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Research paper

Environmental factors influencing the occurrence of coyotes and conflicts in urban areas

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HIGHLIGHTS

- We surveyed 105 urban areas in the United States regarding coyotes and conflicts.
- Larger urban areas were more likely to have coyotes and conflicts.
- Urban areas in the western regions were more likely to have conflicts.
- Cities with less forest and more development were more likely to have conflicts.
- Landscape design and citizen education may reduce human-coyote conflicts.

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ABSTRACT

The increase of global urbanization can have effects on wildlife species, including carnivores such as coyotes (*Canis latrans*). As coyotes continue to settle in more urban areas, reports of human-coyote conflicts, such as attacks on humans or pets, may also increase. Understanding environmental variables that might influence whether or not coyotes and human-coyote conflicts will occur in certain urban areas may assist wildlife officials in creating management plans for urban wildlife. We conducted a survey of 105 urban areas in the United States requesting information on the occurrence of coyotes and human-coyote conflicts. We analyzed the responses with data on human population size, geographic region, land cover, housing density, and precipitation. Larger urban areas were more likely to contain both coyotes and human-coyote conflicts, and were also more likely to have greater numbers of conflicts. Urban areas in the western regions with larger amounts of high-intensity development and less forested and agricultural areas were more likely to have conflicts. Most urban areas considered the management of conflicts to be of low priority and emphasized education of citizens rather than removal of individual coyotes. Our results may assist urban wildlife managers in understanding the geographic and demographic factors correlated with the occurrence of coyotes and human-coyote conflicts. Practices such as education campaigns and landscape design incorporating wildlife habitat modifications (e.g., reducing dense cover) may reduce human-carnivore conflicts in urban ecosystems.

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1. Introduction

Urbanization is increasing on a global scale, and by 2030 almost 5 billion people in the world will be living in urban areas (United Nations Population Fund, 2007). Urban expansion leads to significant changes in the landscape, including habitat loss and fragmentation (Markovchick-Nicholls et al., 2008; McKinney, 2002), which can alter the structure of ecosystems (Niemela, 1999). Urbanization is one of the leading causes of species endangerment (Czech, Krausman, & Devers, 2000) and can have a negative impact on biodiversity (Mcdonald, Kareiva, & Forman, 2008; Seto, Güneralp, & Hutyra, 2012). However, in some cases, urbanization can enhance native wildlife species richness (McKinney, 2008) and increase densities of certain animal species (Magle et al., 2007; Prange, Gehrt, & Wiggers, 2003). To accommodate wildlife, resource managers in some urban areas have begun incorporating

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wildlife habitat requirements into landscape planning and design (Adams, 2005).

Some carnivore species have become established in urban environments (Bateman and Fleming, 2012; Gehrt, Riley, & Cypher, 2010). Carnivores residing in urban areas range from kit foxes (*Vulpes macrotis*; Cypher, 2010) and mountain lions (*Puma concolor*; Beier, Riley, & Sauvajot, 2010) in North America to red foxes (*Vulpes vulpes*; Soulsbury, Baker, Iossa, & Harris, 2010) and Eurasian badgers (*Meles meles*; Harris, Baker, Soulsbury, & Iossa, 2010) in Europe to leopards (*Panthera pardus*; Athreya, Odden, Linnell, Krishnaswamy, & Karanth, 2014) in Asia. Carnivores successfully occupying urban areas generally have small to medium body sizes, are dietary generalists, and behaviorally have a tolerance for humans (Fuller, DeStefano, & Warren, 2010). Coyotes (*Canis latrans*) embody these characteristics (Gese and Bekoff, 2004; Morey, Gese, & Gehrt, 2007) and have colonized urban landscapes throughout North America (Gehrt and Riley, 2010; Gehrt, Anchor, & White, 2009; Magle, Poessel, Crooks, & Breck, 2014).

Coyote populations generally respond positively to urban environments. In southern California, coyote occurrence increased with both proximity and intensity of urbanization (Ordeñana et al., 2010). In Indiana, coyotes occupied suburban areas with high housing densities adjacent to large forested patches, suggesting coyotes can tolerate high levels of human activity when protective cover is nearby (Atwood, Weeks, & Gehring, 2004). Similarly, in metropolitan Detroit, Michigan, locations on trails and roads with evidence of coyote use (i.e., carcasses, dens, scats, tracks, or sightings) were closer to forested tracts than expected in both urban and suburban areas (Dodge and Kashian, 2013). Other studies have found urban coyotes selected natural habitat patches within their home ranges and minimized activity in developed areas (Gehrt et al., 2009; Gese, Morey, & Gehrt, 2012; Riley et al., 2003). However, some coyotes will utilize urban and suburban developed areas (Lukasik and Alexander, 2011; Poessel et al., 2013). Coyotes in captivity selected pens with a mixture of both natural and unfamiliar, anthropogenic structures, indicating coyotes preferred heterogeneous environments (Poessel, Gese, & Young, 2014). Hence, coyotes may thrive in highly developed areas when natural habitat patches are nearby and readily available.

Habitat selection by coyotes also may be influenced by the availability of water, in both arid sites, where coyotes primarily use water for drinking, and in moister environments, where coyotes use riparian areas for cover. In the Chicago metropolitan area, Gese et al. (2012) found home ranges of coyotes in less-developed and mixed-habitat areas contained more riparian habitats than were available in the study area; Gehrt et al. (2009) also determined water habitats (i.e., retention ponds) were consistently highly selected by coyotes in the same study area. In a desert site in west Texas, Atwood, Fry, and Leland (2011) found coyote activity near water features (i.e., stock tanks and impoundments) increased as the number of days since the last rainfall increased. In another arid site in Arizona, DeStefano, Schmidt, and deVos, Jr. (2000) determined coyote sign (e.g., scats and tracks) was seven times greater near water than away from water. These results indicated the potential importance of water or riparian areas to coyotes and that precipitation might influence coyote distribution.

Although the majority of urban coyotes tend to utilize the landscape in ways that avoid humans (Gehrt et al., 2009), some coyotes may become involved in coyote-human conflicts (hereafter, "conflicts", defined in Table 1, question 2; Grubbs and Krausman, 2009; Poessel et al., 2013). Such conflicts might occur spatially in a non-random manner. In the Denver metropolitan area of Colorado, conflicts occurred more frequently than expected in developed areas and less frequently than expected in natural and agricultural areas (Poessel et al., 2013). In addition, conflicts occurred more often than expected in suburban areas and less often than expected in exurban and rural areas. In Calgary, Alberta, the highest numbers of conflicts were in two small parks located near the urban core of the city, and the fewest conflicts were in two large, natural parks located near the city boundary (Lukasik and Alexander, 2011). Furthermore, conflicts were most often reported in close proximity to a river. Management of conflicts may be an important priority for wildlife officials in many urban areas, and an understanding of the various ecological factors that might be associated with such conflicts is becoming increasingly essential (Magle et al., 2014; Poessel et al., 2013, 2014).

