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A Social-Ecological Approach to Understanding Human-Coyote Interactions in Cities

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A Social-Ecological Approach to Understanding Human-Coyote Interactions in Cities

By

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DISSERTATION

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Abstract

In social-ecological systems like cities, where humans are the dominant drivers of most ecological processes, humans affect wildlife through direct and indirect interactions. Direct interactions, i.e., human-wildlife encounters, result in individual-level costs and benefits important for the interacting individuals' health and well-being. Indirect interactions often occur when human behavior, especially at the group or institutional level, affects the abundance and distribution of resources and risks important for wildlife in cities. Importantly, direct interactions can influence indirect interactions by influencing human attitudes towards wildlife and support for conservation or management practices that benefit or harm wildlife. Despite the importance of human-social systems in shaping urban ecosystems and interactions with wildlife, there is little research incorporating social-system characteristics into the study of urban wildlife ecology. I examined the effect of direct- and indirect- interactions between humans and coyotes (*Canis latrans*) on processes important for coyote ecology and human-coyote coexistence. Coyotes are an ideal system for studying these interactions because they occupy every major city in North America, interacting with humans across a range of social and environmental contexts. Results from this work indicate that human-coyote interactions are shaped by both environmental and social-system characteristics. The availability of suitable habitat plays a major role in increasing survival and reducing coyote behavior related to human-coyote conflicts. Social structures based on socio-demographics, which are responsible for shaping many of the indirect effects of social systems on wildlife, influenced direct human-coyote interactions. Survey respondents from marginalized groups tended to have fewer interactions with coyotes, observe less nonthreatening coyote behavior, and ultimately had less positive attitudes towards coyotes. This research adds to the growing literature demonstrating the interrelatedness of ecosystems and social systems in cities and suggests that increasing human-wildlife coexistence in cities requires the amelioration of environmental injustices.

Impacts of within-city variation in habitat, human density, and income on coyote survival

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Abstract

Understanding species responses to urbanization is key for gaining insights into the ecology and management of wildlife in these rapidly expanding environments. Survival is a key process linking individual-level responses to broad-scale ecosystem dynamics. The factors affecting survival in urban wildlife are in large part shaped by aspects of the human-social system which influence the distribution of resources, like green space, and risks, like pollutants. However, there is little research exploring the effect of social-system attributes on survival in urban areas. We assessed the effects of environmental and socio-demographic characteristics on survival in urban coyotes (Canis latrans) - a species of management interest due to their large urban populations and occasional conflict with humans. Using estimated survival times and location data from animals captured as pups and radiocollared as adults, we conducted a survival analysis using a Cox proportional hazards regression. The results indicate that the availability of natural habitat positively affects survival in these animals. While the relationship between human-disturbed habitat availability and survival was less clear, it also tended to increase survival. Neither median income nor human density were significantly associated with survival time. These results suggest that survival in this highly adaptable species benefits from environmental features associated with measures of habitat availability but is not impacted by other risks or resources associated with socio-demographic characteristics.

Introduction

As urbanization continues its rapid expansion, more wildlife have to contend with the challenges of these built environments. Understanding species responses to urbanization is critical to developing a theory of urban ecology, conserving biodiversity, and managing urban wildlife. Responses occur across scales from individual-level traits like behavior (Sol et al. 2013; Fossett and Hyman 2021; Lee and Thornton 2021), morphology (French et al. 2018; Winchell et al. 2018), and physiology (Birnie-Gauvin et al. 2016; Le Tollac et al. 2016), to population and community dynamics (Magle et al. 2012; Rodewald and Gehrt 2014). Survival is a key process linking individual-trait responses to broad-scale dynamics and ultimately evolution. Therefore, exploring survival responses to urbanization may provide insights for both theoretical and applied inquiries (Ouyang et al. 2018; Lambert et al. 2021).

Interspecies variation in survival responses to urbanization is often attributed to life history traits, diet, and behavioral plasticity; however, intraspecies variation is less understood (McKinney 2006; Lowry et al. 2013; Caspi et al. 2022). Studies evaluating survival within urban wildlife populations often have contradictory results (Prange et al. 2003; Brearley et al. 2013; Halfwerk et al. 2018). Importantly, these studies rarely account for differences in the type of urbanization animals experience (McDonnell and Hahs 2008). Instead, the categories “urban” or “developed” are used as catchalls for any anthropogenic structures or landscapes (McPhearson et al. 2016). This oversimplification obscures the effects of the specific urban environmental features that influence an animal’s survival (McDonnell and Hahs 2013). Certain aspects of the urban environment may act as evolutionary traps, attracting wildlife to the detriment of their survival, while others may serve as high quality habitat (Szulkin et al. 2020). Shifting from qualitative descriptions of urban environments to quantitative measures of the features relevant to survival will contribute to a more mechanistic understanding of responses to urbanization.

Since survival is largely dependent on an animal’s ability to acquire resources and avoid risks, environmental features significant to wildlife survival will be associated with those resources and risks.

Many urban species require some amount of natural food or habitat to survive (Krausman 1999; Magle et al. 2021). Areas with high vegetation cover and low impervious surface cover can provide opportunities for urban wildlife to forage as well as structures for burrowing, denning, etc. (Fidino et al. 2020). These areas can also provide refuge from many of the risks urban wildlife face. Risks like vehicle collisions, conflict with humans and domestic animals, and exposure to pollutants may be more easily avoided in areas with relatively low human activity and more cover (Adams et al. 2005; Rodewald and Gehrt 2014). Often, urban green spaces like nature preserves, city parks, or even golf courses are cited as an important habitat for urban wildlife because they tend to have higher productivity and lower human activity than the surrounding areas (Gallo et al. 2017; Wurth et al. 2020). In addition to benefiting from increased resource availability and fewer interactions with humans, green space can also have lower levels of noise, light, and chemical pollution which can have negative impacts on survival (Markevych et al. 2017; Sepp et al. 2019). Despite the potential benefits of green space to urban wildlife, most animals living in cities have limited access to these areas. When access to green space is low, wildlife can use disturbed areas that are altered by humans but are still relatively low in human activity with some unmanaged vegetation growth (Rodewald and Gehrt 2014). These disturbed habitats often consist of areas surrounding transportation and utility infrastructure or vacant land and have been shown to be an important resource for some wildlife species (Rega-Brodsky and Nilon 2016; Fig. 1.1).

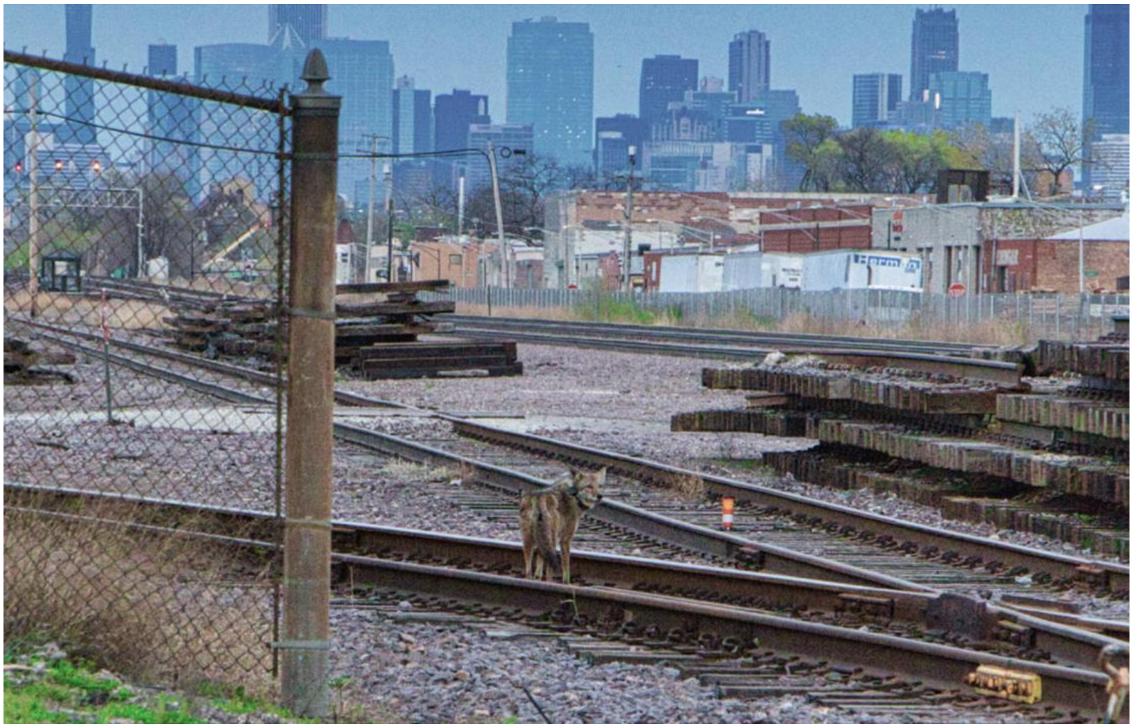

Figure 1.1. A radiocollared coyote frequently located along the rail lines in Chicago, IL.

In social-ecological systems like urban areas, where humans are the dominant driver of many ecological patterns and processes, incorporating characteristics of the human-social system is a key part of identifying the mechanisms behind responses to urbanization (McPhearson et al. 2016; Des Roches et al. 2020; Schell et al. 2020). Social system structures like classism and racism shape urban environments such that wealthier communities and areas with more white residents tend to have more access to green space, higher levels of vegetation cover, and increased plant species diversity (Mennis 2006; Gerrish and Watkins 2018). This association is the result of multiple processes including the ability of wealthy, white people to influence institutional policies affecting urban planning decisions and the resources wealthy homeowners have for managing large residential lots (Pickett and Grove 2020; Schell et al. 2020). The effects permeate throughout ecosystems to produce phenomena like the luxury effect, the positive association between biodiversity and income observed in many urban areas (Romero et al. 2012; De La Barrera et al. 2016; Gupta et al. 2016; Leong et al. 2018).

Social-system structures also affect the distribution of environmental risks. Unlike green space, heat, noise, and chemical pollution occur in higher concentrations in less wealthy communities (Evans and Kantrowitz 2002; Dionisio et al. 2010; Tonne et al. 2018). The impacts of inequality on pollution distribution have been observed to impact wildlife living in these areas. For instance, McKinnon et al. (1976) found that gray squirrels (*Sciurus carolinensis*) living in lower income areas had significantly higher concentrations of lead, a highly toxic metal, in their kidneys. Other studies have demonstrated a negative association between vehicle-pedestrian collisions and income due to increased traffic volume in low-income areas (Cottrill and Thakuriah 2010; Morency et al. 2012). Given that vehicle collisions are a major risk to many urban wildlife, animals living in these areas may suffer from increased mortality rates.

Coyotes (*Canis latrans*) are a particularly interesting urban species because they are one of the few relatively large-sized carnivores to establish populations in urban environments. Despite the major risk of human-related mortality either due to direct persecution or vehicle collisions, they have established growing populations in all major urban areas in North America (Hody and Kays 2018). This may be in part due to their adaptability in avoiding these risks. Coyotes readily adjust their activity patterns to avoid humans temporally and spatially (Riley et al. 2010). They prefer natural habitat patches but in highly developed areas will use disturbed habitat that is low in human activity – areas like rail lines or cemeteries (Wurth et al. 2021). In addition to providing refuge, urban coyotes use natural and disturbed habitat to forage for natural resources like insects, rodents, and lagomorphs (Newsome et al. 2015; Sugden et al. 2020). Coyotes living in urban environments where natural resources are limited often increase their use of anthropogenic resources which negatively impacts their health (Murray et al. 2015). There is also evidence that human-social systems influence coyote ecology. Income is associated with coyote distribution in some urban areas and likely influences coyote survival through its effect on vegetation cover and resource availability (Magle et al. 2016, Zepeda et al. 2023a). Finally, lethal management practices represent a substantial risk to coyotes living outside of city centers (Riley et al. 2003; Gehrt et al. 2011). Support for these practices has been explained, in part, by individual's socio-demographic characteristics providing another potential mechanism through which the human-social system influences coyote survival (Manfredo et al. 2020). For instance, individuals belonging to marginalized groups who have fewer opportunities for positive interactions with nature and wildlife can exhibit less tolerance for wildlife (Hosaka et al. 2017; Zepeda et al. 2023b).

To understand the effect of environmental and social factors on survival in urban coyotes, we analyzed the movement data of 92 radiocollared coyotes living in the Chicago Metropolitan Area (CMA). We examined the effect of natural habitat, disturbed habitat, human population density, and median income on survival. We hypothesized that coyote survival in the CMA would be most dependent on the coyote's ability to acquire natural resources and avoid risks associated with human activities. We predicted that the availability of natural and disturbed habitat, and median income would be positively associated with coyote survival and that human population density would be negatively associated with survival.

