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ARTICLE

Socio-Ecological Systems

Neighborhood ethnicity is related to mammal occupancy and activity across a desert metropolitan area

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Abstract

Cities support abundant human and wildlife populations that are shaped indirectly and directly by human decisions, often resulting in unequal access to environmental services and accessible open spaces. Urban land cover drives biodiversity patterns across metropolitan areas, but at smaller scales that matter to local residents, neighborhood socio-cultural factors can influence the presence and abundance of wildlife. Neighborhood income is associated with plant and animal diversity in some cities, but the influence of other social variables is less well understood, especially across desert ecosystems. We explored wildlife distribution across gradients of neighborhood ethnicity in addition to income and landscape characteristics within residential areas of metropolitan Phoenix, Arizona, USA. Utilizing data from 38 wildlife cameras deployed in public parks and undeveloped open spaces within or near suburban neighborhoods, we estimated occupancy and activity patterns of common mammal species, including species native to the Sonoran Desert (coyote [*Canis latrans*] and desert cottontail rabbit [*Sylvilagus audubonii*]), and non-native domestic cat (*Felis catus*). Neighborhood ethnicity (percentage of Latino residents) appeared to exhibit a negative relationship with occupancy for coyotes and cottontail rabbits. Additionally, daily activity patterns of coyotes occurred later in the evenings and mornings in neighborhoods with higher proportions of Latino residents, but activity was unaffected by differences in neighborhood income. This study is one of the first to show that social-ecological mechanisms associated with patterns of neighborhood ethnicity as well as income may help to shape wildlife distribution in cities. These findings have implications for equitable management and provisioning of ecosystem services for urban residents and highlight the importance of considering a range of social covariates to better understand biodiversity outcomes in urban and urbanizing areas.

KEYWORDS
biodiversity, LTER, luxury effect, Phoenix, residential

INTRODUCTION

Urbanization is characterized by rapid and widespread land use and land cover change that results in fragmentation of wildlife habitats into distinct heterogenous landscapes to accommodate human populations (Grimm et al., 2008). Historical and systemic social forces, such as racism and classism, have also separated people geographically across metropolitan areas, resulting in unequal distribution of open spaces and potential wildlife habitat (Locke et al., 2021). Despite habitat loss within metropolitan areas, residential properties and parks can support diverse wildlife communities—particularly in moderately developed suburban areas—especially species that have adapted to utilize or persist in residential landscapes (Lerman & Warren, 2011; McKinney, 2002; Parsons et al., 2018). Although urban land cover is a strong predictor of biodiversity at large scales (Aronson et al., 2014; Lerman et al., 2021), as well as income (Magle et al., 2021), it is less clear whether and how social factors such as income and race/ethnicity shape wildlife distribution and composition in metropolitan areas. Proximity to the non-human living world can influence people's perceptions of and experiences with nature (Engebretson et al., 2020; Turner et al., 2004). Thus, understanding the distribution and activity of free-roaming animal species across diverse neighborhoods may help to develop equitable biodiversity management and positive nature experiences.

Residential landscapes are social-ecological systems that include neighborhoods of people with diverse lifestyles and values, as well as vegetation, wildlife, and other geographic and biophysical elements that shape urban, suburban, and rural habitats (Cook et al., 2012; Larson et al., 2010; Roman et al., 2018). Within residential areas of similar density, social factors are associated with the quality of habitat for many wildlife species and shape species distributions (Belaire et al., 2014; Loss et al., 2009; Luck et al., 2013). For example, neighborhood wealth is often positively correlated with tree cover and species richness of taxa such as lizards, birds, and bats (Hope et al., 2003; Leong et al., 2018). However, this association, commonly called "the luxury effect," is not consistent across cities, nor for all types of organisms (Kuras et al., 2020). Mechanistic explanations vary for the presence or strength of a luxury effect, ranging from wealthier residents' ability to control landscaping or to move to areas with more vegetation, homeowner preferences for vegetation and certain plant traits, or cultural legacies of landscape choices (Chamberlain et al., 2020; Larsen & Harlan, 2006; Locke & Baine, 2015). Additionally, methodological approaches vary across studies and confound clear associations between neighborhood income and biodiversity patterns (Kuras et al., 2020; Watkins & Gerrish, 2018). Increasing wealth does not always correlate to higher biodiversity, and biodiversity's correlation with wealth varies depending on the region and associated climate (Kuras et al., 2020). Furthermore, "luxury" can be a misleading term, because having more vegetation or wildlife in a neighborhood is not always perceived as positive by residents (Larson et al., 2019). Residents often have diverse perceptions of what "luxury" is, and particularly whether luxury is associated with the presence or absence of wildlife species. In many instances, the presence of wildlife in urban areas is considered to be a positive ecosystem service (e.g., wildlife viewing, nature connectedness), but in other cases, wildlife presence can lead to significant disservices or conflict-like physical attacks or property damage (Soulsbury & White, 2015). Understanding wildlife distributions across diverse neighborhoods can inform management that aims to minimize the risks of human–wildlife conflict while maximizing the positive services of urban wildlife for all residents.