Table 1
List of questions included in the survey of 105 urban areas in the contiguous United States.

Number	Text of Question
1	Does the [city name] urban area currently have coyotes residing within it? This would not include an occasional, nomadic coyote coming into the city. Rather, this would include coyotes permanently living or residing within the metro area, either in urban areas or in open spaces contained within the metro area.
2	If coyotes do reside in the [city name] urban area, do you have human-coyote conflicts? A conflict is defined as either (1) a physical attack by a coyote on a human or pet; or (2) a coyote showing aggressive behavior toward a human or pet, e.g., baring teeth, growling, stalking, or other behavior that could potentially endanger human or pet safety.
3	If the [city name] urban area does have human-coyote conflicts, do you consider this to be an issue of high priority, low priority, or no priority? High priority would indicate a critical need to address or manage the conflict issue, no priority would indicate no concern and no management taken to address the issue, and low priority would be between these two, i.e., concern over coyote conflicts but little action is taken.
4	If the [city name] urban area does have human-coyote conflicts, can you provide an estimate of the number of conflicts during the last year (2013) or for the most recent year for which you have data? (a) 1–10 (b) 11–40 (c) 41–100 (d) >100

Although others have examined the seasonality and types of victims of severe conflicts with coyotes (involving human injury; White and Gehrt, 2009), in this study we analyzed potential environmental variables that may influence urban coyote presence and conflicts, broadly defined, at a national and regional scale. Our primary objectives were to determine why certain urban areas in the United States have coyotes and why some of those have conflicts by examining geographic, demographic, and climatic characteristics of those urban areas, including human population size, geographic region, land cover, housing density, and precipitation. Additional objectives were to determine annual rates of conflicts and the priority level urban wildlife managers assign to the handling of such conflicts. We predicted that most urban areas would contain resident coyotes and that urban areas without conflicts would contain higher amounts of natural areas, higher rural or exurban housing densities, and higher precipitation levels. We further predicted that management of conflicts would be of high priority for most urban areas and that larger urban areas would have higher annual rates of conflicts. Our results may assist urban wildlife managers throughout the coyote's range to understand the most likely areas to contain coyotes and conflicts and, accordingly, to consider implementing habitat management and educational programs to mitigate such conflicts.

2. Methods

2.1. Data collection

We surveyed 105 urban areas within the contiguous United States, focusing on coyotes and conflicts. We used the U.S. Census Bureau's definition of an urban area: "a densely settled core

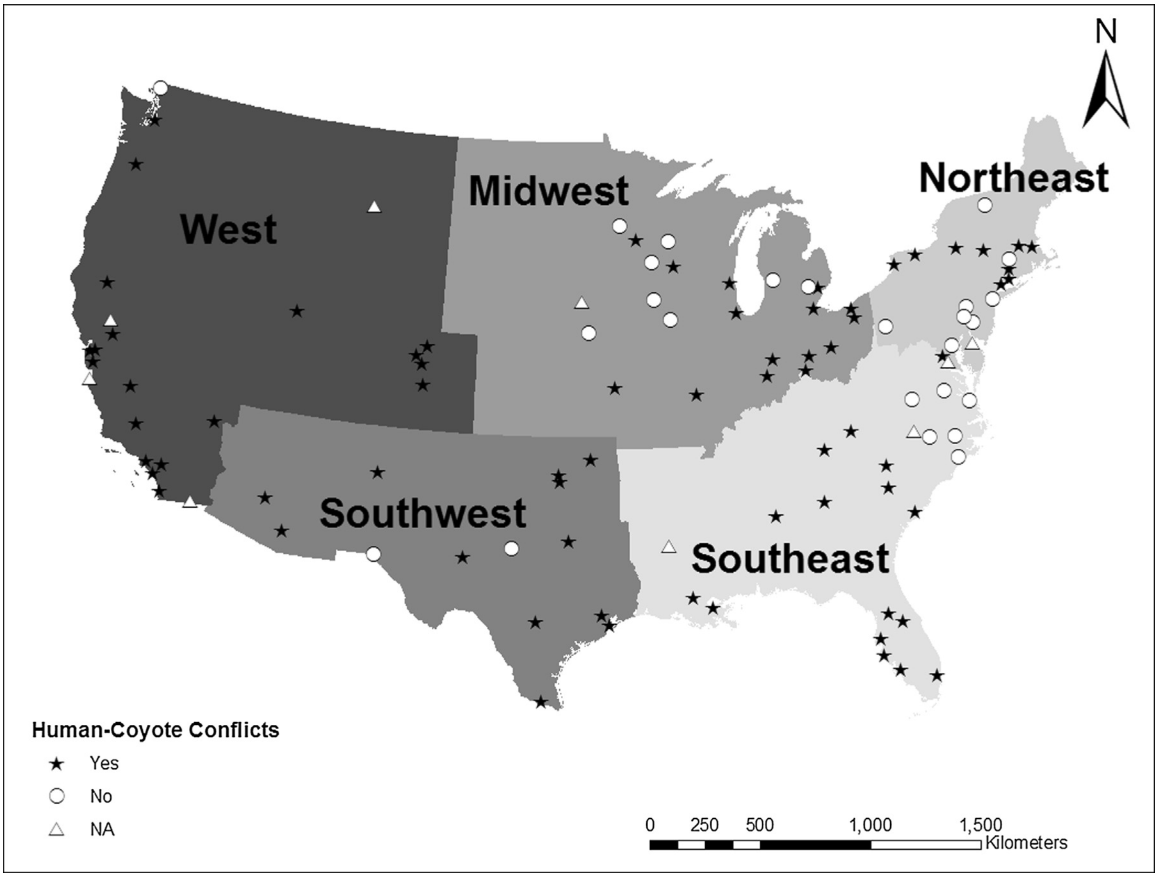

Fig. 1. Map of the contiguous United States divided into five geographic regions. Black stars represent urban areas that have both coyotes and human-coyote conflicts, white circles represent urban areas that have coyotes but do not have human-coyote conflicts, and white triangles represent urban areas that do not have coyotes or human-coyote conflicts.