Methods

Study area

This study is part of a long-term research program, the Urban Coyote Research Project, exploring coyote ecology in the CMA. The region is one of the largest metropolitan areas in North America and has a robust coyote population of over 4,000 individuals (S. Gehrt, personal communication, 2022). It is made up of diverse land uses including nature preserves which are areas protected against development and other human activities that are disruptive to plant and animal life.

Like other urban areas, resources and risks important for coyote survival have been shown to be associated with socio-demographics in the CMA. Tree cover, green space, and avian density, potential indicators of resource availability, are higher in areas with higher median income (Iverson and Cook 2000; Loss et al. 2009; Liu et al. 2021). Risks like environmental pollution and waste treatment plants tend to be concentrated in low-income areas (Pellow 2004). A positive association between pedestrian-vehicle collisions and low-income communities has also been observed in the region (Cottrill and Thakuriah 2010).

Animal captures and monitoring

Animals included in this study were captured and monitored between 2001 and 2020. Pups were captured in the natal den at an estimated age of 2-6 weeks old. After samples were collected, a subcutaneous passive integrated transponder was implanted in between the animal's shoulder blades for later identification. Adult captures were carried out using foot-hold traps or cable restraints which were set in nature preserves and private properties throughout the CMA. After animals were captured, they were transported to a laboratory where they were immobilized with Telazol (Zoetis Manufacturing & Research) and fitted with very high frequency radiocollars (Advanced Telemetry Systems and Lotek Wireless). Each coyote was weighed and sexed. Animals were released at the trap site on the day of capture after recovering from the effects of the anesthetic. All procedures were approved by Ohio State University's Institutional Animal Care and Use Committee (Protocol Nos. 2006A0245, 2010A00000113, 2013A00000012).

Coyotes were located using triangulation with a truck mounted antenna or by visual observations. Triangulations were recorded using a minimum of three bearings with a maximum of twenty minutes between first and final bearings. Coordinates were recorded with the program LOCATE II (Pacer). Coyotes were located once during the day, typically two or three times per week, and at night during tracking shifts in which we focused on a group of coyotes and obtained sequential locations at 60–120-minute intervals for 5–6 hours during the night. We did not conduct systematic telemetry error testing for this study; however, previous work conducted by the project involving the triangulation and then visual identification of resting animals using the same equipment revealed that the average error was 49.1 m. This is similar to the average error of 42.9 m reported by Bartolommei et al. (2012).

When radiocollared coyotes could not be located by vehicle, we conducted flights with a helicopter or fixed-wing aircraft to locate signals and then confirmed their location on the ground. Such flights were deployed opportunistically in most years and covered northeastern Illinois and parts of Wisconsin and Indiana. Animals recovered postmortem were usually located using their radiocollar but were occasionally located by residents who notified technicians.

Environmental and social characteristics

To determine the environmental and social characteristics experienced by each coyote, we created a landscape raster in R (R Core Team 2022; Fig. 1.2). We extracted median income and population density data from the United States Census (United States Census Bureau 2010) and the American Community Survey (United States Census Bureau 2012) using the package *tidycensus* (Walker and Herman 2022). Both surveys collect data on the socio-demographic characteristics of small areas across the country. We used data from Census block groups because they provide the highest resolution data for our study. Census block groups are established based on population and housing density resulting in substantial variation in block group area across the CMA (median = 0.48 km^2, range = 0-96 km^2) but sampling intensity that is relatively consistent with the level of socio-demographic heterogeneity. We rasterized each social variable layer to a resolution of 0.09 km^2/cell, about the size of two city blocks.

To avoid omitting data in areas with no residents, e.g. nature preserves, we performed a nearest neighbor interpolation using the *gstat* package in R (Pebesma 2004). We used a simple kriging model with a large window of 100 neighbors. The kriging model uses the spatial arrangement of observed values in neighboring cells to weight cells within the window so that the values of cells closest to the interpolated location are weighted more heavily.

Natural and disturbed habitat availability were determined using data from the Chicago Metropolitan Agency for Planning which inventories land use types across the CMA at the parcel level (Chicago Metropolitan Agency for Planning 2015). Natural habitat is mostly made up of nature preserves which comprise 10% of the landcover in the CMA, but also includes cemeteries and golf courses – land uses selected for by coyotes in urban areas (Wurth et al. 2020). Disturbed habitat encompasses areas affected by human activities but with less human traffic than developed and residential areas and some natural features like unmanaged vegetation growth. These areas include lands used for transportation and utility infrastructure and vacant lots. We chose to calculate the proportion of natural and disturbed habitat within a 1 km radius of each location. While there is significant variation in resident coyote home range size, the average in the CMA is about 5 km^2. By constraining habitat availability to a 1 km radius, we aimed to increase the likelihood that habitat experienced by the animal was included in the metric and habitat that lies outside their home range was excluded (Gehrt et al. 2011).

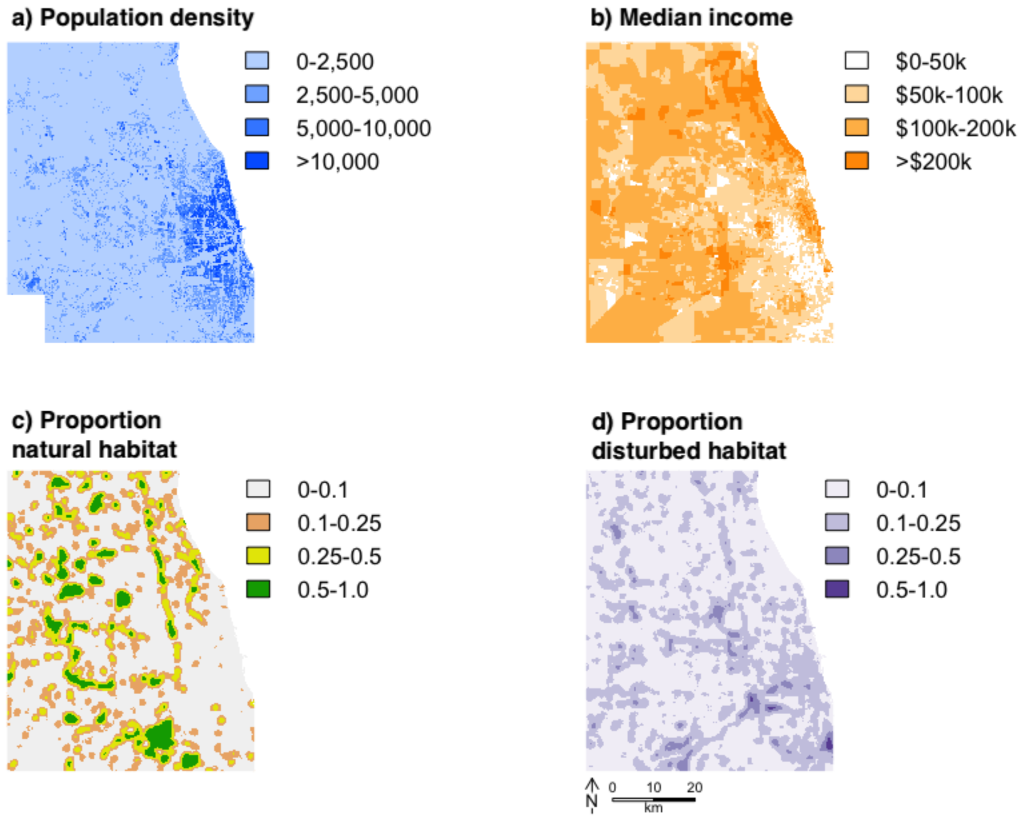

Figure 1.2. Social and environmental raster. Population density (a) was measured at the Census block-group level and calculated as residents per km^2. Household income was used to calculate median income (b) for Census block groups. The proportion of natural (c) and disturbed habitat (d) represent the proportion of the habitat type within 1 km of each raster cell.

Data analysis

To test the effects of the environmental and social characteristics on survival, we conducted a survival analysis that included the last 6 months of tracking data for 92 animals with 54 recorded mortalities. The average environmental and social characteristics experienced by individuals in the sample were calculated using the locations from the 6-month period (number of locations per individual: mean = 70, SD = 38). Animals with less than 30 locations collected during that period were excluded from the analysis.

We used a Cox proportional hazards regression adjusted for right-censoring with the R package *survival* (Therneau and Grambsch 2000). For the 54 animals recovered postmortem, survival time was calculated based on the estimated date of death and the date of birth approximated from pup-capture records. Animals who were not recovered postmortem were considered censored and were assigned a "survival" time based on the date of their last recorded location and their approximate date of birth. All independent variables were standardized. The assumption of proportional hazards was assessed using a chi-square significance test. Independent variables in the model were tested for multicollinearity using variance inflation factors (VIF).

The Cox proportional hazards regression models the relationship between covariates and the hazard rate or the instantaneous probability that an event, in this case mortality, will occur. Consequently, positive estimates indicate the predictor has a positive association with hazard rate and a negative association with survival.

Results

Significant multicollinearity was not detected with VIFs ranging from 1.19-4.84. Considering the previously established spatial correlations between the independent variables (e.g., between income or density and natural or disturbed habitat), this is unexpected. However, the analysis only includes locations used by the animals, indicating they use locations where these general trends are decoupled.

The median proportion of natural habitat in a 1 km radius was the only variable that was significantly associated with mortality probability (Table 1.1). Model predictions indicate that for the crucial state of reaching reproductive maturity (~2 years of age) coyote mortality probability is 3.8 times higher in areas low in natural habitat, i.e., one standard deviation below mean proportion natural habitat (mean -1 SD), than those in high natural habitat areas (mean +1 SD) (Fig. 1.3). Disturbed habitat was just slightly above the significance threshold ($p = 0.052$) suggesting that it may influence survival. Model predictions indicate that 2-year-old animals in areas low in proportion disturbed habitat (mean -1

SD) have a mortality probability 2.4 times those in areas high in disturbed habitat (mean +1 SD) (Fig. 1.4).

Variable	***Estimate***	***Standard error***	***z***	***p***	
Natural habitat	-0.736	0.315	-2.339	0.019	*
Disturbed habitat	-0.442	0.228	-1.942	0.052	.
Median income	0.154	0.136	1.133	0.257	
Population density	-0.203	0.249	-0.815	0.415	

Table 1.1. Model estimated effects on mortality probability. Statistical significance ($p < 0.05$) denoted with an asterisk.

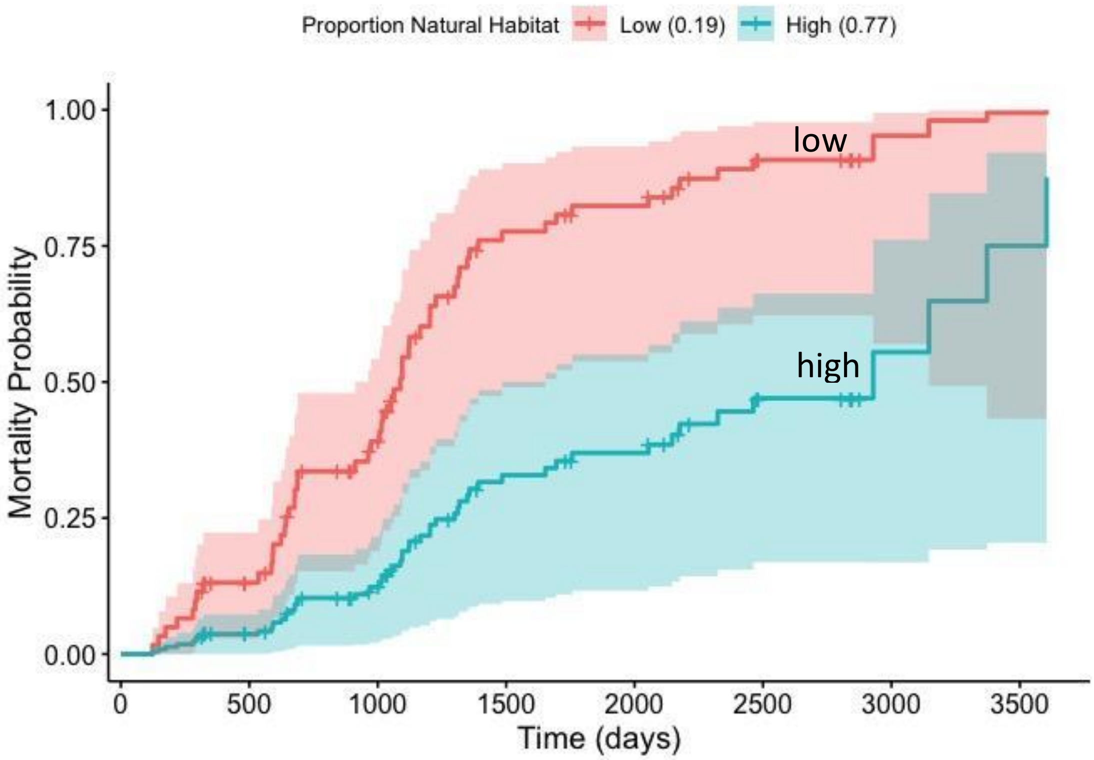

Figure 1.3. Model predicted mortality probability curves for areas with low (mean -1 SD, red) and high (mean +1 SD, blue) natural habitat. Shading is 95% CI. Disturbed habitat, median income, and population density were set to mean value.

