each trap and we classified substrate as hard clay, soft clay, rock, gravel, or sand. We considered any substrate type recorded in at least two of the samples at a given trap the dominant substrate. We took GPS points at the edge of the buffer zone nearest to the water and the edge of the buffer zone nearest to human developments, such as fences, parking lots, streets, backyards, or the like. We then calculated buffer zone width in ArcMap10.

We estimated buffer zone composition (BZC) at each trap by visual survey using four categories: grass, shrubs, trees, and bare ground. The buffer zone composition was described by the predominant category. In the case of no single predominant category, we recorded all categories. To be considered prominent, a category must have been visible when the observer was facing each of the cardinal directions. We adopted this simplified method of vegetation assessment to allow members of the general public involved with urban ditches (e.g., builders, land owners, and maintenance crews) to replicate it easily when participating in conservation efforts.

Data analysis.—Abundance was represented by the total number of turtles captured per net during each trapping event. We built generalized linear mixed models (GLMMs) with a negative binomial error distribution to determine associations between abundance and the six habitat variables (stream length, stream width, stream depth, substrate, buffer zone width, and buffer zone composition). Species richness (i.e., number of species captured at each net) was also modeled with GLMMs using a negative binomial error distribution because of overdispersion. We performed all analyses using the glmmADMB package (Fournier et al. 2012) in the statistical software program R (R Core Team 2012).

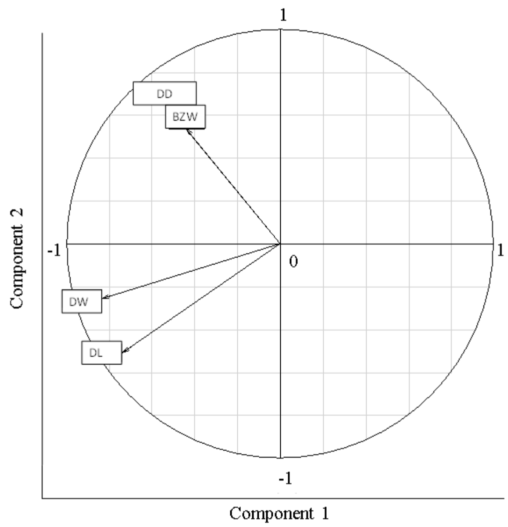

FIGURE 3. Circle of correlations for four habitat variables and principal components 1 and 2 for a study of ditch use by turtles in Jonesboro, Arkansas, USA. An increase in Component 1 results in decreased values for each of the quantitative variables, i.e., a decrease in habitat size. Correlation coefficients with component 1 were -0.538 for DD (Ditch Depth); -0.440 for BZW (Buffer Zone Width); -0.834 for DW (Ditch Width); and -0.740 for DL (Ditch Length).

To account for temporal and spatial pseudo-replication in our data, we modeled trap location, ditch, and year as random effects in the GLMM, with trap location nested within ditch location. Fixed and random effects were the same for species richness and abundance, and we adopted the following procedure for both types of models. All of the quantitative habitat variables (ditch length, width, depth, and buffer zone width) were correlated, so we performed a principal component analysis (PCA) to identify variables that would synthesize most of the variation among the original correlated habitat variables (Abdi and Williams 2010). Resulting eigenvalues for first to last components were 1.723, 1.0378, 0.915, and 0.321, respectively. The first component contained 43.15% of the variation represented by the four quantitative variables. Even though the second component (explaining another 25.94% of variation) could also be included in the model, we only retained the first principal component for further analysis because it was the only component that could be logically interpreted. All correlations between habitat variables and the first principal component were negative (Fig. 3), indicating a positive correlation among all variables and a decrease in ditch length, width, depth, and buffer zone width. An increase in value along the first component consequently resulted in decreased values of each quantitative variable (Fig. 3), i.e., a decrease in habitat size. Therefore, we labeled the PCA variable Inverse Habitat Size (IHS).

TABLE 1. Mean ditch segment length, width, depth, and buffer zone width for each ditch as well as the overall statistics for all ditches combined, in Jonesboro, Arkansas. A total of 150 measurements were taken at each ditch.