of census tracts and/or census blocks that meet minimum population density requirements, along with adjacent territory containing non-residential urban land uses as well as territory with low population density included to link outlying densely settled territory with the densely settled core. To qualify as an urban area, the territory identified according to criteria must encompass at least 2500 people, at least 1500 of which reside outside institutional group quarters" (U.S. Census Bureau, 2014). Although coyotes are found throughout North America, we limited our survey to United States urban areas to maintain consistency in the datasets used in our analyses, each of which was obtained from a single source at a national scale. We selected 105 urban areas based on 2010 human population size. We grouped urban areas into three categories, large, medium, and small, with 35 urban areas in each category. Our goal for the survey was to receive at least 90 responses, or 30 in each category, so we surveyed 35 in each category to account for potential non-responses. The "large" category consisted of the largest 35 urban areas based on human population size, beginning with New York then down from there to the 35th largest (population size range included in the study: 18,351,295–1,368,035). The "medium" category consisted of urban areas beginning at a population size of 500,000 then up from there to include the next 35 largest cities in order (population size range included in the study: 507,643–953,556). The "small" category consisted of urban areas beginning at a population size of 100,000 then up from there to include the next 35 largest cities in order (population size range included in the study: 100,868–119,911). We did not include the smallest urban areas as defined by the U.S. Census Bureau (i.e., population size of 2500) because these smaller cities may not have been large enough to meet the objectives of our study, which were to address coyote presence and conflicts in urbanized areas containing large numbers of people where a wildlife official would have enough information to respond to our survey questions. Finally, we assigned a geographic region to each urban area, i.e., Northeast, Southeast, Midwest, Southwest, or West, based on maps from the National Planning Network and the U.S. Federal Highway Administration (Fig. 1).

Next, we contacted the state or district wildlife agency overseeing each urban area and asked four questions regarding coyotes in that urban area. First, we asked whether the urban area contained resident coyotes. If so, we next asked whether the urban area had conflicts (as defined in Table 1) and if conflicts were a high priority, low priority, or not a priority for the agency. Finally, we asked for an estimate of the annual numbers of conflicts. Because many wildlife officials do not maintain records of actual numbers of conflicts, we structured this question so that the respondent could select one of four ranges of numbers (see Table 1 for the full text of the four questions submitted to survey respondents). If the wildlife agency did not have all of the information requested, we next contacted the local animal control office for the urban area. In some cases, the wildlife agency directed us to contact the local United States Department of Agriculture-APHIS-Wildlife Services (Wildlife Services) office or the local police department for answers to the questions. If the response to question 1 was "no", then the responses to the remaining three questions were "NA". If the response to question 2 was "no", then the responses to questions 3 and 4 were "NA". For some urban areas, the wildlife official could not provide an answer to question 4 due to a lack of data. Hence, possible responses for each of the four questions included for question 1, yes or no; for question 2, yes, no, or NA; for question 3, high, low, no, or NA; and for question 4, 0, 1–10, 11–40, 41–100, >100, no answer, or NA.

After collecting the responses, we then used land cover, housing density, and precipitation data for each urban area, as well as the human population size category and geographic region assigned to each urban area, to compare responses. We obtained land cover data from Landscape Fire and Resource Management Planning Tools (LANDFIRE), a program producing national geospatial datasets that provide information for landscape strategic planning for fire and natural resource management activities (LANDFIRE, 2013). We used ArcGIS v.10.0 (ESRI, Redlands, California) to condense the land cover dataset, in 30-m resolution, into eight types: (1) forest (naturally-occurring areas dominated by trees); (2) shrubland (naturally-occurring areas dominated by shrubs); (3) grassland (naturally-occurring areas dominated by herbaceous/non-vascular plants); (4) riparian (naturally-occurring areas dominated by water or water-dependent vegetation, i.e., wetlands, floodplains, swamps, marshes, riparian systems, and open water); (5) sparse (barren and sparsely-vegetated areas with no dominant life form); (6) altered open (urban vegetated systems, i.e., city parks, golf courses, and cemeteries); (7) development (commercial and residential developed areas and roads); and (8) agriculture (croplands, pasture and hay fields, orchards, and vineyards). We attained housing density data from the Spatially Explicit Regional Growth Model (SERGoM v3; Theobald, 2005), which depicts housing density for the coterminous United States at 100-m resolution. We used ArcGIS to classify private developed land into four classes: (1) rural (>16.18 ha per unit); (2) exurban (0.68–16.18 ha per unit); (3) suburban (0.1–0.68 ha per unit); and (4) urban (<0.1 ha per unit plus industrial and commercial development; Theobald, 2005). For each of the 105 urban areas, we then calculated percentages of each land cover type and housing density class contained within the urban area. Finally, we obtained 30-year average annual precipitation values for each urban area from the National Oceanic and Atmospheric Administration (http://average-rainfall.findthebest.com). We included precipitation in the analysis as a metric for water in arid urban areas and as a proxy for primary productivity of vegetation in moister urban areas.

2.2. Data analyses

We analyzed the responses to the coyote conflict question (question 2) with univariate logistic regression models. Because of the low number of "no" responses (Table 2), we could only include one covariate at a time in a model. We ran models with human population size category, geographic region, each land cover type, each housing density class, and precipitation separately as covariates. We used $P < 0.05$ to determine significant variables. We could not run models for the responses to each of the other three survey questions (questions 1, 3, and 4; Table 1) because of the low number of responses in ≥1 response category; we instead report the percentages in each response category for these questions. We also used analysis of variance (ANOVA) to separately analyze the differences in each land cover type, housing density class, and precipitation among the three human population size categories and five geographic regions. For all models with category or region as predictor variables, we analyzed pairwise comparisons for any significant effects, correcting *P*-values with a Tukey adjustment. For the ANOVA land cover models, we logit-transformed the grassland and sparse land cover response variables to meet distributional assumptions. For the ANOVA housing density models, we logit-transformed the rural and urban housing density response variables. We used R in all statistical analyses (R Core Team, 2014).

3. Results

We received responses from all 105 urban areas (100% response rate), 90 from state wildlife agencies only (85%), five from Wildlife Services only (5%), three from animal control only (3%), four from both state agencies and animal control (4%), one from both a state agency and Wildlife Services (1%), one from a state agency, animal control, and the police department (1%), and one from a university researcher experienced with coyote issues in that particular urban area when we did not receive a response from any other agency (1%). Ninety-six urban areas (91%; based on $n = 105$) contained resident coyotes, and 71 of these areas (74%; based on $n = 96$) had conflicts (Fig. 1). For the 71 urban areas reporting conflicts, officials from 58 of them (82%; based on $n = 71$) considered conflicts to be a low priority, two of them (3%) stated conflicts were not a priority, and only 11 of them (15%) regarded management of conflicts as a high priority. Fifty-two urban areas of those reporting conflicts (73%) had either 1–10 or 11–40 conflicts occurring on an annual basis, whereas four urban areas (6%) reported > 100 annual conflicts. These four areas were Denver-Aurora (Colorado), St. Louis (Missouri), Portland (Oregon), and Colorado Springs (Colorado). Six urban areas (8%) provided an actual number of conflicts rather than a range; five of these were placed in the 1–10 range and one was placed in the 11–40 range. Wildlife officials from nine urban areas (13%) could not answer the question regarding numbers of conflicts due to a lack of data, and three urban areas (4%) reported they have conflicts, but had none in 2013, the year for which data were requested (see Table 1).