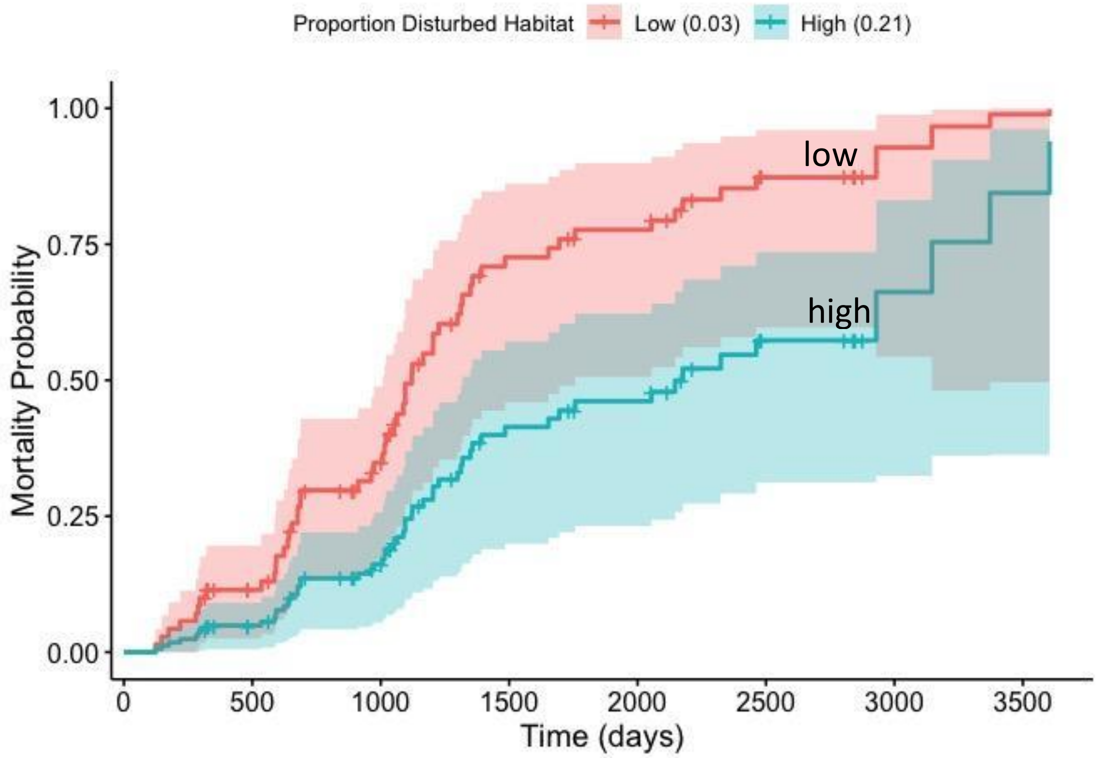

Figure 1.4. Model predicted mortality probability curves for areas with low (mean -1 SD, red) and high (mean +1 SD, blue) disturbed habitat. Shading is 95% CI. Natural habitat, median income, and population density were set to mean value.

Discussion

Survival is a key ecological outcome mediating individual responses to environmental change and ecosystem dynamics. Our study explored how environmental and social characteristics affecting wildlife resources and risks in the Chicago Metropolitan Area affect survival in coyotes. We found that the availability of natural habitat had a positive effect on survival and evidence that the availability of disturbed habitat might also positively influence survival. Interestingly, despite evidence of their influence over other urban ecological processes, median income and human population density had no significant relationship with survival.

Coyotes in cities across North America exhibit strong selection for natural areas indicating these habitats provide resources or refuge that developed areas do not (Grubbs and Krausman 2009; Poessel et al. 2016; Thompson et al. 2021). The positive relationship between urbanization and coyote home range size found in some studies further emphasizes the role natural habitat plays in coyote ecology as individuals living in more developed areas are forced to increase their range to meet their needs (Riley et al. 2003; Ellington and Gehrt 2019). This can affect survival twofold. First, coyotes may not have access to the quality of resources needed to maintain adequate body condition (Murray et al. 2015). Additionally, ranging over larger, developed areas may increase their exposure to vehicle collisions and conflict with humans (Gese et al. 2012)

Although disturbed habitats have lower productivity, structural complexity, and higher human activity than natural habitat, our results suggest that they may provide benefits to coyote survival. A study on the occurrence of passerines in Madrid, Spain found that when their preferred habitat was no longer suitable due to high densities, most species would use tree-lined streets making these disturbed habitats with natural features an important habitat alternative (Fernández-Juricic 2001). Despite countless reports of coyotes traveling, foraging, and denning in vacant lots, rail lines, and other areas lower in human disturbance, no previous studies have quantified their importance for coyote ecology. Interestingly, a study of vacant lots as habitat for songbirds in Baltimore found that the quality of the lots was dependent on shrub density but not on any lot site or landscape variables (Rega-Brodksy and Nilon 2016). This suggests that future research may benefit from measuring specific environmental features within disturbed habitats that impact the utility of these spaces for coyotes and other wildlife. Exploring these habitat alternatives may provide important information for conservation and management. In highly developed areas where green space is limited, these habitats could be managed to increase their suitability for desired species or to reduce suitability for undesired species.

There are several possible explanations for the lack of relationship between the social variables and survival in our study. First, coyotes are an incredibly adaptable species whose ability to survive in diverse environments is evidenced by their impressive range expansion in the last century (Hody and

Kays 2018). While resources and risks associated with human social characteristics are likely affecting some animal's survival, they may be resilient to those effects at the population level. Another urban-adapted species, the black sparrowhawk, exhibits a similar lack of survival response to urbanization (Sumasgutner et al. 2019). Alternatively, the characteristics we chose to include in the study may not capture the social-ecological features important to coyotes. For instance, socio-demographic characteristics can be good predictors of large-scale patterns like pollution or green space distribution; however, individual human behavior is not always closely associated with these characteristics. Behaviors like gardening or feeding domestic animals outside which provide anthropogenic resources to coyotes can vary greatly within socio-demographic groups (Goddard et al. 2013; but see Schupp et al. 2016).

Importantly, due to a limited sample size our study did not include individual attributes. Characteristics like sex, age, and body condition are known to impact survival in wildlife. While Gehrt et al. (2011) showed survival rate is relatively stable across life stages and sexes for coyotes in the CMA, there are other important characteristics to consider. For coyotes, their status as a resident, an animal who is part of a mated pair and defends a territory, or a transient, a solitary animal without an established territory, influences their survival. Transients are forced to range over a larger area and use lower quality habitat increasing their exposure to risks (Gese 2001). This effect may be magnified in urban areas if traveling increases the chance of experiencing a vehicle-related mortality (Thompson et al. 2021). Measuring behavioral traits could provide insight into which behavioral responses result in higher survival and increased reproductive opportunities (Lee and Thornton 2021; Schell et al. 2021; Caspi et al. 2022). Incorporating behavior into survival studies could be especially useful for the management of species like the coyote whose behavior often dictates its level of conflict with humans.

Our results contribute to the existing evidence that habitat availability is key to the development of sustainable cities capable of supporting biodiversity (Gallo et al. 2017; Fidino et al. 2020; Magle et al.

2021). The benefits of green space in urban areas extends beyond wildlife (Kondo et al. 2018). Humans living in proximity to coyotes may experience indirect negative effects if animals in poor condition cannot access natural resources and seek out anthropogenic resources increasing the likelihood of conflict (Zepeda et al. 2023a). Conversely, an absence of coyotes in areas with low levels of suitable habitat could further disadvantage residents by reducing their opportunities to observe this rather unique urban species (Soga and Gaston 2016). While developing cities should incorporate green space to combat these problems, existing, highly developed urban areas might benefit from exploring alternatives to urban parks and other green spaces (Newman et al. 2015). Managing existing areas low in human activity, like the disturbed habitats described in this study, could be a powerful way to increase habitat availability in highly developed urban areas and increase human-wildlife coexistence.

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Socioeconomic and environmental characteristics influence human-tolerance behavior in urban coyotes

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Abstract

Wildlife tolerance for humans i.e., their willingness to overlap with humans spatially and temporally, is a key factor mediating the frequency and nature of an animal's interactions with humans. However, little is known about the extrsinic factors shaping this important behavior. We explored the effects of environmental and human social characteristics known to influence wildlife on human-tolerance behavior in urban coyotes - a species of management concern due to their occasional conflicts with humans. Using the movement data of GPS-collared animals, we estimated the effect of habitat availability and socio-demographic characteristics on human-tolerance behavior by quantifying their spatial overlap with humans. We found that habitat availability, including human-altered habitats like vacant lots and agricultural areas, reduced human-tolerance behavior while median income increased human-tolerance behavior. These results suggest that human-coyote coexistence in urban areas may benefit from increasing the availability of suitable habitat. Additionally, future research that looks at the fine-scale environmental features and human behaviors associated with high-income communities could provide insight into how these areas can be managed to reduce human tolerance in coyotes.

Introduction

Urbanization is increasing at a rapid rate, with both urban human populations and urban land expansion growing exponentially (Chen et al. 2020). The concurrent increase in abundance of some wildlife species in urban areas creates more opportunities for humans and wildlife to interact in these environments (Hansen et al. 2020; Perry et al. 2020). Human-wildlife interactions (HWI) can provide important benefits for participating species; however, conflicts can be costly (Soulsbury and White 2015). For humans these costs are usually experienced in the form of property damage or attacks on domestic animals. Wildlife often experience greater adverse impacts, especially when conflict increases human support for management practices that negatively impact wildlife welfare, reproduction, and survival on broad scales (Liordos et al. 2017; Schell et al. 2021).

In an effort to develop management interventions that minimize conflict, wildlife professionals have identified factors contributing to these interactions. Wildlife's tolerance for humans is one factor that seems to play a particularly important role in shaping their responses to humans (Samia et al. 2015). Human tolerance describes an animal's willingness to overlap with humans in space and time (Blumstein et al. 2016). It can increase through learning mechanisms which change the perceived costs and benefits of associating with humans (Møller et al. 2015; Honda et al. 2019; Goumas et al. 2020). Proximity to humans increases opportunities for wildlife to interact with and habituate to humans especially in urban areas where most humans pose little risk to wildlife (Schell et al. 2018; Uchida and Blumstein 2021). Food conditioning, another learning mechanism, is particularly powerful at altering human-tolerance behavior in wildlife. This type of associative conditioning can drastically increase their use of areas of high human activity and change the behavior they exhibit upon encountering a human (Lowry et al. 2013; Newsome and Van Eeden 2017; Mohammadi et al. 2019). Necessity can also increase human tolerance, for instance when a sick or injured animal relies on anthropogenic structures or resources to survive (Murray et al. 2015). Despite the identification of these individual-level processes, little research has explored broad-scale, external factors driving human-tolerance behavior (but see Poessel et al. 2013; Lute et al. 2020).

As urbanization progresses the availability and distribution of suitable habitat undergo drastic changes with the resulting landscape influencing human-tolerance behavior in several ways (Hahs and McDonnell 2006). Landscape changes can result in urban wildlife living in closer proximity to areas with high human population densities, increasing opportunities for interactions and habituation (Herrero et al. 2005; Tätte et al. 2018). Moreover, habitat loss may encourage or necessitate the use of anthropogenic structures and resources if the abundance of natural options is insufficient (Cahill et al. 2012; Mohammadi et al. 2019). In highly developed areas, where natural habitat remnants are scarce, areas that are lower in human activity and in impervious surface cover, like areas surrounding transportation and utility infrastructure, agricultural areas, or even vacant lots, can serve as refuge and may reduce human-tolerance behavior (Gallo et al. 2017; Wurth et al. 2020).