Ditch	Length (m)	Width (m)	Depth (cm)	Buffer Zone Width (m)
Higginbottom Creek	588	8.4	49.5	18.7
Christian Creek	220	5.4	50.8	7.1
Hotel Creek	202	6.3	45.5	5.2
Lost Creek	297	4.7	47.7	23.0
Whiteman's Creek	534	10.0	68.6	18.8
Neil Creek	211	5.1	35.9	3.6
Turtle Creek	775	8.4	45.3	9.7
Mean (± SD)	464.72 ± 249.99	7.28 ± 2.54	49.14 ± 14.30	13.39 ± 8.81
Min-Max	161.00–860.00	1.32–13.64	17.78–91.00	2.95–35.14

We constructed seven models for both abundance and species richness: (1) a full model with all explanatory variables (i.e., date, IHS, substrate, and BZC); (2) a null model (i.e., with no explanatory variables); and (3) five models with one to three of the four possible explanatory variables. We compared all models using the Akaike Information Criterion in accordance to the Information Theory approach (Burnham and Anderson 2002). The model with the lowest AIC and a ΔAIC < 2 was considered the best model. If ΔAIC < 2 models were considered equivalent, we applied the principle of parsimony (i.e., the most parsimonious model is the model with the fewest parameters among the lowest-AIC models) to determine which model to retain. We validated the selected model using a pseudo-coefficient of determination (pseudo-R^2) between predicted and observed values, as an indication of the amount of variation explained by the model.

RESULTS

There were 150 measurements recorded for each ditch component over both field seasons (Table 1). Ditches varied in their characteristics (Table 1), with Neil Creek being an overall small ditch (all quantitative variables combined) contrasting substantially with the bigger Whiteman's Creek. Substrate was soft at 41.4% of the trapping sites (22.8% soft clay/muck and 18.6% sand) and hard at 58.6% of the sites (27.6% hard clay, 17.2% rock, and 13.8% gravel).

We captured and marked 452 turtles (six species) in the ditches of Jonesboro between 2011 and 2012 (Table 2). Additionally, there we recaptured 161 individuals,

TABLE 2. Number of captures and recaptures for six species of turtles in Jonesboro, Arkansas, USA. Number captured represents the number of individuals marked per species. Number recaptured represents the number of individuals per species recaptured at least one time.

Species	Number Captured	Number Recaptured
Trachemys scripta elegans	386	131
Apalone spinifera spinifera	36	16
Chelydra serpentina	21	14
Pseudemys concinna concinna	7	0
Graptemys ouachitensis ouachitensis	1	0
Kinosternon subrubrum hippocrepis	1	0
Total	452	161

providing a 26.3% collective recapture rate. The Red-eared Slider (*Trachemys scripta elegans*) accounted for 85.4% (n = 386) of all turtle we captured. Eastern Spiny Softshell (*Apalone spinifera spinifera*) turtles comprised 8% of individuals, and Snapping Turtles (*Chelydra serpentina*) represented 4.6% of individuals. Although *A. s. spinifera* and *C. serpentina* together constituted a very minor proportion of individual turtles, they had the highest percentage of recaptures. We recaptured approximately 44.4% of marked *A. s. spinifera* and 66.7% of marked *C. serpentina* at least once. The remaining 2% of turtle captures consisted of Eastern River Cooters (*Pseudemys concinna concinna*), a single Mississippi Mud Turtle (*Kinosternon subrubrum hippocrepis*), and a single Ouachita Map Turtle (*Graptemys ouachitensis*). The capture of the Ouachita Map Turtle was of special significance as it was a county record and was likely brought by a record high flooding event in May of 2011.

For habitat components associated with species abundance, the top two models were No Substrate and Only IHS (Table 3). No Substrate was comprised of buffer zone composition and IHS, while Only IHS was comprised solely of IHS. The AIC, ΔAIC, relative likelihood, and weight were nearly identical for both models. According to the principle of parsimony, we selected Only IHS as the best model for abundance. This model with IHS as the only explanatory variable accounted for 46.4% (R^2) of the variation in number of turtles per net. Abundance decreased with IHS (slope = -1.28 ± 0.26; Fig. 4).

The top two models for habitat components associated with species richness were No BZC and Only IHS (ΔAIC < 2; Table 4). No BZC was comprised of the explanatory variables Substrate and IHS, whereas only IHS was included in Only IHS. Both models were similarly supported with relative likelihoods near 1. We chose Only IHS again as the best model for species richness based on the principle of parsimony. Species richness decreased with IHS (slope = -0.12 ± 0.06, Fig. 5). During model validation, this model with IHS as the only explanatory variable accounted for just 13.5% of variation in the number of species per net. However, the full model with all variables included still accounted for only 41.4% of the variation in number of species per net. Additionally, model No BZC accounted for only 14.1% of the variation, despite the additional variable.