For responses by human population size category, every urban area (100%; based on $n = 35$ for each category) in the large and medium categories had coyotes, but only 26 urban areas (74%) in the small category reported they had resident coyotes (Table 2). Thirty urban areas (86%) in the large category, 28 (80%) in the medium category, and 13 (50%; based on $n = 26$, or the number of urban areas reporting coyotes) in the small category had conflicts (Table 2). Human population size category was a significant predictor of whether or not urban areas had conflicts ($\chi_2{}^2 = 9.97$, $P = 0.007$). The small category was less likely to have conflicts than both the large ($P = 0.011$) and medium ($P = 0.043$) categories (Table 2). Most urban areas in all three categories considered management of conflicts to be a low priority (Table 2). Three of the four urban areas reporting > 100 annual conflicts were in the large human population size category (Table 2).

For responses by geographic region, all urban areas in the Southwest (100%; based on $n = 14$), ≥90% of the urban areas in the Northeast (based on $n = 20$), Southeast (based on $n = 23$), and Midwest (based on $n = 24$), and 83% of the urban areas in the West (based on $n = 24$) had resident coyotes (Table 2). Conflicts occurred in 95% of urban areas with coyotes in the West, 86% of urban areas with coyotes in the Southwest, >65% of urban areas with coyotes in both the Southeast and Midwest, and 56% of urban areas with coyotes in the Northeast (Table 2). Geographic region was not a significant predictor of whether or not urban areas had conflicts ($\chi_4{}^2 = 7.71$, $P = 0.103$); however, this result was marginally significant and the region logistic regression model may have been over-parameterized (with four parameters estimated) for the number of responses. A direct comparison of urban areas with conflicts between the Northeast and West regions indicated urban areas in the West were more likely to have conflicts ($\chi_1{}^2 = 5.80$, $P = 0.016$); two-way comparisons for the other regions were not significant. Three of the four urban areas reporting >100 annual conflicts were in the West (Table 2).

Forest ($\chi_1{}^2 = 4.17$, $P = 0.041$), development ($\chi_1{}^2 = 8.52$, $P = 0.004$), and agriculture ($\chi_1{}^2 = 4.30$, $P = 0.038$) were significant predictors of whether or not urban areas had conflicts; urban areas containing more forested and agricultural areas and less developed areas were

Table 2
Percentage of responses to each of four questions included in the survey of 105 urban areas in the contiguous United States, by human population size category and geographic region. Human population size categories were large, the largest 35 urban areas based on human population size; medium, the 35 urban areas beginning at a population size of 500,000 and up; and small, the 35 urban areas beginning at a population size of 100,000 and up. Geographic region refers to the geographic area of the contiguous United States. Numbers in parentheses refer to the question number from Table 1.

		Coyotes (1)		Conflicts (2)[a]		Management Priority (3)[b]			Number of Conflicts (4)[b]					
Category	*n*	Yes	No	Yes	No	High	Low	No	0	1–10	11–40	41–100	>100	No Answer
Large	35	100	0	86	14	20	77	3	0	44	23	10	10	13
Medium	35	100	0	80	20	11	89	0	7	36	39	0	4	14
Small	35	74	26	50	50	15	77	8	8	38	46	0	0	8
Region	*n*	Yes	No	Yes	No	High	Low	No	0	1–10	11–40	41–100	>100	No Answer
Northeast[c]	20	90	10	56	44	30	60	10	20	70	10	0	0	0
Southeast[d]	23	91	9	71	29	0	100	0	0	27	53	7	0	13
Midwest[e]	24	96	4	65	35	13	87	0	0	33	26	7	7	27
Southwest[f]	14	100	0	86	14	25	67	8	8	42	25	8	0	17
West[g]	24	83	17	95	5	16	84	0	0	37	42	0	16	5

[a] Percentages for the conflict question were based on the number of urban areas responding "Yes" to the coyote question.
[b] Percentages for the management priority and number of conflicts questions were based on the number of urban areas responding "Yes" to the conflict question.
[c] Sample sizes for each population size category in the Northeast region: large—6, medium—8, and small—6.
[d] Sample sizes for each population size category in the Southeast region: large—5, medium—10, and small—8.
[e] Sample sizes for each population size category in the Midwest region: large—10, medium—5, and small—9.
[f] Sample sizes for each population size category in the Southwest region: large—4, medium—6, and small—4.
[g] Sample sizes for each population size category in the West region: large—10, medium—6, and small—8.

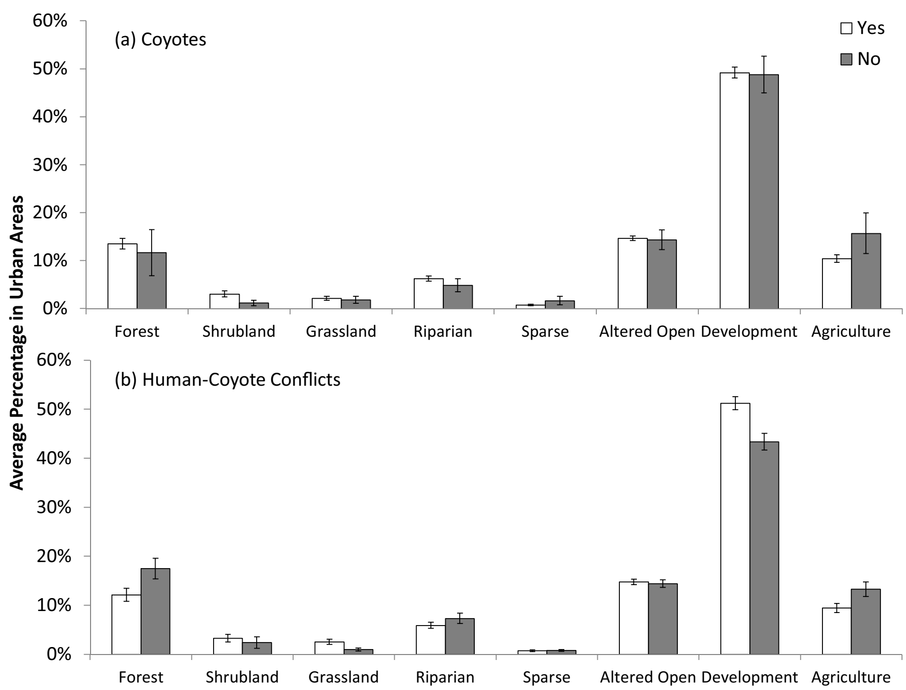

Fig. 2. Average percentages of each of eight land cover types in United States urban areas with (yes) and without (no) (a) resident coyotes ($n = 105$) and (b) human-coyote conflicts ($n = 96$). Bars represent standard error around the mean.

less likely to have conflicts (Fig. 2). Shrubland ($\chi_1^2 = 0.35$, $P = 0.552$), grassland ($\chi_1^2 = 2.49$, $P = 0.115$), riparian ($\chi_1^2 = 1.41$, $P = 0.235$), sparse ($\chi_1^2 = 0.03$, $P = 0.865$), and altered open areas ($\chi_1^2 = 0.10$, $P = 0.753$) did not predict whether or not urban areas had conflicts (Fig. 2).