In urban areas, ecological patterns and processes are heavily influenced by human behavior (Schell et al. 2020; Des Roches et al. 2021). At large scales, institutional policies influence the abundance and distribution of green space, vegetation cover, and biodiversity in cities (Rigolon et al. 2018; Leong et al. 2018). Fine-scale human behaviors like wildlife feeding, gardening, and composting are also important for shaping animals' association with humans as they can attract wildlife to residential areas increasing the opportunities for habituation and food conditioning (Goddard et al. 2013; Murray et al. 2015; Theimer et al. 2015).

Social-ecological research, which emphasizes the impact of human behavior and society on ecosystems, has identified two social constructs that can be powerful predictors of urban ecology: class and race (Park and Pellow 2004; Leong et al. 2018; Pickett and Grove 2020). Classism and racism have a well-documented role in shaping the institutions and policies that organize urban environments (Lock and Baine 2015). For instance, due to racist policies like redlining in the US or apartheid in South Africa, present day plant and animal biodiversity in cities is often highest in predominantly white communities (Rigolon et al. 2018; Kuras et al. 2020; Schell et al. 2020). Racism and classism also impact individual human behavior by limiting access to resources, increasing the barriers to engage in activities, and influencing within-group social norms (Lerman and Warren 2011; Winter et al. 2019; Lerman 2021). Including measures of racial identity and wealth is not only important for identifying the mechanisms shaping urban wildlife ecology. It can also reveal how different socio-demographic groups experience wildlife and aid in the design of management strategies that work to ameliorate existing inequities (König et al. 2020; Zepeda et al. 2023).

In this study, we evaluated the relationship between human social and environmental factors and human-tolerance behavior in a species of high management interest, the coyote (*Canis latrans*). Over the last 100 years coyotes have experienced a remarkable range expansion despite enduring severe persecution by humans (Flores 2016). They now occupy almost every major city in North America (Gompper 2002; Hody and Kays 2018). Like many other wildlife, coyotes have a well-documented aversion towards humans. In urban areas they avoid humans spatially and temporally (Grubbs and Krausman 2009; Poessel et al. 2016; Ellington and Gehrt 2019). However, when a coyote's tolerance for humans increases this avoidance breaks down (Schell et al. 2018; Young et al. 2019). Individuals with the highest levels of tolerance can be seen foraging in residential areas during the day, predating upon pets in the vicinity of owners, and approaching humans, especially children (Timm et al. 2004). While the public's perception of the frequency of coyote conflict is often exaggerated, there is a legitimate concern about how humans and domesticated animals can coexist with coyotes as their populations continue to grow (White and Gehrt 2009).

There is evidence that coyote human-tolerance behavior is influenced by human behavior and environmental characteristics. The use of anthropogenic resources often results in food-conditioned animals that lose their innate avoidance of humans (Beckmann and Berger 2003; Timm et al. 2004;

Ditchkoff et al. 2006; White and Gehrt 2009; Alexander and Quinn 2011). Murray and St. Clair (2017) found that both resource subsidies and certain landscape management behaviors influence coyotes' anthropogenic space use. Coyotes were more likely to use yards without fencing, with higher vegetation cover, and with accessible resources, especially fruit trees, compost, and bird seed. Environmental characteristics like low natural habitat availability force urban coyotes to incorporate developed areas into their home range increasing their spatial overlap with humans (Riley et al. 2003; Gehrt et al. 2011; Murray et al. 2015; Newsome et al. 2015). A study by Lukasik and Alexander (2011) found that urban coyotes living in smaller habitat patches had significantly higher amounts of anthropogenic foods in their scat. Increased use of anthropogenic space and resource use likely play a role in decreasing flight initiation distances, a measure of human-tolerance behavior, in urban coyotes (Breck et al. 2018).

To explore the relationship between social and environmental factors and human-tolerance behavior we used fine-scale tracking data from 48 GPS-collared coyotes living in the Chicago Metropolitan Area (CMA). We hypothesized that human-tolerance behavior is driven by the availability of both natural and anthropogenic resources. We predicted that: 1) habitat types providing natural resources reduce human-tolerance behavior in coyotes and 2) a lack of natural habitat and resources on public and private properties in marginalized communities increases human-tolerance behavior in those areas.

Methods

Study area

The CMA is one of the largest metropolitan areas in North America (US Census Bureau 2016). The area consists mostly of developed land uses, but the Forest Preserve Districts of Cook County, Dupage County, and Kane County maintain protected areas which make up 10% of land cover (Chicago Metropolitan Agency for Planning, 2015). Coyote densities are high, with an estimated population of around 4,000 individuals (Gehrt, S., personal communication, 2022). While forest preserves seem to be areas of particularly high coyote population density, coyotes have been observed in highly urbanized areas as well (Gese et al. 2012)

Animal capture and data collection

Animals in this study were captured using foot-hold traps or cable restraints. After the animals were captured, they were immobilized with Telazol (Zoetis Manufacturing & Research) and fitted with GPS collars (Lotek Wireless). Once the animal was recovered, they were released the same day at the site of capture. All procedures were approved by Ohio State University's Institutional Animal Care and Use Committee (Protocol Nos. 2006A0245, 2010A00000113, 2013A00000012).

GPS collars were programmed to collect location data (error: mean = 15.4 m, SD = 10.1 m; Forin-Wiart et al. 2015) every 15 minutes for 24-hour periods about every two weeks. We conducted a population-level analysis, combining the location data of 48 coyotes which included 35 males and 13 females. The average number of steps per individual was 805 (SD = 451) and the average tracking period was 220 days (SD = 119).

Determining periods of potential human-tolerance behavior

Human-tolerance behavior is behavior that increases an animal's temporal and spatial overlap with humans, increasing its chances of encountering a human. There are three components of urban coyote movement behavior that are important for identifying human tolerance: 1) when the behavior occurs in the diel period, 2) the type of behavior exhibited, and 3) whether the animal is in proximity to humans.

Human activity tends to be localized to certain hours of the day during which the chance of encounters is high. Consequently, we expect that only coyotes with high human tolerance are active during these risky periods. To determine the window of highest human activity, we used Illinois

Department of Transportation's hourly traffic data collected at various locations across the study site. We averaged these traffic counts across days and locations and determined that the biggest changes in traffic volume occurred at 6:00 when traffic increased and 21:00 when traffic decreased. Accordingly, we subset the data into periods of highest risk for encounters from 6:00 to 21:00.

Oftentimes, urban coyotes with low human tolerance will avoid humans in areas of high human density during the day by reducing movement - finding fine-scale environmental features, like small patches of vegetation, to rest in. To avoid including this resting behavior in the analysis, we used hidden Markov models from the R package *momentuHMM* (McClintock and Michelot 2018) to identify periods of movement in the GPS data. We generated a movement model to estimate the distributions of step lengths and turning angles of the two states: resting and moving. A zero-inflated gamma distribution was used to model step lengths and a von Mises distribution was used to model turning angles. Starting parameter values were based on the observed distribution of step lengths and turning angles. A Viterbi algorithm based on the distributions estimated by the hidden Markov model was used to estimate the most likely sequence of behavioral states for steps in the location data.

We assessed the final component, proximity to humans, using the step-selection analysis described below. By including human population density as an independent variable, we were able to estimate the coyotes' selection for human population density during the day while the animals were moving, i.e., their human-tolerance behavior.

Social and environmental characteristics

We created a geospatial raster with a resolution of 0.09 km^2 that encompassed the study site and included layers for each of the social and environmental characteristics (Fig. 2.1). The human social characteristics - population density, the proportion of white residents, and median income- were obtained from the US Census (2010) and the American Community Survey (2012). Both the Census and the American Community Survey collect data on the socio-demographic characteristics of small areas across the country. We used data from Census block groups because they provide the highest resolution data for race and median income. Census block groups are established based on population and housing density resulting in substantial variation in block group area across the CMA (median = 0.48 km^2, range = 0-96 km^2). However, because the sampling intensity is proportionate to population density the accuracy of the data should be relatively stable.

The proportion of natural habitat, disturbed habitat, and agriculture in a 1 km radius of each raster cell were obtained using data from Chicago Metropolitan Agency for Planning's Land Use Inventory (2015). We chose to calculate the proportion of habitat with a 1 km radius because the average coyote home range in the area is 5 km^2 (Gehrt et al. 2009). By constraining habitat availability to this area around each location, we aimed to increase the likelihood that habitat that is accessible to the animal is included in the metric and habitat that lies outside their home range is excluded.

Natural habitat included wildlife refuges, nature preserves, cemetries, and golf courses which coyotes have been shown to use preferentially in studies of their urban habitat use (Beckmann and Berger 2003; Timm et al. 2004; Ditchkoff et al. 2006; White and Gehrt 2009; Alexander and Quinn 2011; Wurth et al. 2020). Disturbed habitat, comprised of areas used for utility infrastructure (e.g., transmission tower), transportation (e.g., railroad tracks, rights of way), and vacant lots, is characterized by moderate to high levels of permeable surface cover and low human activity making it a potentially valuable habitat in developed areas where the availability of natural habitat is low.

The goal of the study was to understand how home-range level characteristics influence selection for human population density. To account for the high level of heterogeneity in human population density in high density areas like downtown Chicago, we increased the resolution of the human population density raster to 900 m^2. This allowed the model to differentiate between coyotes who lived in high density areas but avoided humans by using small areas of low human density, e.g., rail lines, and those that selected for areas of higher human densities.

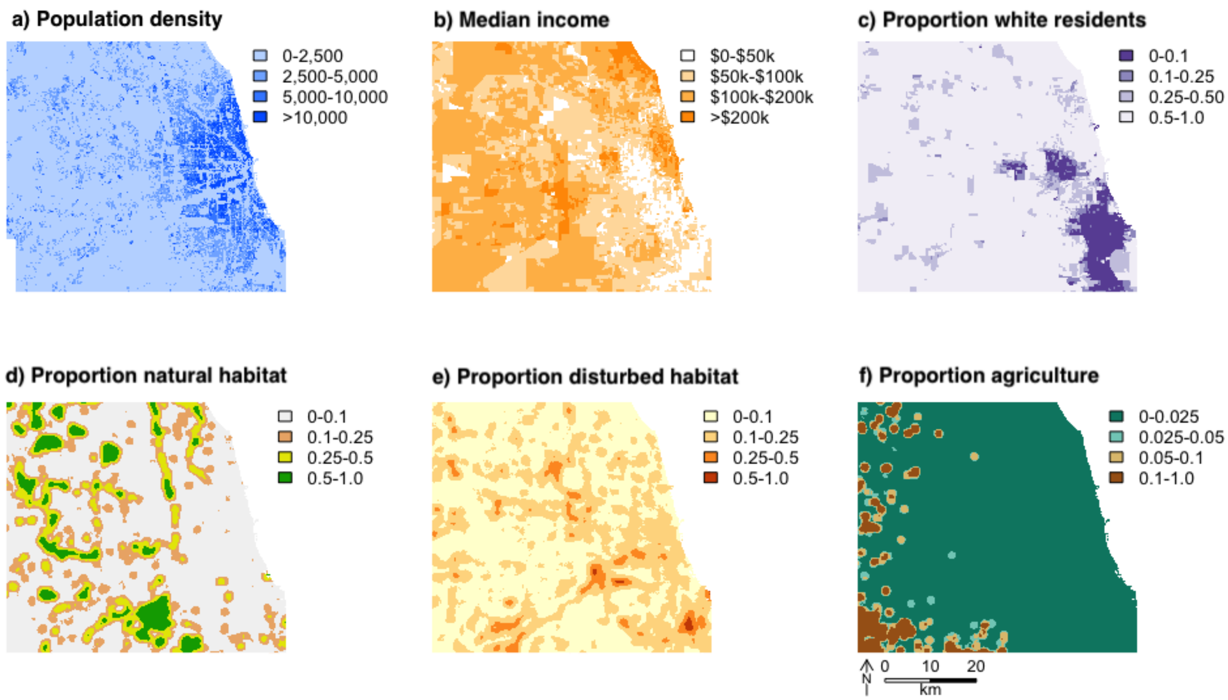

Figure 2.1. Social and environmental rasters. Social variables include population density (a) represented as the number of residents per km^2, median income of Census block groups (b) and the proportion of white residents in Census block groups (c). Environmental variables include the proportion of natural habitat (d), disturbed habitat (e), and agriculture (f) within a 1 km radius of each raster cell.