As we know from urban studies of people, other social forces beyond income—such as race and ethnicity—are often associated with differences in neighborhood structure, quality, and services. These neighborhood differences often have social-ecological consequences for minoritized human residents (e.g., Black, Hispanic/Latino, and Asian people) (Miller, 2022; Seamster & Purifoy, 2020), and may also affect wildlife habitat quality (Lambert & Schell, 2023; Schell et al., 2020). Due in part to historical legacies of housing segregation in the United States (Frey, 2021a), in aggregate, residents of similar income levels but different races/ethnicities often live in neighborhoods with vastly different socioeconomic compositions (Logan & Stults, 2011; Reardon et al., 2015). For example, middle class Latino and Black residents typically live in poorer neighborhoods (neighborhood-level income) than white residents of the same income level (Firebaugh & Acciai, 2016; Reardon et al., 2015), and White residents tend to live in predominantly White neighborhoods (Frey, 2021a). These patterns may be linked to preferences of residents and remnants of unequal housing practices, such as the racially motivated discriminatory practice of redlining that excluded minoritized residents from higher ranking neighborhoods (Jesdale et al., 2013). The purposeful segregation of racial and ethnic groups and systemic investment of resources into majority White neighborhoods has led to unequal exposure of residents to ecosystem services and disservices, with potential consequences for wildlife habitat. For example, minoritized neighborhoods often have less tree cover (Locke et al., 2019; Watkins & Gerrish, 2018), are more exposed to air and water pollutants (Grineski et al., 2007; Tessum et al., 2019), often have less access to safe open spaces (Rigolon, 2016; Rigolon & Németh, 2021), experience more intense urban heat island effects (Hsu et al., 2021; Jesdale et al., 2013; Wilson, 2020), and inequitable distribution to noise (Nelson-Olivieri et al., 2023). Notably, cities in the Southwestern United States show some of the largest heat differences between formerly redlined and non-redlined neighborhoods (Hoffman et al., 2020).

Despite extensive documentation of environmental differences between minoritized and White neighborhoods, few studies have explored the relationship between neighborhood ethnic/racial composition and wildlife distribution. Self-reported ethnicity relates to the cultural background and descent of residents and is often utilized in social-ecological research (Dean & Platt, 2016; Ford & Harawa, 2010; US Census Bureau, 2022). Correlations between income and ethnicity are common and thus are often grouped into a single wealth metric in research, making it difficult to discern the independent effect of race and ethnicity on ecological models (Kinzig et al., 2005; Schmidt & Garroway, 2022). For example, in metro Phoenix, lower income Latino neighborhoods are associated with fewer native bird and plant species (Kinzig et al., 2005), while higher income neighborhoods with lower percentages of Latino residents more commonly contain desert-adapted vegetation and xeric-style landscaping types (Lerman & Warren, 2011; Warren et al., 2019). While minoritized and low-income neighborhoods are often negatively associated with the presence of bird and plant species, the extent to which similar patterns with wealth and mammal communites varies across regions (Magle et al., 2021). Deliberate site selection across gradients of neighborhood race/ethnicity and income may provide clearer information about where wildlife species occur, which in turn may improve predictive models that can inform wildlife management and lead to improved resident experiences.

In this research, we investigated the relationship between ethnicity, income, environmental variables, and the spatial and temporal distribution of three mammal species across neighborhoods in the arid metro Phoenix area, Arizona, USA. We hypothesized that the ethnic composition of neighborhoods is significantly associated with the distribution of both native species (coyote [*Canis latrans*] and desert cottontail rabbit [*Sylvilagus audubonii*]) and non-native species (free-roaming domestic cats [*Felis catus*]). To test this hypothesis, in the summers of 2019 and 2021 we identified animal species from an array of 38 motion/heat-triggered wildlife cameras within community parks and open spaces across gradients of median neighborhood household income and ethnicity. Using these data, we conducted single-season, single-species occupancy models to evaluate the effect size and importance of two social covariates (neighborhood median household income and percentage of Latino residents), and three landscape covariates (percentage of impervious surface, normalized difference vegetation index [NDVI], and presence of water) on the presence of the three mammal species. Additionally, we investigated potential shifts in daily activity patterns based on neighborhood income and ethnicity.