DISCUSSION

Several studies have highlighted the influence of habitat characteristics such as stream length on turtles, but this study is the first to combine these characteristics and show the importance of habitat size on abundance and species richness of urban turtles. The influence of habitat size is not surprising, but the comparatively low influence of sediment type and buffer zone composition were unexpected. Among all models tested, our Inverse Habitat Size (IHS) variable best described variation in both abundance and species richness. This single variable represented all four of the quantitative habitat variables (ditch length, width, depth, and buffer zone width). Abundance decreased with increasing IHS. In other words, higher turtle abundances in the study were associated with ditches that were longer, wider, deeper, and with a wider buffer zone. More generally, results suggest that smaller habitat supports fewer turtles and larger habitat supports more turtles. The GLMM with only the synthesized IHS explained 46.4% of the variation in the number of turtles captured per net. Because this PCA variable accounted for less than half (43.15%) of the total variation represented by the quantitative variables, it would be more accurate to say that habitat variables (ditch length, width, depth, and buffer zone width) explained at least 46.4% of the variation in number of turtles captured per net.

Decreased length, width, depth, and buffer zone width in ditches had the same impact on species richness, and resulted in fewer turtle species per net. Niche partitioning in turtles (Congdon and Gibbons 1996; Aresco 2005) suggests partitioning by diet, and use of different microhabitats (Fuselier and Edds 1994; Aresco

TABLE 3. Model selection for turtle abundance, in Jonesboro, Arkansas. All models included the random effect of trap site nested within ditch but differed in their fixed effects (as indicated in parentheses). Fixed effects considered were date (for a temporal effect), substrate, buffer zone composition (BZC), and Inverse Habitat Size (IHS). Abbreviations are for degrees of freedom (df), Akaike Information Criterion (AIC), and the difference in AIC between a given model and the one with the lowest AIC (ΔAIC). The chosen model is in bold.

Model Name (fixed effects)	df	AIC	ΔAIC	Relative Likelihood	Weight
No substrate (BZC+IHS)	13	721.5	0.0	1.00	0.40
Only IHS (IHS)	**5**	**721.6**	**0.1**	**0.98**	**0.40**
No BZC (substrate+IHS)	9	724.0	2.4	0.30	0.12
No date (BZC+substrate+IHS)	17	724.7	3.2	0.20	0.08
Full (date+BZC+substrate+IHS)	57	730.3	8.8	0.01	0.00
No IHS (BZC+substrate)	16	742.0	20.5	0.00	0.00
Null	4	743.1	21.6	0.00	0.00

2009). Smaller habitat would allow for less partitioning among turtle species. The correlation between IHS and species richness was less pronounced than with abundance, but there were only six species captured throughout the entire study, two of them represented by a single individual. Only 13.5% of the variation in species richness was explained by the IHS variable. However, even the full model only explained 41.4% of the variation in species richness, meaning about a third of the variation in species richness was explained by the IHS variable. This implies that other variables not considered here (e.g., food abundance, water quality, connectivity) may have also influenced species richness.

It is not surprising that decreasing habitat space would result in fewer turtles or fewer turtle species. However, the composition of the buffer zone and the type of substrate had unexpectedly little impact on the number of turtles present. Whether the buffer zone consisted of trees, shrubs, grass, or was mostly barren did not appear to make a difference. It mattered more that a barrier merely existed between anthropogenic activity and turtle habitat. In fact, the type of buffer zone only accounted for 4% of the variation in number of turtles captured per net. This relates to a question Ryan et al. (2008) raised in a study where they found associations between turtle abundance and woodlot buffer zones surrounding the area. They questioned if it was the quality of the woodlot or perhaps just its presence that influenced turtle abundance; our results suggest that simply the presence of a buffer influences abundance, although further research is warranted.

Similarly, the type of substrate did not influence turtle abundance; substrate accounted for approximately 3% of

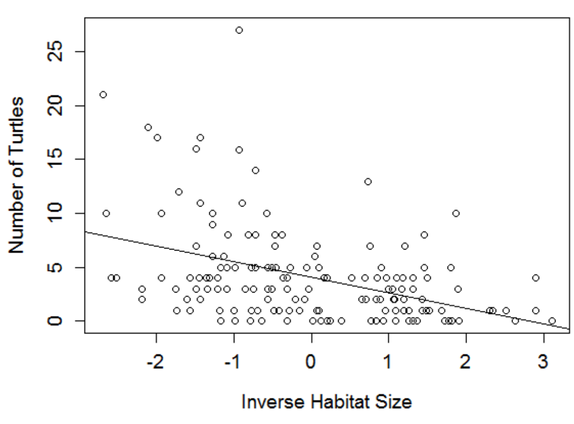

FIGURE 4. Number of turtles per net (in Jonesboro, Arkansas, USA) by Inverse Habitat Size (IHS) value. IHS is a synthesis of ditch length, width, depth, and buffer zone width. Negative IHS values represent high values of ditch length, width, depth, and buffer zone width. Total abundance decreases as habitat space decreases (i.e., higher IHS values). The regression line is the GLMM Only IHS (slope = -1.28 ± 0.26).