Data analysis

To analyze the relationship between human-tolerance behavior and the social and environmental variables we conducted a step-selection analysis using the *AMT* package in R (Signer et al. 2019). Step-selection analysis uses a function, in this case a conditional logistic regression, to estimate selection for environmental characteristics by comparing the characteristics of used steps, the locations recorded by deployed GPS collars, to the characteristics of available steps. Available steps are locations generated using the origin of the used step and randomly assigned a step length and turning angle from parametric distributions informed by the movement data. We generated 10 available steps for each used step.

The main effects in the model represent estimates of selection for those variables. Importantly, the main effect for population density is the estimate of human-tolerance behavior, i.e., selection for areas of human population density during periods of high human activity. To estimate the effect of social and environmental characteristics on human-tolerance behavior, we included an interaction term for each characteristic and human population density. The interaction terms estimate the change in human-tolerance behavior in the presence of the social and environmental characteristics.

The conditional nature of this regression prevents the use of variables that do not vary within strata – the groups of used and available locations; therefore, we could not include sex in the model. To assess the effect of sex on human-tolerance we ran a female only and male only model and found no major differences in the significance of predictors or the direction or magnitude of their effects. We thus combined the data from males and females in our full analyses.

Finally, to illustrate the effects of the social and environmental characteristics on human-tolerance behavior, we calculated the log relative selection strength for human population density at high (sample mean +1 SD) and low (sample mean -1 SD) levels of each characteristic (Fig. 2.2). Relative selection strength is used to interpret coefficients estimated in selection studies and reflects the magnitude of change in selection between two different values of a predictor variable (Avgar et al. 2017). For each interaction, we calculated the log relative selection strength across a range of human population densities at high and low levels of the focal characteristic using the average human population density in the sample as the reference selection strength value.

Multicollinearity

Variance inflation factors (VIF) quantify multicollinearity in a model and measure its effect on an independent variable's estimate. The VIFs for population density and the interaction between natural habitat and population density exceeded more conservative ranges for acceptable VIF values (VIF < 5; Table 2.1) increasing the likelihood of type II errors for those variables.

We chose not to exclude these variables for two reasons. First, VIFs for these variables were less than 10 which is within the acceptable range according to some statisticians (Gareth et al. 2017). Additionally, interaction terms are expected to inflate VIF values without necessarily indicating a model estimation issue (Belsley 1991). Most importantly, the major concern when including variables with high multicollinearity in a model is that coefficient variance estimates are inflated resulting in an increased likelihood of type II errors; however, both variables were statistically significant.

Results

Main effects of social and environmental characteristics on selection

The model's main effects estimate the population-level selection for or avoidance of the social and environmental characteristics (Table 2.1). These results indicate that human population density elicits the strongest response of all characteristics with coyotes exhibiting avoidance of areas of even moderate human population densities. The results also revealed significant selection for areas with higher median incomes. Despite the association between neighborhoods with a high proportion of white residents and certain beneficial environmental features (e.g., higher vegetation cover), coyotes tended to avoid areas with higher proportions of white residents.

Unsurprisingly, coyote selection was positively associated with the proportion of natural habitat. Selection for disturbed habitat was weaker but still significant. Agricultural areas were avoided and, notably, this effect was stronger than the effects of the other habitat types.

Human-tolerance behavior

The model's interaction terms estimate the effects of the social and environmental characteristics on selection for human population density during periods of high human activity, i.e., their effect on human-tolerance behavior (Table 2.1). Based on these results, higher median income increased human-tolerance behavior (Fig. 2.2 a). While the effect of the proportion of white residents trended towards significance, the log relative selection strengths indicate the potential effect is negligible (Fig. 2.2 b). All three environmental characteristics significantly reduced human-tolerance behavior; i.e., coyotes were less likely to move into areas with high human population density if their home ranges included large amounts of natural, disturbed, or agricultural habitat. Natural habitat and agriculture had a more substantial effect than disturbed habitat (Fig. 2.2 c, d, e).

Parameter	**β**	**SE**	***z***	***p***	**VIF**
Median income	0.101	0.013	7.554	< 0.001 **	1.010
Proportion white	-0.077	0.014	-5.396	< 0.001 **	1.060
Disturbed habitat	0.045	0.023	1.983	0.047 *	1.480
Natural habitat	0.068	0.033	2.058	0.040 *	2.660
Agriculture	-0.075	0.023	-3.319	< 0.001 **	4.140
Population density	-1.155	0.044	-26.360	< 0.001 **	8.090
Median income*Population density	0.124	0.013	9.454	< 0.001 **	1.640
Proportion white*Population density	-0.028	0.015	-1.897	0.058	1.670
Disturbed habitat*Population density	-0.059	0.030	-1.972	0.049 *	1.570
Natural habitat*Population density	-0.490	0.060	-8.159	< 0.001 **	9.230
Agriculture*Population density	-0.206	0.056	-3.709	< 0.001 **	4.810

*Table 2.1. Model estimated effects of social and environmental variables on selection. Interaction terms (gray box) estimate the effect of social and environmental variables on human-tolerance behavior by estimating selection for human population density at different levels of the variable of interest. Variance inflation factors (VIF) measure multicollinearity. Significance denoted by asterisks ($p < 0.05$ = *; $p < 0.001$ = **).*

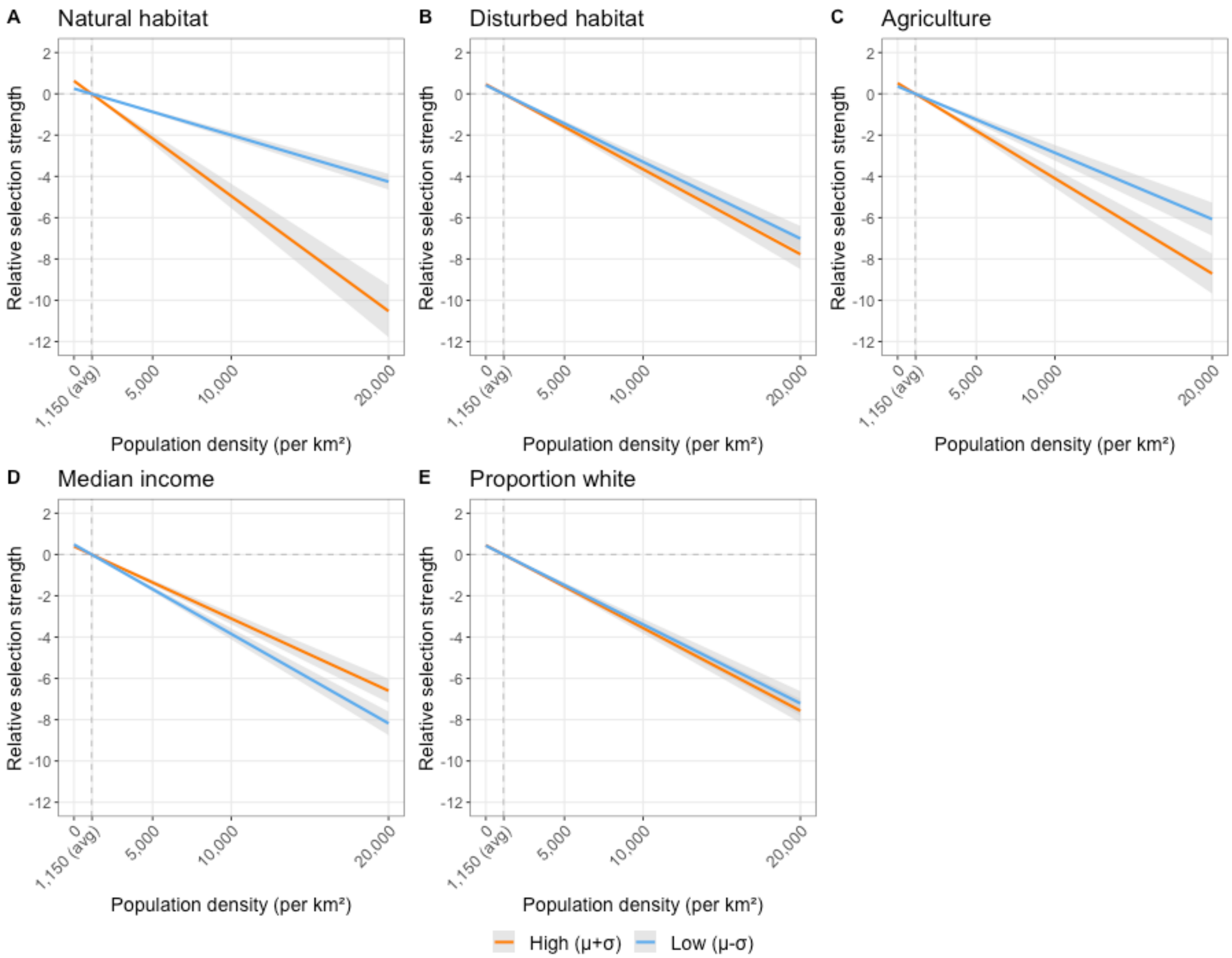

Figure 2.2. Predicted effects of median income (a), proportion white (b), disturbed habitat (c), natural habitat (d), and agriculture (e) on relative selection strength across standardized human population densities. Model predictions were generated using high (mean +1 SD) and low (low (mean -1 SD) values of the focal social or environmental variable. Variables not included in the focal interaction were set to their mean. Shading is 95% CI.

Discussion

We used tracking data from coyotes living in the Chicago Metropolitan Area to assess how social and environmental characteristics influence their human-tolerance behavior. Specifically, we used a step-selection function to determine if selection for areas of high human density while humans are most active, i.e., human-tolerance behavior, is affected by median income, the proportion of white residents, and the abundance of natural habitat, disturbed habitat, and agriculture in the surrounding area.

While the main effects of the step-selection analysis were not the central interest of this study, they provide insight into coyotes' habitat use within the CMA. Like wildlife in other movement and activity studies, these animals exhibited strong avoidance of areas with high human population densities during the day (Gaynor et al. 2018). This result adds to the growing literature demonstrating coyotes' general avoidance of human-use areas (Grubbs and Krausman 2009; Poessel et al., 2016; Ellington and Gehrt 2019). Given the consistency of these findings, human-tolerance behavior at the population level should not be an immediate management concern in densely populated urban areas.

The effects of median income and proportion of white residents might be explained by human behavior affecting resource availability on a finer scale than the habitat metrics included in this study. Magle et al. (2016) found that coyote occurrence in the CMA is positively associated with income and suggested income's association with higher vegetation cover in residential areas might be a cause (Belaire et al. 2016; Lin et al. 2017). Individuals with higher incomes are also more likely to engage in behaviors that attract coyotes like gardening and wildlife feeding (Fuller et al. 2013; Murray et al. 2015; Schupp et al. 2016). The observed avoidance of areas with high proportions of white residents is surprising given the general patterns of beneficial environmental features associated with predominantly white communities. This avoidance may be a result of resident's direct attitudes or behavior towards coyotes. Variation in access to and attitudes towards wildlife management has been attributed, in part, to race and the exclusion of marginalized communities from public services and wildlife-related activities (Yarbrough 2015, Zepeda et al. 2023). As a result, areas with higher proportions of white residents may be more empowered to use public or private management services to remove animals resulting in fewer and more fearful animals in those communities.

Natural and disturbed habitat both positively affected selection; however, disturbed habitat had a weaker effect. Human disturbance in areas like rail lines or vacant lots reduces the productivity and the quality of the refuge, potentially reducing the suitability and selection for these areas. Interestingly, coyotes in our study avoided agricultural areas. High proportions of permeable surface cover, resource subsidies, and the presence of potential prey in domestic animals could be attractive environmental features to some species. However, research exploring wildlife selection for agricultural areas yields mixed results (Rajaratnam et al. 2007; Lande et al. 2014; Hinton et al., 2015; Karelus et al., 2016). This may be due to variation in agriculturists' attitudes toward wildlife, especially large predators and nuisance species. In northern Illinois, where coyotes are relatively large predators and have historically been regarded as nuisance animals, hunting, and trapping related mortalities are much higher in agricultural areas than in more urbanized areas (Van Deelen and Gosselink 2006; Gehrt et al. 2011). Antagonist interactions with landowners might cause coyotes to avoid these areas.