Exurban ($\chi_1^2 = 7.82$, $P = 0.005$) and urban ($\chi_1^2 = 7.11$, $P = 0.008$) housing densities were significant predictors of whether or not urban areas had conflicts; urban areas containing higher percentages of exurban housing density were less likely to have conflicts, and those containing higher percentages of urban housing density were more likely to have conflicts (Fig. 3). Rural ($\chi_1^2 = 0.03$, $P = 0.874$) and suburban ($\chi_1^2 = 0.72$, $P = 0.395$) housing densities did not predict whether or not urban areas had conflicts (Fig. 3).

Average annual precipitation (±SD) in urban areas containing resident coyotes was 91 ± 35 cm and in urban areas without coyotes was 77 ± 45 cm. Average annual precipitation in urban areas with conflicts was 89 ± 38 cm and in urban areas containing coyotes but without conflicts was 97 ± 23 cm. Precipitation was not a significant predictor of whether or not urban areas had conflicts ($\chi_1^2 = 1.04$, $P = 0.308$). Results for the ANOVA models analyzing the differences in each land cover type, housing density class, and precipitation among the three human population size categories and five geographic regions are included in Appendices A-E and displayed in Figs. 4 and 5.

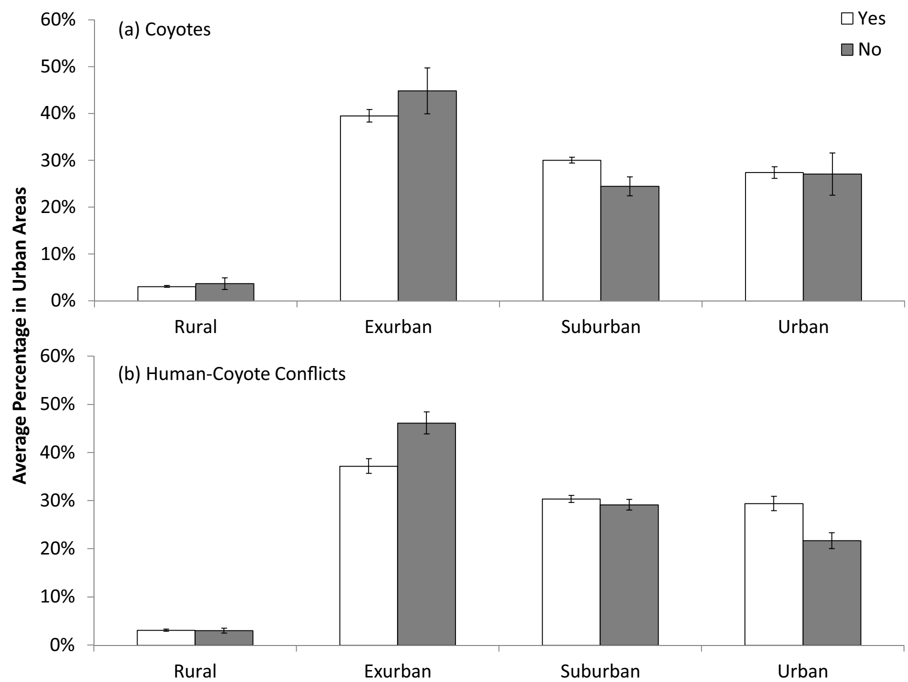

Fig. 3. Average percentages of each of four housing density classes in United States urban areas with (yes) and without (no) (a) resident coyotes (n = 105) and (b) human-coyote conflicts (n = 96). Bars represent standard error around the mean.

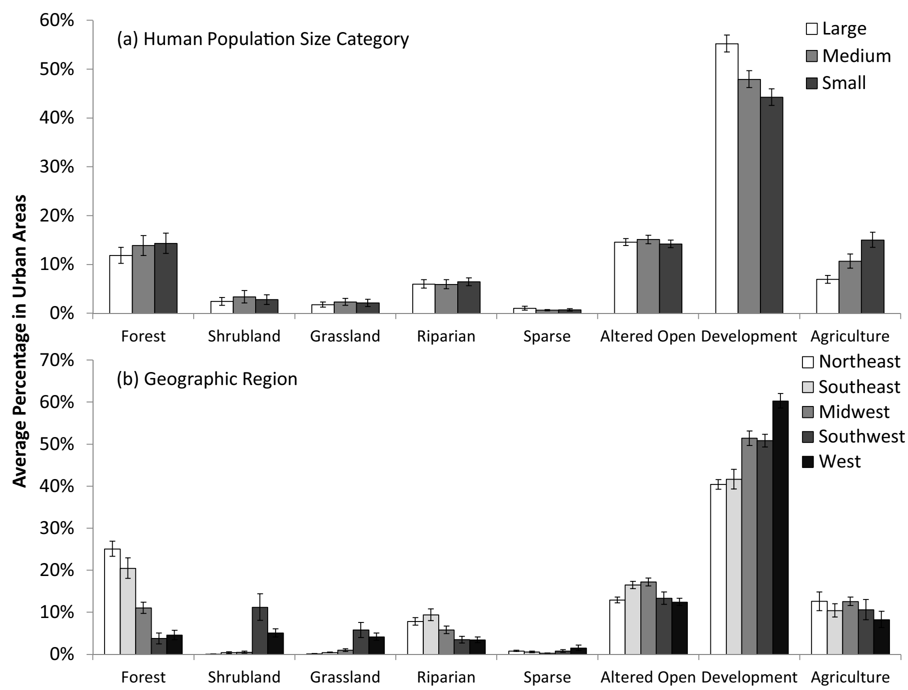

Fig. 4. Average percentages of each of eight land cover types in United States urban areas by (a) human population size category and (b) geographic region. Human population size categories were large, the largest 35 urban areas based on human population size; medium, the 35 urban areas beginning at a population size of 500,000 and up; and small, the 35 urban areas beginning at a population size of 100,000 and up. Geographic region refers to the geographic area of the contiguous United States. Bars represent standard error around the mean.