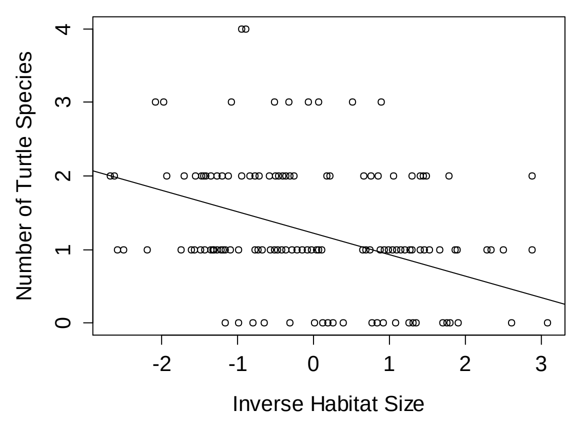

FIGURE 5. Number of turtle species per net (in Jonesboro, Arkansas, USA) by Inverse Habitat Size (IHS) value. IHS is a synthesis of ditch length, width, depth, and buffer zone width. Negative IHS values represent high values of ditch length, width, depth, and buffer zone width. Species richness decreases as habitat space decreases (i.e., higher IHS values). The regression line is the GLMM Only IHS (slope = -0.12 ± 0.06).

TABLE 4. Model selection for turtle species richness, in Jonesboro, Arkansas. All models included the random effect of trap site nested within ditch but differed in their fixed effects (as indicated in parentheses). Fixed effects considered were date (for a temporal effect), substrate, buffer zone composition (BZC), and Inverse Habitat Size (IHS). Abbreviations are for degrees of freedom (df), Akaike Information Criterion (AIC), and the difference in AIC between a given model and the one with the lowest AIC (ΔAIC). The chosen model is in bold.

Model Name (fixed effects)	df	AIC	ΔAIC	Relative Likelihood	Weight
No BZC (substrate+IHS)	9	394.9	0.0	1.00	0.49
Only IHS (IHS)	**5**	**395.1**	**0.2**	**0.91**	**0.45**
Null	4	399.2	4.3	0.12	0.06
No date (BZC+substrate+IHS)	17	405.8	10.9	0.00	0.00
No IHS (BZC+substrate)	16	405.9	11.1	0.00	0.00
No substrate (BZC+IHS)	13	406.1	11.3	0.00	0.00
Full (date+BZC+substrate+IHS)	57	468.8	73.9	0.00	0.00

the variation in species richness, with more species on soft substrates. This is consistent with previous studies in which most of the species captured have been documented as preferring soft substrates like sand, muck, or soft clay (Fuselier and Edds 1994; DonnerWright et al. 1999; Trauth et al. 2004; Aresco 2009). However, the relationship between substrate and species richness was surprisingly low. One possible explanation might be that urban drainage ditches are heavily modified habitat and can be subject to rapid changes in sediment gain and loss (Lee and Jones-Lee 2005). These hydrological alterations may impose conditions (including siltation conditions) that are beyond the range of conditions to which some turtle species are adapted. The size of these ditches is also greatly reduced compared to what is found in non-constructed streams inhabited by turtles. These size constraints may force turtles to use what habitat (e.g., substrate type) is available to them. Alternatively, this weak association between species richness and soft substrate could be because of a low variation in species richness among ditches.

Species richness in the study site was relatively low compared to that of larger streams and natural water bodies. In their six-year survey in Illinois, Dreslik et al. (2005) captured 10 turtle species. The highest number of species captured in any singular trap in our study was four. Although nine species have been documented in Craighead County (Trauth et al. 2004), only six species were captured during the study, with two of these species each represented by a single individual. Urban ditches are constructed to remove storm water effluent and tend to be relatively uniform without offering the same hydraulic and physical gradients found in natural water bodies (Williams et al. 2003, Vermonden et al. 2010, Verdonschot et al. 2011). Urban ditches also tend to sustain lower diversity in terms of micro- and mega-fauna assemblages (Williams et al. 2003). These restrictions may explain the absence and low incidence of map turtles (*Graptemys* sp.), *Kinosternon subrubrum hippocrepis*, *Sternotherus odoratus* (Stinkpots), and *Pseudemys c. concinna* (Eastern River Cooters) within the Jonesboro ditch system. Kinosternids and *Sternotherus* can, however, be more commonly found in the larger ditches throughout Craighead County outside of Jonesboro (Trauth et al. 2004; pers. obs.).