The primary goal of our study was to identify significant relationships between social and environmental characteristics and human-tolerance behavior in coyotes. As expected, increased natural habitat had a negative effect on human-tolerance behavior. This result, along with previous research showing that coyotes living in the nature preserves of the CMA consume relatively low amounts of anthropogenic resources, supports our hypothesis that natural habitat reduces the opportunities or motivation for coyotes to use anthropogenic resources thus reducing human-tolerance behavior (Newsome et al. 2015; Jensen et al 2022). Interestingly, there is evidence that high human density areas in proximity to natural habitats experience the most human-coyote conflict (Lukasik and Alexander 2011; Poessel et al. 2013). A potential explanation for the discrepancy between these results is the differences between human-tolerance behavior and conflict behavior. While conflict-prone individuals often have high levels of human-tolerance, animals with low human tolerance may engage in conflict as after failed attempts to avoid humans spatially or temporally (Baker and Timm 2017). For instance, coyotes with low human tolerance in high density areas may use urban parks to avoid humans but may engage in conflict with humans, or their pets, inside the park out of fear or territoriality.

The effect of disturbed habitat on human tolerance was also significant, but much weaker than the natural habitat effect. While low human activity in disturbed areas may provide some refuge for coyotes living in high density areas, the productivity of natural resources may be low, increasing the animals' space-use requirements and their use of more developed areas. Previous research on urban coyote home range behavior found that home range size increases with the degree of urbanization suggesting that limited resource availability forces animals to range farther into developed areas to meet their energetic needs (Riley et al. 2003; Gehrt et al. 2009; Poessel et al. 2016; but see: Šálek et al. 2014). Despite a general avoidance of agricultural areas, agriculture had a negative effect on the coyotes' human-tolerance behavior. Coyotes experiencing higher rates of hunting and trapping near agricultural areas, may generalize their experience, developing a stronger avoidance of humans in the more densely populated areas surrounding agricultural land.

Human socio-demographic metrics can be powerful predictors of urban ecological patterns and processes (Barnes et al. 2016; McPhearson et al. 2016; Leong et al. 2018; Des Roches et al. 2020; Schell et al. 2020). While previous studies have explored the relationship between human socioeconomic indicators and population biology and community ecology, ours is one of the first studies to explore the effects of human socio-demographic characteristics on animal behavior. Similar to research demonstrating a positive relationship between the frequency of human-coyote interactions and income, our results indicate that human-tolerance behavior increased in areas with higher median incomes (Wine et al. 2015; Fidino et al. 2022). Fine-scale environmental features associated with high income areas like larger lot sizes and higher vegetation cover likely contribute to this relationship by attracting coyotes to residential areas where they have opportunities to habituate to humans (De La Barrera et al. 2016; Leong et al. 2018). Individual human behaviors might also attract coyotes to wealthier residential areas. The previously mentioned human behaviors that encourage selection for high-income areas, e.g., bird feeding, may also increase selection for areas of higher human density if habituation or food-conditioning results from the use of anthropogenic resources (Murray et al. 2016).

The proportion of white residents did not significantly influence human-tolerance behavior potentially because the relationship between race and factors influencing coyote behavior are complex. Green space is associated with race in the CMA, but some of the most developed, densely populated areas are predominantly white (US Census 2010). This complexity has been observed in other urban areas where environmental factors like climate or regional social and economic characteristics produce patterns dissimilar to the general trends between income, race, and the environment reported in the literature (Leong et al. 2018).

While population-level human-tolerance behavior is low in the CMA, the results suggest that areas with low access to suitable habitat and higher income areas are most likely to experience human tolerant coyotes. This adds to the growing literature indicating that sustainable urban ecosystem require suitable wildlife habitat (Hosaka et al. 2016; Zungu et al. 2020; Campos-Silva et al. 2021; Elliot Noe et al. 2022). The negative effect of disturbed habitat on human-tolerance behavior in our study suggests that for highly developed cities, managing existing areas that are low in human activity may also provide benefits to wildlife and the people they interact with (Villaseñor and Escobar 2019).

While large-scale analyses like ours contribute to the identification of general trends and inform future inquiries, the challenge of urban social-ecological systems often lies in gathering the data to uncover relationships across scales. Measuring environmental characteristics at fine scales is easier and less costly with advances in remote sensing; however, collecting data on individual human attitudes and behavior remains challenging. Despite the challenge, truly effective management must be inclusive (Picket and Grove 2020; Schell et al. 2020; Harris et al. 2023; Miriti et al. 2023). Understanding the diverse experiences and perspectives of urban residents is important for increasing coexistence with wildlife and engendering attitudes and behavior that support sustainable conservation and management.

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Socio-demographics shape human-coyote interactions and human attitudes towards coyotes

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Abstract

Human-wildlife coexistence in urban areas depends on urban residents' support for wildlife in cities. Human attitudes shape human behavior towards wildlife making them a key component of managing human-wildlife interactions. In addition to direct experience with wildlife, research shows that socio-demographic characteristics and regionality can influence a human's experience with the environment and, consequently, their attitudes towards wildlife. We used data from an online survey distributed to residents of Cook County, Il and Los Angeles County, CA to evaluate the relationship between socio-demographics, previous experience with coyotes, and attitudes towards. The results indicate that respondents from marginalized groups – low-income, Black, Indigenous, people of color, and women – and respondents living in Cook County tended to have fewer interactions with coyotes, observed less nonthreatening behavior in coyotes, and had less positive attitudes towards coyotes. This relationship was moderated by the positive relationship between encounter frequency and observations of nonthreatening coyote behavior and positive attitudes. This study contributes to the growing literature indicating that direct experience with wildlife can be a powerful tool for increasing human-wildlife coexistence and that equitable management interventions are required to address the needs of groups affected by environmental injustice.

Introduction

As urbanization continues to expand rapidly, managing urban human-wildlife interactions (HWI) is becoming increasingly important (Soulsbury and White 2015). In non-urban areas, ecologists often focus on the costs and benefits of HWI experienced by wildlife to understand the impacts of these interactions. However, in urban areas where humans disproportionately affect ecology, understanding the human dimensions of HWI is particularly important (Dickman 2010; Frank and Glikman 2019).

When humans experience positive interactions, they enjoy benefits which can increase appreciation for wildlife and reduce the perceived cost of living with wildlife (Curtin 2009; Cox et al. 2017; Mumaw et al. 2017). This can result in changes to human behavior that facilitate human-wildlife coexistence. At the individual level, positive HWIs can motivate people to engage in conservation behaviors like including wildlife habitat features on personal property (Toomey and Domroese 2013). At the institutional level, urban residents are important catalysts for improving conservation and management policies and practices that impact species on larger scales (McCance et al. 2017).

Negative interactions can have the opposite effect. Human-wildlife conflict reduces quality of life for stakeholders. This can have devastating effects on wildlife when it increases human behavior or management policies that negatively affect wildlife welfare, reproduction, and survival (Treves and Santiago-Ávila 2020). Furthermore, research on human-wildlife interactions in cities has found that a lack of interactions with nature or wildlife, i.e., the extinction of experience, can have similarly negative effects on humans attitudes towards wildlife (Soga and Gaston 2016). By centering HWI management around stakeholders and the impacts they experience, urban wildlife managers can design more effective interventions, potentially increasing interest in coexistence with wildlife (Decker et al. 2012; McCance et al. 2017).

Impacts experienced by stakeholders are a complex component of HWI because they are the product of external and internal factors that vary among individuals. Previous experience with wildlife is one external factor that accounts for some of the variation in perceived impacts (Kretser et al. 2009). Direct interactions with animals can increase appreciation and tolerance for those species (Velsor and Nilon 2006; Ballantyne et al. 2011; Basak et al. 2022). However, this effect is moderated by the species interacted with and the nature of the interaction. Interactions with pest species or interactions where the animal exhibits threatening behavior can increase a person's perceived costs of living with wildlife (Fitzgerald et al. 2007). Internal factors are also powerful predictors of perceptions of wildlife and HWI (Kansky et al. 2016). Attitudes are sets of beliefs, thoughts, and feelings, used to evaluate a target "object" (Eagly and Chaiken 1993). Attitudes influence a person's perception of the costs and benefits of HWIs, their behavior towards wildlife, and their support for various conservation and management policies making them an important human dimension of human-wildlife interaction management (Frank 2016; Lischka et al. 2018; Bhatia et al. 2020).

Managing the human dimensions of HWI can be particularly challenging in urban environments where humans with different internal and external experiences live in proximity to each other. However, due to the unequal distribution of resources within human-social systems, individuals in the same socio-demographic groups can have similar experiences that shape their relationship with wildlife (Barua et al. 2013; Kansky et al. 2014; Schell et al. 2020). For instance, the distribution of vegetation and biodiversity in urban environments is often associated with race and wealth (Casey et al. 2017; Leong et al. 2018). Urban green space provides habitat for wildlife and an opportunity for humans to interact with them (Elliot Noe and Stolte 2023). Low-income communities and communities with predominantly Black residents, Indigenous residents, or residents of color, which are often associated with reduced access to green space and fewer opportunities for interactions with wildlife, may experience reduced tolerance for wildlife (Velsor and Nilon 2006; Hosaka et al. 2017a). Additionally, these communities often experience higher occurrences of environmental disamenities like pollutants or high-density pest populations which can be generalized to negatively affect their relationship with the environment or other wildlife species (Jordan et al. 2020; Schell et al. 2020). The marginalization of Black, Indigenous and people of color (BIPOC), women, and people with low income in outdoor recreation further reduces opportunities for positive experiences with nature that increase positive attitudes towards wildlife (Powers et al. 2020). Wealth and race are even associated with residential land management behaviors that attract or deter wildlife to residential areas (Nilon 2014). For instance, higher-income properties tend to have more vegetation cover and more diverse bird assemblages which has been attributed to high-income homeowners' increased access to landscaping resources (Avolio et al. 2020). Importantly, understanding how different socio-demographic groups experience wildlife can provide insight into management interventions that support biodiversity and contribute to repairing existing environmental injustices.

In addition to the cultural norms born of social inequities, regional differences in background environments, city planning, economic systems, and culture influence the perceptions and behaviors of humans towards wildlife (Drake et al. 2020; Fidino et al. 2020; Jacobs et al. 2022). In India, farming communities in regions with more mutualistic values towards wildlife engage in fewer retaliatory killings of crop-raiding macaques (*Macaca sp.*) than communities with extractive values often resulting in higher rates of conflict for mutualistic communities (Anand et al. 2018). Even exposure to different local news content can influence attitudes towards wildlife and wildlife management (Nardi et al. 2020). Evaluating variation in human attitudes and experience with wildlife within and among urban areas may produce a more complete understanding of which factors are important for shaping these relationships.

Coyotes (*Canis latrans*) are a species of particular interest in wildlife management because of their rapidly increasing urban populations and occasional conflict with humans (Hody and Kays 2018). As a result of their remarkable range expansion over the last century, they now occupy almost every major city in North America. While the number of human-coyote conflicts remains proportionately low, their status as a medium-sized predator makes them a controversial presence to many urban residents (Elliot et al. 2016; Lute et al. 2020; Vaske and Sponarski 2021). Some stakeholders express concerns about the risks coyotes present to their pets, children, or even themselves. Others believe they are a nuisance, negatively impacting populations of species of economic or recreational value. In contrast, some have positive attitudes towards coyotes believing they are a valuable part of urban ecosystems. Understanding urban residents' attitudes towards coyotes and how those attitudes are influenced by their interactions with coyotes and their membership to socio-demographic groups will provide information on how wildlife managers can design interventions to increase coexistence in different communities.

In this study, we explored the relationship between the socio-demographic characteristics of humans living in proximity to coyotes and their positive attitudes towards, perceived risk of, and previous experience with these animals. Surveys were distributed to residents of Los Angeles County (LAC), CA and Cook County (CC), IL which were chosen for their large human and coyote population sizes. The counties are the two most populous in the US (US Census 2020) and it is estimated that they have coyote populations above 4,000 individuals (S. Gehrt, personal communication 2022; California Department of Fish and Wildlife 2016). Due to the prevalence of coyotes in these highly urbanized areas, human-coyote encounters are frequent in these regions. Notably, however, Los Angeles County has had historically high rates of coyote attacks on humans compared to other metropolitan areas with nearly half of reported coyote attacks on humans since the 1970s taking place in California (Baker and Timm 2017). Increased conflict in LA has been attributed, in part, to residents' positive attitudes towards coyotes and resistance to lethal management interventions.

We hypothesized that attitudes towards coyotes are shaped by previous experience with coyotes, access to nature, and cultural norms. We predicted that individuals with few coyote encounters, observations of threatening coyote behavior, and those with limited access to nature or wildlife, i.e., low-income, female, and BIPOC individuals, and those with lower educational attainment, would have less positive attitudes towards coyotes and higher perceived risk of coyotes. Finally, we predicted that regional, cultural differences in attitudes towards wildlife would result in higher positive attitudes towards and less perceived risk of coyotes in LA.