4. Discussion

Most (91%) of the urban areas in our study contained resident coyotes, confirming coyotes are ubiquitous throughout North America and have learned to adapt to and thrive in one of the most extreme habitats for wildlife species, urban development. Every urban area in both the large and medium human population size categories had coyotes, compared to only 74% of urban areas in the small category. These results suggest coyotes may be able to survive and be successful in areas with larger numbers of humans because of the refugia they provide. Trapping or hunting of coyotes by citizens usually does not occur in larger cities, so coyotes may be more protected in these urban areas (Gehrt and Riley, 2010). Coyotes also may be consuming anthropogenic food sources commonly found in urban areas. Although human-related foods usually constitute a small proportion of the coyote diet (Fedriani, Fuller, &

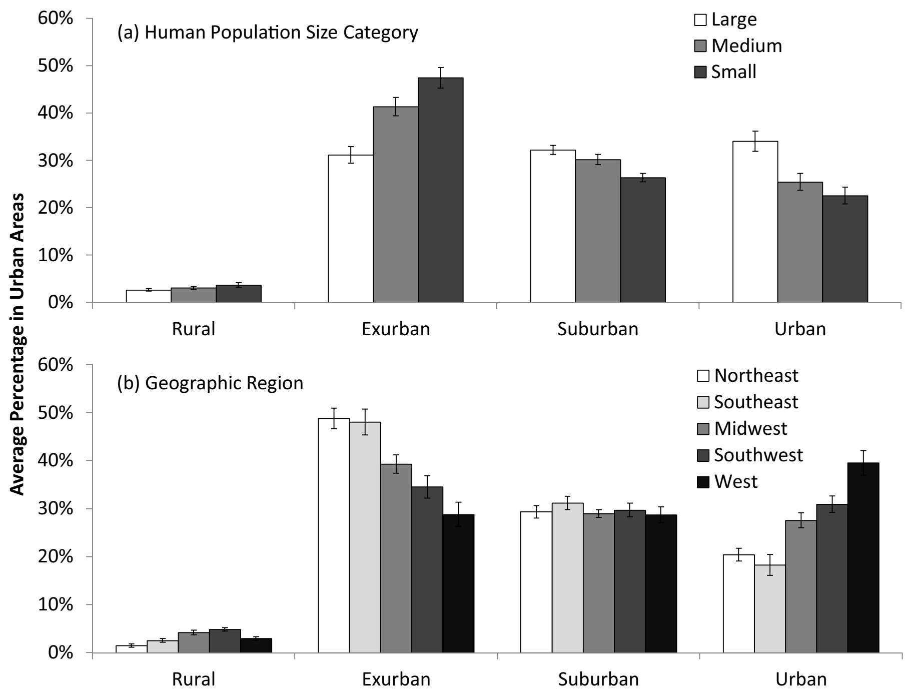

Fig. 5. Average percentages of each of four housing density classes in United States urban areas by (a) human population size category and (b) geographic region. Human population size categories were large, the largest 35 urban areas based on human population size; medium, the 35 urban areas beginning at a population size of 500,000 and up; and small, the 35 urban areas beginning at a population size of 100,000 and up. Geographic region refers to the geographic area of the contiguous United States. Bars represent standard error around the mean.

Sauvajot, 2001; Morey et al., 2007), at times they may use such food items as partial substitutes for more natural foods, such as rodents (McClure, Smith, & Shaw, 1995). Gehrt et al. (2009) did not find evidence that coyotes were attracted to human-associated areas, but this finding was at the finer scale of the coyote's home range, rather than at the broader scale of the urban area. Our results indicate coyotes might be using larger urban areas not only because they provide refugia, but also due to the heterogeneous habitats and anthropogenic food sources provided by such areas.

We found that 80% or more of urban areas in each of the large and medium human population size categories reported conflicts, whereas only 50% of urban areas in the small category that had coyotes reported such conflicts. The occurrence of conflicts also appeared to have a regional bias, with conflicts more likely to occur in western urban areas, consistent with White and Gehrt's (2009) analysis of coyote attacks on humans. In the Northeast region, only 56% of those urban areas with coyotes reported conflicts, the lowest percentage among the five regions. Further, 64% of urban areas with coyotes in the Northeast and Southeast regions combined had conflicts, compared to 81% of urban areas with coyotes in the other three regions combined. Coyotes began to expand into the eastern United States only during the 20th century and reached the Northeast region by the 1950s and the Southeast region by the 1960s (Parker, 1995). This relatively recent occupation might explain the reduced level of conflict in the eastern regions. Coyotes unfamiliar with urbanized environments may require a period of adjustment before they can thrive in these areas, as Bogan (2004) discovered in an urban coyote study near Albany, New York where annual survival was low (20%). Further, coyotes may become habituated to humans over time, leading to increased conflicts (Geist, 2007). Residents of these eastern areas also may not be as likely to report conflicts as citizens in western areas, where greater experience and longer history with coyotes may result in increased conflict reporting. However, other factors also may contribute to a reduced likelihood of conflicts in the Northeast region.

First, eastern coyotes in the Northeast are hybrids between western coyotes and eastern wolves (*C. lycaon*; Kays, Curtis, & Kirchman, 2010; Rutledge, Devillard, Boone, Hohenlohe, & White, 2015; Way, Rutledge, Wheeldon, & White, 2010) and have been labeled coywolves (*C. latrans* × *C. lycaon*; Way, 2013; Way et al., 2010). Perhaps the presence of wolf DNA in these animals has influenced their behavior to be less bold towards humans, as wolves, especially in forested areas, are generally shy and avoid people (Fritts, Stephenson, Hayes, & Boitani, 2003), whereas certain coyotes may become habituated to humans and develop bold behavior (Gehrt and Riley, 2010). However, coyote conflict levels in eastern rural areas have been high (Mastro, Gese, Young, & Shivik, 2012). Hybridizing with wolves also has contributed to the development of larger coyotes (Parker, 1995), so perhaps coyotes are more dependent on larger prey which may be less likely to occur in highly developed areas. Second, harsh winters in the Northeast region (Kug et al., 2015; Parker, 1995; Way et al., 2010) might reduce the likelihood of coyote encounters with pets if residents and their pets do not venture outside as much during this time of year, which coincides with the breeding season of coyotes when conflicts might be more likely to occur (Poessel et al., 2013). Finally, white-tailed deer (*Odocoileus virginianus*) densities are high in the Northeast region, including urban areas (Lund, 1997; Stromayer & Warren, 1997), and deer can be an important component of the diet of eastern coyotes (Crimmins, Edwards, & Houben, 2012; Gompper, 2002; Parker, 1995). Perhaps the high availability of natural prey is associated with a decrease in conflicts between humans and coyotes in the northeastern urban areas, as has been reported for a western urban area (Magle et al., 2014). However, conflicts have been reported in U.S. national parks which have an abundance of native prey, but the most serious of these conflicts (i.e., aggressive behavior towards humans) were infrequent and were likely due to feeding of coyotes by park visitors (Bounds and Shaw, 1994).