One species, *T. s. elegans*, represented 85% of turtle captures. Other studies have also reported high percentages of *T. s. elegans*. In a survey of 24 wetlands along the Missouri River, Bodie et al. (2000) found that *T. s. elegans* accounted for over 78% of all lentic turtle species. Similarly, Dreslik et al. (2005) found that *T. s. elegans* constituted 67% of all turtle captures. Conner et al. (2005) reported that 65% of turtle captures in urban waters of Indianapolis were *T. s. elegans*. Therefore, the turtle-habitat associations we detected may have been more applicable towards *T. s. elegans* than less common species. However, *a posteriori* analyses of turtle abundance indicated the same patterns when *T. s. elegans* was excluded from the data and when only *T. s . elegans* was considered (Appendix Tables 1 and 2), suggesting that these associations are relevant to most if not all species captured at our study site.

Our results indicate that for turtles, the physical space available for habitat use was more important than its composition. Higher turtle abundance and species richness were associated with longer, wider, and deeper ditches surrounded by wider buffer zones. Overall, few species used ditches of Jonesboro, Arkansas. This low species richness can probably be related to constraints on area available for habitat use and other factors such as water quality. Nonetheless, as fragmented as they may be, these ditches represent the last habitats available in urban environments. Future planning of ditch maintenance and modification should take into account opportunities to enhance turtle habitat requirements for their conservation. The quantitative habitat variables we studied (as opposed to food abundance for instance) can be practically manipulated by land managers and construction crews, and further research will focus on providing specific recommendations.

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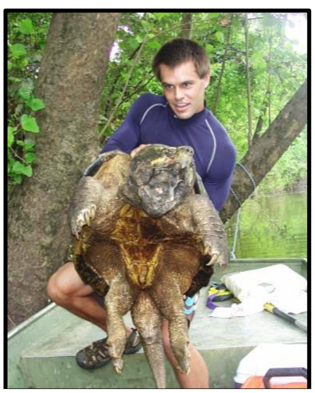

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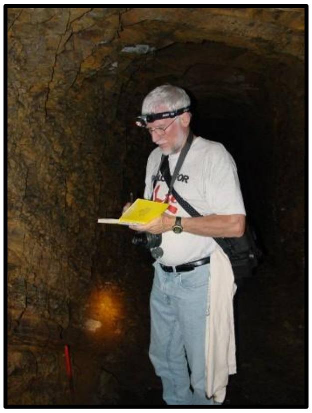

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Appendix Table 1. Model selection for abundance of Red-eared Slider (*Trachemys scripta elegans*) only. All models included the random effect of trap site nested within ditch but differed in their fixed effects (as indicated in parentheses). Fixed effects considered were date (for a temporal effect), substrate, buffer zone composition (BZC), and Inverse Habitat Size (HIS). Abbreviations are for degrees of freedom (df), Akaike Information Criterion (AIC), and the difference in AIC between a given model and the one withlowest AIC (ΔAIC). The chosen model is in bold.

Model Name (fixed effects)	df	AIC	ΔAIC
No substrate (BZC+IHS)	13	691.2	0.0
Only IHS (IHS)	**5**	**691.8**	**0.6**
No BZC (substrate+IHS)	9	693.3	2.1
No date (BZC+substrate+IHS)	17	694.4	3.2
Null	4	698.1	6.9
Full (date+BZC+substrate+IHS)	57	702.6	11.4
No IHS (BZC+substrate)	16	701.4	10.2

Appendix Table 2. Model selection for abundance of all turtles captured but Red-eared Slider (*Trachemys scripta elegans*). All models included the random effect of trap site nested within ditch but differed in their fixed effects (as indicated in parentheses). Fixed effects considered were date (for a temporal effect), substrate, buffer zone composition (BZC), and Inverse Habitat Size (HIS). Abbreviations are for degrees of freedom (df), Akaike Information Criterion (AIC), and the difference in AIC between a given model and the one with lowest AIC (ΔAIC). The chosen model is in bold.

Model Name (fixed effects)	df	AIC	ΔAIC
No BZC (substrate+IHS)	9	320.3	0
Only IHS (IHS)	**5**	**321.5**	**1.2**
Null	4	323.2	2.9
No IHS (BZC+substrate)	16	324.6	4.3
No date (BZC+substrate+IHS)	17	325.7	5.4
No substrate (BZC+IHS)	13	333.5	13.2
Full (date+BZC+substrate+IHS)	57	361.5	41.2