Methods

Data collection

Between April 26th-29th, 2013, a web-based survey was administered to participants using the survey research company, Survey Sampling International (SSI). SSI maintains a platform where potential respondents can participate in various surveys. Participation is rewarded with points which can be redeemed for money. Residents of CC and LAC over the age of 18 were randomly selected from among the members of SSI's pool of potential respondents. Three hundred and seven respondents from CC and 300 from LAC took part in this study's survey. Of the 607 respondents, 577 were included in the final model. Respondents were excluded based on the lack of completeness of their survey.

The survey collected information about respondents' attitudes towards coyotes, experience with coyotes, and their socio-demographic information (see Appendix 3.1 for details). Additionally, the survey collected information about the respondents' attitudes towards wildlife more broadly, their knowledge of coyote ecology, and lifestyle questions. These data were used in a previous study by Elliot et al. (2016) which evaluated the general patterns of residents' attitudes towards, experiences with, and knowledge of coyotes. We built on that research by evaluating the potential causal mechanisms of attitudes towards coyotes using a structural equation modeling.

Measures

Our study sought to evaluate the relationships between the socio-demographic factors contributing to respondents' social and environmental experience, previous experience with coyotes, positive attitudes towards coyotes, and perceived risk of coyotes (Fig. 3.1). The analysis used five socio-demographic factors collected in the survey. These included total yearly household income, race, educational attainment, gender, and county of residence (Table 3.1). These are causal indicators for the latent variable social and environmental experience (SEE) which is meant to represent the broader social (e.g., environmental racism impacting proximity to green space) and cultural (e.g., differences in recreational activities) processes that may influence how different groups of people interact with the environment and regard coyotes.

Previous experience with coyotes (PE) was represented as a composite variable measured by two indicators. The first, sighting frequency, initially asked respondents if they had seen coyotes in their county of residence in the last 12 months. Those who had seen a coyote were given the following sighting frequency options to choose from: 'daily', 'weekly', 'monthly', 'once a year' and 'only saw coyote(s) once'. The second, sighting nature, listed coyote behaviors that could be observed during an interaction. These ranged from the least threatening behavior, 'ran away', to highly threatening behavior, 'physically attacked me'. Respondents were allowed to select as many behaviors as they had observed. Behaviors were assigned a number value ranging from -4 for the most threatening behavior to +3 for the least threatening behavior. Each respondent was assigned a score based on the sum of the behaviors they had observed. Respondents who did not report a coyote sighting in the last 12 months were assigned a score of zero for this variable to avoid the listwise deletion of those respondents' data during the analysis.

This study looked at two attitudes towards coyotes: perceived risk of coyotes and positive attitudes towards coyotes. Each attitude was measured by four 5-point Likert scale statements ranging from 'strongly disagree' to 'strongly agree'. Point 3 on the scale was represented by the option 'neutral'.

Variable	Subcategory	Count	%
Gender	Female	286	50
	Male	291	50
Race	Nonwhite	180	31
	White	397	69
Income	< $10,000	37	6
	$10,000 - $39,999	172	30
	$40,000 - $69,999	167	30
	$70,000 - $99,999	107	18
	> $100,000	94	16
County	Cook County	291	50
	Los Angeles County	286	50
Education	Less than high school	12	2
	High school	154	27
	College	325	56
	Graduate program	86	15

Table 3.1. Sample characteristics

Data analysis

The hypothesized structural equation model (Fig. 3.1) was estimated using maximum likelihood estimation methods in the *lavaan* package (Rosseel 2012) in R (R Core Team, 2022). Confirmatory factor analysis was used to estimate factor loadings for the latent variable PA. Indicator intercepts were constrained to 1.0 (Little et al. 2006).

PE is a composite variable which summarizes the collective influence of its indicators, sighting frequency and sighting nature, therefore its variance was fixed to zero (Grace and Bollen 2008). Factor loadings for PE were estimated using a maximum-likelihood fitting function. SEE factor loadings were also estimated using a maximum-likelihood fitting function; however, because a person's social and environmental experience is not explained entirely by the 5 indicators included in this model, its variance was estimated.

We used four indices to evaluate model fit. The normed chi-square ($\chi 2$ /df) assesses the discrepancy between the predicted model and observed data but is less sensitive to sample size than the traditional chi-square test. The acceptable range is ≤ 2 (Ullman 2001). The Root Mean Square Error of (RMSEA) is another method for assessing model discrepancy while correcting for large sample sizes and it has an acceptable range of ≤ 0.05 (MacCallum et al. 1996). The Comparative Fit Index (CFI) assesses model fit by comparing its performance to a baseline model and the criterion used for a good fit is ≥ 0.95 (West et al. 2012). Finally, the Standardized Root Mean Square Residual (SRMR) calculates the difference between the observed correlation and the predicted correlation with values closer to zero indicating a better fit. SRMR values of ≤ 0.08 are considered acceptable (Hu and Bentler 1999).

After global fit statistics indicated our hypothesized model fit was poor, we conducted local fit testing using correlation residuals. Correlation residuals are the difference between the model estimated correlations and observed correlations and can be used to determine the source of model-data discrepancies. The correlation residuals revealed that the predicted covariances of the indicators of perceived risk, i.e., the Likert scale questions measuring perceived risk, and other variables in the model were consistently over- or underestimated. Consequently, perceived risk was removed from the final model.

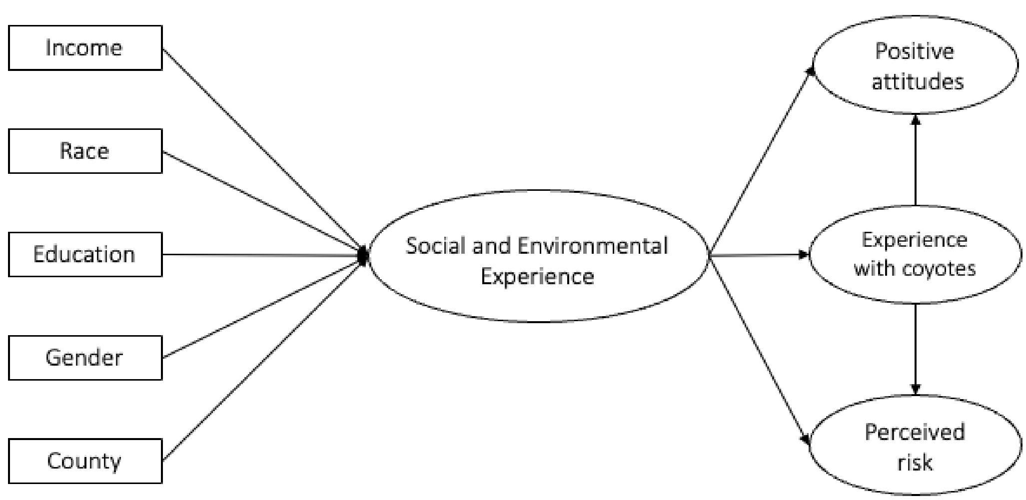

Figure 3.1. Hypothesized structural equation model. Socio-demographic variables included as causal indicators of social and environmental experience.

Results

The internal reliability of positive attitudes was in the acceptable range (Cronbach's α = 0.769). Indicator loadings for positive attitudes and previous experience were also acceptable (Table 3.2). The indicators for social and environmental experience: gender, race, income, and county of residence were significantly and positively associated with the latent variable, while education did not have a significant relationship with social and environmental experience (Table 3.2). The final model (Fig. 3.2) exhibited global fit statistics indicating an acceptable fit ($\chi 2$ /df = 1.93, RMSEA = 0.040, CFI = 0.972, and SRMR = 0.028). Social and environmental experience had a significant, positive effect on both positive attitudes and previous experience (Table 3.3). Previous experience had a positive, significant effect on positive attitudes towards coyotes (Table 3.3).

Variable	Indicator	Standardized loadings	SE
Positive attitudes (PA)	Coyotes are an important part of nature	0.785	0.025
	We should learn to live with coyotes	0.745	0.026
	Coyotes help control pest populations	0.649	0.030
	I would like to see coyotes in my neighborhood	0.623	0.031
Previous experience with coyotes (PE)	Sighting frequency	0.769	0.047
	Nature of interactions	0.820	0.049
Social and environmental experience (SEE)	Gender	0.674	0.520
	Race	0.381	0.520
	Income	0.467	0.300
	County	0.270	0.116
	Education	-0.115	0.125

Table 3.2. Measurement model results including standardized loadings and standard errors (SE) of latent variable indicators.

Regression	Estimate	SE	*z*	*p*
PA ~ SEE	0.200	0.046	4.352	< 0.001 *
PA ~ PE	0.261	0.052	5.062	< 0.001 *
PE ~ SEE	0.306	0.043	7.160	< 0.001 *

Table 3.3. Structural model results. Estimates are standardized. PA = positive attitudes, SEE = social and environmental experience, PE = previous experience with coyotes. Significance ($p < 0.05$) denoted by asterisks.

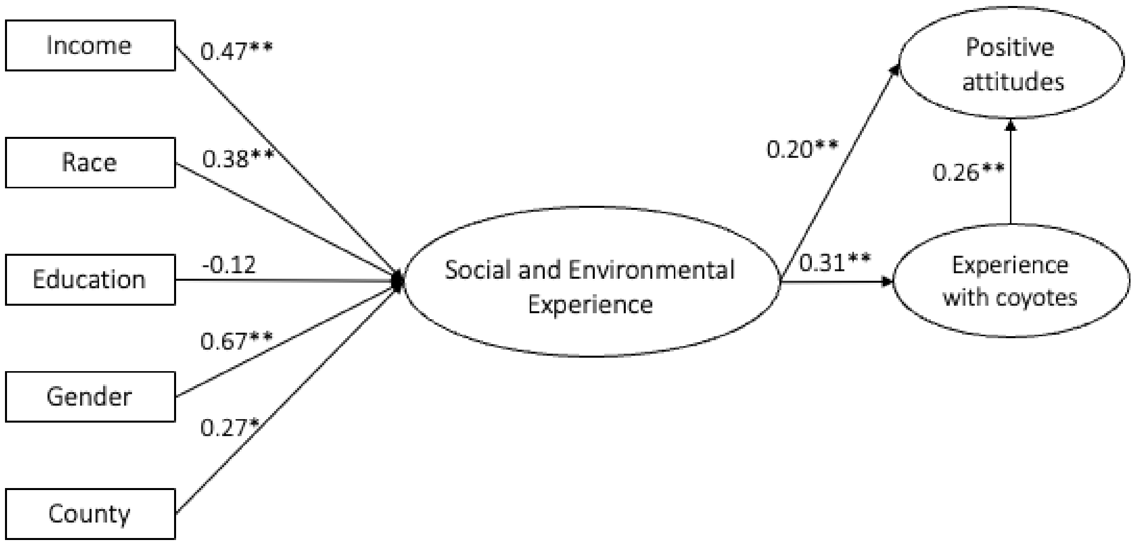

*Figure 3.2. Final structural model, including causal indicators, with standardized parameter estimates. Significance denoted by asterisks (*p = 0.01; ** p < 0.001).*

Discussion

Incorporating human dimensions into wildlife management research is necessary for developing effective and equitable management strategies. Using survey data and a structural equation model we explored how different socio-demographic groups experience coyotes. The results indicate that men, individuals with higher incomes, white-identifying individuals, and residents of Los Angeles County tended to have more positive attitudes towards coyotes. This relationship occurs directly through a person's social and environmental experience and through the effects of this experience on experience with coyotes.

The effect of previous experience with coyotes on positive attitudes in our study supports existing research on the role direct interactions with wildlife play in shaping human perceptions of wildlife. Kansky and Knight (2016) conducted a meta-analysis evaluating factors influencing human attitudes towards damage-causing wildlife and found that, of the factors measuring experience with a species, direct exposure was the strongest predictor of both positive and negative attitudes. Importantly, interactions with wildlife can be generalized. Early-life experience with wildlife or nature have lasting impacts on appreciation and tolerance for wildlife (Soga et al. 2016; Hosaka et al. 2017a). Hosaka et al. (2017b) found that early life experience with nature improved attitudes and tolerance for hornets and wild boars, animals usually regarded as nuisance species by residents of the study area. These direct experiences are gaining attention as important tools for influencing humans' willingness to coexist with wildlife (Sponarski et al. 2019).