Urban areas with conflicts contained lower percentages of forested and agricultural areas and higher percentages of developed areas. Additionally, urban areas with conflicts contained lower percentages of exurban and higher percentages of urban housing densities. Several urban coyote studies have determined the importance of natural cover, including forests, for coyotes. Gehrt et al. (2009) and Riley et al. (2003) both found coyotes were predominantly associated with natural land use, with smaller percentages of development in coyote home ranges. Gese et al. (2012) determined coyotes preferred less-developed areas with low levels of human activity. Dodge and Kashian (2013) found availability and access to tree cover was more important for coyote occupancy than the presence of open space. Poessel et al. (2013) determined conflicts were greater in developed land cover than in natural and agricultural land cover, and they occurred less often than expected in exurban housing densities. These results are consistent with our findings and suggest that cover provided by forests may help reduce encounters between coyotes and humans and their pets, whereas coyote encounters and conflicts are more likely to occur in developed areas, especially areas with dense concentrations of humans and pets.

We found several patterns among land cover types, housing density classes, precipitation, human population size categories, and geographic regions (Appendices A-E). As might be expected, development, including suburban and urban areas, was higher in the large human population size category, whereas agriculture and exurban development were highest in the small category, likely contributing to reduced conflicts in urban areas with lower concentrations of people. Forested and riparian areas were higher in the eastern regions (Northeast and Southeast), which may further explain why the Northeast region had fewer conflicts. Development, especially urban housing densities, was higher in the western regions (Midwest, Southwest, and West), and exurban housing densities were higher in the eastern regions, additionally clarifying the difference in conflicts between eastern and western urban areas. Annual precipitation was higher in eastern urban areas, although precipitation did not predict whether or not urban areas had conflicts.

Contrary to our predictions, management of conflicts was a low priority or not a priority for the majority (85%) of urban areas that had conflicts, and only 15% of urban areas with conflicts considered this issue to be a high priority. Many wildlife managers stated they provide education to the public and advice on how to reduce conflicts, rather than active management of individual coyotes. However, for many urban areas, conflict management would become a high priority if a coyote attacked a person or if human safety became a concern. We emphasize that, although conflict management was a low priority for wildlife managers, it is likely a high priority for urban residents, especially for those directly involved in conflicts with coyotes. Citizens experiencing a coyote attack on a pet or an interaction with an aggressive coyote may have a reduced tolerance for wildlife (Poessel et al., 2013). Wildlife managers should recognize these differing perceptions of conflicts and be more proactive in their urban wildlife policies rather than reactive, i.e., only prioritize conflicts when they have reached unacceptable levels, such as attacks on humans. If human and coyote populations continue to grow in North American urban areas, conflicts between them are likely to escalate. By implementing proactive policies, such as habitat modifications and targeted education campaigns, wildlife managers may be able to prevent conflicts from becoming a high priority.

Most urban areas reported annual numbers of conflicts in the 1–10 or 11–40 ranges. Only seven (10%) urban areas with conflicts reported annual conflicts in the 41–100 or >100 ranges, with six of these in the large human population size category (20% of this category) and four of these in the Southwest and West regions (13% of these two regions combined). These results indicate large urban areas, especially those in the western United States, not only are more likely to have conflicts, but they also are more likely to have greater numbers of conflicts.

We emphasize that some bias may be present in our results. Wildlife managers based their responses to the coyote conflict questions (questions 2 and 4) on conflict reports received from their citizens, which may introduce reporting bias (Poessel et al., 2013). Conflicts may occur at a reduced level in the small human population size category simply because of fewer numbers of people to report conflicts or because of less opportunities for conflicts, which may also explain why some urban areas in this category reported they did not have resident coyotes. Bias may also occur if people in this category are less likely to report conflicts with coyotes if they do not perceive coyotes as a threat. The small human population size category contained higher percentages of agriculture and exurban housing development than the other categories, so perhaps humans residing in these low-density urban areas observe coyotes more often and are more tolerant of them than people residing in more densely-populated urban areas (Poessel et al., 2013). Residents of these low-density areas also may be more likely to remove coyotes, which may reduce habituation to humans and, hence, decrease conflicts (Farrar, 2007), and also result in a refuge effect for coyotes in larger urban areas (Gehrt and Riley, 2010), leading to more conflicts in these large areas. Another factor that may have influenced our results is that some urban areas may have implemented active coyote management programs, which may have affected the occurrence of conflicts; however, information provided by many respondents indicated that most urban areas did not have such programs. For those urban areas that do have such management programs, the reduction in coyote conflicts could result in conflict management being considered a low priority. Additional biases in all urban areas may include socioeconomic factors. For example, people with higher incomes whose properties contain more resources for coyotes (e.g., food or cover) may be more likely to encounter a coyote and, thus, report the coyote sighting or conflict (Wine, Gagné, & Meentemeyer, 2015). Finally, the results for numbers of conflicts in each urban area should be interpreted with caution. Wildlife officials from most urban areas were not maintaining records of conflict numbers and could only provide us with an estimate; hence, the actual numbers of annual conflicts could be higher or lower than reported in our study. Further, some urban areas may have standardized tracking systems in place for conflicts and, thus, may report a higher number of conflicts than those that have no such system. Any of these biases may have had a considerable influence on our results.

5. Conclusions

We identified multiple factors associated with the occurrence of coyotes and conflicts in urban areas of the United States. Coyotes and conflicts were more likely to occur in larger urban areas with higher concentrations of humans, and conflicts also were more likely to occur in western regions with larger amounts of high-intensity development and less forested and agricultural areas. These results should allow urban wildlife managers to determine whether or not conflicts between humans and coyotes will arise or increase based on the geographic and demographic factors in place within their cities. An assessment of such factors, such as the amount of forest or open space within the urban area, may allow wildlife officials to identify the most appropriate tools to prevent or mitigate conflicts.

A variety of tools to prevent or mitigate conflicts exist that could be applied to urban landscapes. One such tool would be to encourage citizens to reduce food sources (e.g., pet food, trash, bird feeders, etc.) that attract coyotes into neighborhoods and eliminate intentional feeding of coyotes by humans. Another method is consistent, aggressive hazing of coyotes by residents in the early stages of coyote habituation to humans. Education of citizens should be enhanced by increasing signage in open space areas that inform citizens what they should do if they encounter a coyote. Each urban area should also develop a written coyote management plan that addresses procedures to be taken to resolve potential conflicts (Poessel et al., 2013). Finally, modifying habitat in open space areas used by both humans and coyotes by reducing dense cover can increase visibility by humans and may decrease the potential for conflicts (Timm, Coolahan, Baker, & Beckerman, 2007; USDA, 2002). Because the scope of our study was on a national level, appropriate procedures to reduce conflicts should be analyzed on a site-specific basis, and wildlife managers in each urban area should evaluate their own situation before implementing these tools. As coyotes continue to expand into North American urban areas, proactive management could assist in reducing conflicts in increasingly urbanized regions.

Although our results were specific to coyotes, these carnivores are an indicator of escalating human-wildlife interactions in urban ecosystems. If carnivore populations increase in urban areas throughout the world, encounters and conflicts with humans also will inevitably increase (Ditchkoff, Saalfeld, & Gibson, 2006). We determined certain environmental factors may be associated with conflicts with carnivores in urban landscapes. These results have important implications for urban ecology, and future research should be focused on determining which factors are associated with conflict with other urban carnivore species. By implementing practices such as sustainable urban planning (Tanner et al., 2014), landscape design that includes habitat modifications, and citizen education, wildlife and urban managers may be able to proactively reduce human-carnivore conflicts, promote coexistence between urban citizens and wildlife, and maintain the biological diversity of urban ecosystems.

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Appendix A

Results of ANOVA models comparing percentages of eight land cover types in 105 urban areas with the three population size categories. *P*-values in bold indicate significance at the 0.05 level. For these land cover types, significant Tukey pairwise comparisons among the population size categories are included.

Land Cover Type	*F*	df	*P*
Forest	0.45	2, 102	0.638
Shrubland	0.20	2, 102	0.816
Grassland	0.32	2, 102	0.724
Riparian	0.11	2, 102	0.900
Sparse	4.07	2, 102	**0.020**
Altered Open	0.32	2, 102	0.728
Development	10.43	2, 102	**<0.001**
Agriculture	9.68	2, 102	**<0.001**
Sparse:			
large > small			0.015
Development:			
large > medium			0.010
large > small			<0.001
Agriculture:			
small > large			<0.001

Appendix B

Results of ANOVA models comparing percentages of eight land cover types in 105 urban areas with the five geographic regions. *P*-values in bold indicate significance at the 0.05 level. For these land cover types, significant Tukey pairwise comparisons among the geographic regions are included. Although the region effect for sparse land cover was significant, none of the pairwise comparisons were significant.

Land Cover Type	*F*	df	*P*
Forest	29.02	4, 100	**<0.001**
Shrubland	15.80	4, 100	**<0.001**
Grassland	16.09	4, 100	**<0.001**
Riparian	6.79	4, 100	**<0.001**
Sparse	2.86	4, 100	**0.027**
Altered Open	5.87	4, 100	**<0.001**
Development	21.56	4, 100	**<0.001**
Agriculture	1.08	4, 100	0.372
Forest:			
Northeast > Midwest			<0.001
Northeast > Southwest			<0.001
Northeast > West			<0.001
Southeast > Midwest			<0.001
Southeast > Southwest			<0.001
Southeast > West			<0.001
Midwest > West			0.043
Shrubland:			
Southwest > Northeast			<0.001
Southwest > Southeast			<0.001
Southwest > Midwest			<0.001
Southwest > West			0.003
West > Northeast			0.009
West > Southeast			0.013
West > Midwest			0.015
Grassland:			
Southwest > Northeast			<0.001
Southwest > Southeast			0.001
Southwest > Midwest			<0.001
West > Northeast			<0.001
West > Southeast			0.001
West > Midwest			<0.001
Riparian:			
Northeast > West			0.019
Southeast > Southwest			0.002
Southeast > West			<0.001
Altered Open:			
Midwest > Northeast			0.012
Midwest > West			0.002
Southeast > West			0.015
Development:			
Midwest > Northeast			<0.001
Midwest > Southeast			0.001
Southwest > Northeast			0.005
Southwest > Southeast			0.013
West > Northeast			<0.001
West > Southeast			<0.001
West > Midwest			0.003
West > Southwest			0.009

Appendix C

Results of ANOVA models comparing percentages of four housing density classes in 105 urban areas with the three population size categories. *P*-values in bold indicate significance at the 0.05 level. For these housing density classes, significant Tukey pairwise comparisons among the population size categories are included.

Housing Density Class	F	df	P
Rural	0.17	2, 102	0.842
Exurban	17.58	2, 102	**<0.001**
Suburban	9.39	2, 102	**<0.001**
Urban	10.55	2, 102	**<0.001**
Exurban:			
medium > large			0.001
small > large			<0.001
Suburban:			
large > small			<0.001
medium > small			0.017
Urban:			
large > medium			0.007
large > small			<0.001

Appendix D

Results of ANOVA models comparing percentages of four housing density classes in 105 urban areas with the five geographic regions. *P*-values in bold indicate significance at the 0.05 level. For these housing density classes, significant Tukey pairwise comparisons among the geographic regions are included.

Housing Density Class	F	df	P
Rural	12.25	4, 100	**<0.001**
Exurban	13.46	4, 100	**<0.001**
Suburban	0.55	4, 100	0.699
Urban	20.50	4, 100	**<0.001**
Rural:			
Southeast > Northeast			0.013
Midwest > Northeast			<0.001
Southwest > Northeast			<0.001
Southwest > Southeast			0.009
Southwest > West			0.042
West > Northeast			0.002
Exurban:			
Northeast > Midwest			0.040
Northeast > Southwest			0.003
Northeast > West			<0.001
Southeast > Southwest			0.004
Southeast > West			<0.001
Midwest > West			0.011
Urban:			
Midwest > Southeast			<0.001
Southwest > Northeast			0.007
Southwest > Southeast			<0.001
West > Northeast			<0.001
West > Southeast			<0.001
West > Midwest			0.001

Appendix E

Results of ANOVA models comparing average precipitation values in 105 urban areas with the three population size categories and the five geographic regions. *P*-values in bold indicate significance at the 0.05 level. Significant Tukey pairwise comparisons among geographic regions are included.

Test	F	df	P
Population size category	0.10	2, 102	0.904
Geographic region	45.73	4, 100	**<0.001**
Geographic region:			
Northeast > Southwest			<0.001
Northeast > West			<0.001
Southeast > Midwest			<0.001
Southeast > Southwest			<0.001
Southeast > West			<0.001
Midwest > West			<0.001
Southwest > West			0.006

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