Human attitudes towards wildlife are influenced by both personal and social-system structures. In American cities, socio-demographics influence many facets of these experiences. Well established relationships between marginalized groups and access to nature likely contribute to the relationship between social and environmental experience and attitudes towards coyotes in our study. As previously mentioned, differences in outdoor recreation are likely contributing to variation in the frequency of coyote encounters between groups. Since research on representation in outdoor recreation began, studies have found that BIPOC, women, and people with low incomes tend to be marginalized from these activities reducing their opportunities for interactions with nature that improve appreciation and tolerance for wildlife (Wolch and Zhang 2004; Shores et al. 2007; Krymkowski et al. 2014; Soga and Gaston 2016). In addition to a lack of experience, variation in attitudes towards wildlife have also been attributed to the negative environmental experiences of individuals from marginalized communities resulting from environmental injustice. For instance, in urban areas BIPOC and low-income communities are disproportionately affected by undesirable wildlife species like rats and roaches (Biehler 2013; Schell et al. 2020). Negative experiences with these animals may be generalized to include other wildlife, especially those with existing negative cultural connotations like the coyote. Studies assessing gender differences in attitudes towards wildlife, show that women tend to have more negative attitudes towards and higher perceived risk of carnivores which has been attributed to their traditional role as the primary caregiver of children (Ogra 2008; Campbell and Lancaster 2010; Dickman et al. 2013). Despite previous research demonstrating educational attainment's positive relationship with positive attitudes towards wildlife (e.g. Henderson et al. 2021), it was not significantly associated with the social and environmental experience shaping respondents' relationships with coyotes in our study. It is possible the relationship is mediated by direct experiences and respondents in this study with lower educational attainment lived in more rural areas while those with higher education attainment lived in more urbanized areas with fewer opportunities to interact with nature and wildlife (Soga and Gaston 2016).

The effect of county further highlights the role culture plays in shaping relationships with wildlife. Los Angeles residents tended to have more positive attitudes which is surprising given that 45% of all reported coyote attacks on humans in the US and Canada between 1977 and 2015 occurred in California (Baker and Timm 2017). Timm and Baker (2007) studied some of these human-coyote conflicts in Los Angeles and observed a culture of strong positive attitudes towards wildlife which they believed was a key driver in residents' opposition to invasive management interventions (Kansky et al. 2016). Meanwhile, Cook County is in the Midwest where individuals tend have more traditional extractive values towards wildlife, believing animals should be managed for the benefit of human well-being (Teel and Manfredo 2009).

The history of coyotes in these two areas might also play a role. Humans and coyotes have been interacting in the urban areas of Los Angeles since at least the 1960s, while the urban coyote population in Cook County began growing significantly in the 1990s (Gill 1965; White and Gehrt 2009). For humans living in proximity to coyotes, tolerance for the animals tends to increase with the duration of the coyotes' presence in the area (Drake et al. 2020). A longer duration of coexistence and a larger coyote population may have increased opportunities for the residents of Los Angeles to experience more neutral encounters with coyotes influencing attitudes through respondents' direct experiences and the experiences of those in their community (Zimmerman et al. 2001; Zinn et al. 2008; Jackman and Rutberg 2015).

Interestingly, positive attitudes towards coyotes may contribute to the inordinate number of attacks in California. Elliot et al. (2016) found that individuals who had more positive attitudes towards wildlife were also more likely to engage in behaviors that attract coyotes to residential areas, like bird feeding or maintaining compost (Murray et al. 2016). During their study of coyote attacks on humans, Timm and Baker (2007) also emphasized that humans with positive attitudes towards coyotes can exacerbate conflict by encouraging coyote habituation to humans and opposing lethal management strategies known to be effective in removing dangerous animals. This illustrates the complexities of managing urban carnivores. Positive attitudes towards carnivores play an important role in increasing tolerance for these animals, but when positive attitudes become too extreme, they can influence wildlife behavior and even evolution, creating feedback loops that worsen human-wildlife conflict (Barrett et al. 2019; Schell et al. 2021).

In urban areas, the social processes influencing human behavior from individual to institutional scales have profound impacts on human-ecosystem interactions. In this study, we see that individuals from marginalized groups are disadvantaged in their relationships with coyotes - experiencing fewer and less positive interactions and less positive attitudes. The results suggest that attitudes towards coyote can be improved, in part, by increasing exposure to nonthreatening animals. Whereas management interventions like the distribution of educational materials often fail to significantly impact human dimensions of HWI, research suggests that experience with viewing wildlife or even signs of wildlife can provide psychological benefits that improve attitudes (Frank 2016; McCance et al. 2017; McIntosh and Wright 2017). Given that coyotes very rarely act aggressively towards humans, encouraging people living near coyotes to engage in behaviors that increase their likelihood of safely observing these animals could have positive impacts on their attitudes.

Outside of direct interactions with coyotes, increasing opportunities for individuals from to marginalized groups to interact with nature may also be beneficial. Soga and Gaston (2016), reviewed evidence for the “extinction of experience” – the process in which decreased exposure to nature reduces pro-environmental attitudes and behavior. They suggest that increasing the availability of urban parks and natural areas can increase human-nature interactions. This may have the added benefit of reducing wildlife use of human areas and opportunities for conflict (Hosaka and Numata 2016; Zepeda et al. 2023). Additionally, evidence indicates increased participation in nature-related activities in childhood has a strong effect on human’s interest in nature and tolerance for wildlife in adulthood (Thompson et al. 2008; Soga et al. 2016; Hosaka et al. 2017a). Early-life experiences could be one tool for overcoming social-norms that reduce participation in outdoor activities or reduce tolerance and appreciation for wildlife. Importantly, the mechanisms driving socio-demographic differences in humans’ relationships with nature are complex (Whiting et al. 2017; Winter et al. 2019). Managers seeking to improve human-coyote coexistence should conduct research to understand exactly which challenges communities in their region are facing.

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Supplemental Information

Appendix 3.1. The following pages contain the survey questions distributed to the study respondents.

1. Which county are you from:

- ◯ Cook County, IL
- ◯ Los Angeles County, CA

2. What neighborhood are you from?

3. For each statement listed, please check the box that best indicates how much you agree or disagree with each statement on a scale from 1 (Strongly Disagree) to 5 (Strongly Agree). Please check only one box per statement.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I would like to see coyotes in my neighborhood	◯	◯	◯	◯	◯
I enjoy seeing wildlife in my neighborhood	◯	◯	◯	◯	◯
It is important to maintain a diversity of native animals in cities	◯	◯	◯	◯	◯
It is important to maintain a diversity of native animals in suburbs	◯	◯	◯	◯	◯
Coyotes are dangerous to adults	◯	◯	◯	◯	◯
Coyotes are dangerous to small children	◯	◯	◯	◯	◯
Coyotes are dangerous to pets	◯	◯	◯	◯	◯
I am afraid of coyotes	◯	◯	◯	◯	◯
We should learn to live with coyotes in my county	◯	◯	◯	◯	◯
Coyotes are a nuisance in my county	◯	◯	◯	◯	◯
Coyotes should not be tolerated close to people	◯	◯	◯	◯	◯
Coyotes help control populations of pests (e.g. rats, mice) in my county	◯	◯	◯	◯	◯
Coyotes are an important part of nature in my county	◯	◯	◯	◯	◯
Feeding coyotes should be illegal	◯	◯	◯	◯	◯
Feeding all wildlife should be illegal	◯	◯	◯	◯	◯

4. Are you aware that there are coyotes living in your county?

- Yes
- No

5. If you answered yes to Question 4, how did you know there are coyotes in your county? (check all boxes that apply)

- TV
- Internet
- Newspaper
- I've seen them
- Word of mouth
- I didn't know

Other (please specify)

6. Have you seen coyote(s) in your county in the past 12 months?

- Yes
- No

7. Please list all the places you've seen coyotes in your county (please be as specific as possible, e.g. closest intersection/street name):

8. Please name the one place where you have most often seen coyotes:

9. What best describes how often you see coyotes in your county?

- Daily
- Weekly
- Monthly
- Once a year
- Only saw coyote(s) once

10. What time of year do you mostly see coyotes?

- Summer
- Fall
- Winter
- Spring
- All year round

11. What time of day do you mostly see coyotes?

- In the morning
- During daylight hours
- At dusk
- At night
- At all hours

12. What best describes the coyote's reaction to your presence? (check all boxes that apply)

- Snarled/growled at me
- Ran away
- Walked away
- Watched me
- Followed me
- Didn't notice me
- Physically attacked me
- Physically attacked my pet

Other (please specify)

13. If you have ever been approached or followed by a coyote in your county, what activity were you engaged in when this happened? (check all boxes that apply)

- Jogging/walking with a dog
- Jogging/walking alone
- Biking with a dog
- Biking alone
- Relaxing in a yard/park
- I've never been approached/followed by a coyote in my county

Other (please specify)

14. If approached by a coyote, I should: (check all that apply)

- Hold out my hand and approach it
- Wave my arms and shout
- Walk away
- Run away
- Throw something at it
- Remain still and quiet
- I don't know

Other (please specify)

15. When are urban/suburban coyotes most active?

- In the daytime
- At night
- In the morning and evening
- All the time

16. Coyotes in your county are mainly eating:

- Small rodents
- Garbage
- Raccoon
- Small pets
- I don't know

17. Coyote numbers in your county are:

- Increasing
- Decreasing
- Staying the same
- There are no coyotes in my county
- I don't know

18. Coyotes can be found:

All over the world

Only in North and South America

Only in North America

Only in my county

I don't know

19. Where would you like to see coyotes? (check all that apply)

- Around my home/in my yard or garden
- In neighborhood parks and green spaces
- In forest preserves
- In the suburbs
- In the zoo
- I don't want to see coyotes

Other (please specify)

20. Do coyotes carry any diseases they can pass on to people?

- Yes
- No

If yes, please list the diseases

21. Do coyotes carry any diseases they can pass on to pets?

- Yes
- No

If yes, please list the diseases

22. What is the best method for managing problem coyotes?

- Public education to avoid human-coyote conflicts
- Relocate problem coyote
- Euthanize problem coyote
- Poison, trap or hunt coyotes

23. When is it acceptable to humanely destroy a coyote? (check all that apply)

- When human safety is threatened
- When pet safety is threatened
- When the animal is diseased or injured

- When the coyote is causing property damage
- It is never acceptable

24. Coyote populations in your county:

- Should remain the same
- Should be increased
- Should be decreased

25. Would you support a law that makes feeding coyotes illegal?

- Yes
- No

26. Do you have any pets? (check all that apply)

- [ ] No
- [ ] I have one or more cats
- [ ] I have one or more small dogs
- [ ] I have one or more large/medium-sized dogs

Other (please specify)

27. If you own dogs, do you ever walk them off-leash?

- Yes
- No
- I don't own dogs

28. Do you ever leave your pets outside unattended?

- Yes
- No

29. What best describes how often you leave your pet(s) outside unattended?

- Once or twice a year
- 1-3 months a year
- 3-6 months a year
- 6-9 months a year
- All year around

Other (please specify)

30. Do you believe you have lost a pet to a coyote?

- Yes
- No

31. What kind of pet do you believe you lost to a coyote? (check all that apply)

- small dog
- large/medium dog
- Cat
- Rabbit
- Poultry

Other (please specify)

32. Does anyone in your household ever leave food outside for: (check all that apply)

- Pets
- Strays
- Wildlife
- Our household doesn't leave food outside

33. Approximately how often do you engage in outdoor activities?

- Less than one month year
- 1-3 months a year
- 3-6 months a year
- 6-9 months a year
- 9-12 months a year

34. Do you have children under the age of 6, or children under the age of 6 visiting regularly?

- Yes
- No

35. Do you have a bird feeder?

- Yes
- No

36. Do you have a yard or garden?

- Yes
- No

37. Do you have an uncovered compost pile in your yard?

- Yes
- No

38. Do you have a vegetable garden?

- Yes
- No

39. Do you grow fruit trees in your yard/garden?

- Yes
- No

Now, to help classify your answers and to make statistical comparisons, would you mind answering the following questions:

40. To which age group do you belong?

- Under 20
- 21-30
- 31-40
- 41-50
- 51-60
- 60+

41. Please indicate your gender:

- Female
- Male

42. Please indicate the highest level of education you have completed:

- Less than high school
- High school
- College
- Graduate program

43. Are you Hispanic or Latino?

- Yes
- No

44. Which of the following would you say is your race? (check all that apply)

- American Indian or Alaska Native
- Asian
- Black or African American
- Native Hawaiian or other Pacific Islander
- White

45. What is your total household income?

- Less than $10,000
- $10,000 - 39,999
- $40,000 - 69,999
- $70,000 - 99,999
- $100,000 and more