METHODS

Study area

We tested our hypotheses in community parks and open spaces in or adjacent to moderate-density residential neighborhoods where most residents live within the metro Phoenix area and within the boundaries of the Central Arizona–Phoenix Long Term Ecological Research area (CAP LTER). These sites are in Maricopa County, Arizona, USA, within the Sonoran Desert of the lower Colorado River Basin. The landscape of the metro area comprises of residential and industrial/commercial areas, transportation corridors, crop lands, desert parks, hundreds of public community parks, and >1400 artificial water bodies that sustain a desert "oasis" by irrigation from the Colorado, Verde, and Salt Rivers (Bradley & Colodner, 2020; Larson, Gustafson, et al., 2009). Community parks and open spaces typically contain grassy sportsfields or playgrounds in addition to grass, trees, and other shrubs in undeveloped spaces that support storm runoff (Lara-Valencia & Garcia-Perez, 2018). These open spaces are used by residents for recreation and are also used by wildlife seeking cover and resources (Gallo et al., 2017; Haight et al., 2022, in preparation).

The study area comprises several highly populated sprawling cities, and population trends are among the fastest growing in the United States for the past decade (Hing, 2020; Keys et al., 2007; US Census, 2022). The median household income across the metro area is US $67,799 (US Census, 2021). The racial/ethnic composition of the metro area includes 53.4% White residents, 32.0% Hispanic, 6.7% Black or African American, 4.8% Asian, and 3.3% two or more races, 2.9% American Indian and Alaska Native, and 0.3% Native Hawaiian and other

Pacific Islander (US Census, 2021). Like other US cities, Hispanic-majority neighborhoods in metro Phoenix are common (Arreola, 2012; Lara, 2012). The Hispanic community within metro Phoenix is diverse but dominated by people of Mexican (89%) or Puerto Rican (1.9%) heritage (Pew Research Center, 2016). For this reason, hereafter "Hispanic" is referred to as "Latino."

Like in other metropolitan areas in the United States, neighborhoods within metro Phoenix have a history of segregation driven by redlining and other discriminatory policies that led to settlement of non-White residents into less desirable, more industrial landscapes than White residents (Bolin et al., 2005; Mapping Inequality, 2022). Although understudied in this region, the social-ecological legacies of such actions may be long-lasting (Grove et al., 2018). Varying from national patterns, access to public parks in metro Phoenix neighborhoods is relatively equitable, with similar density of parks in Latino and lower income neighborhoods compared to dominantly White and upper income neighborhoods (Lara-Valencia & Garcia-Perez, 2018; Wen et al., 2013). However, parks in Latino neighborhoods within metro Phoenix tend to have less tree cover and natural characteristics, and more features such as grills and sports facilities, while non-Latino neighborhoods tend to have more natural features (Lara-Valencia & Garcia-Perez, 2018).

Site selection

To focus on wildlife populations that utilize or pass through built landscapes within neighborhoods, we selected sites within or adjacent to residential neighborhoods that spanned a gradient of income (median household income) and ethnic composition (percentage Latino) in the metro Phoenix area (Figure 1) from the pool of publicly funded parks or other open spaces with similar neighborhood urbanization levels (e.g., 23%–72% impervious surface). Our selected sites were located in urban or urbanizing areas >2 km from a desert park preserve and from undisturbed desert areas. Using the 2017 American Community Survey and within ArcMap 10.7, we evaluated the average median household income and average racial/ethnic composition of residents within a 1-km radius of each site (defined in this study as a "neighborhood"). Due to the prevalence of people who identify as White or Latino in the study area, we focused on sites within neighborhoods where these ethnic/racial groups dominate. We aimed to sample across the gradient of ethnic composition and income levels throughout the metro area. To reduce correlation between income and ethnicity data, we considered inclusion of a site in this study if the neighborhood median household income and proportion of Latino residents were within the top or bottom quartile of each category, or if a site's inclusion reduced the correlation between the two variables. To aid in the interpretation of results, we chose neighborhoods in which proportions of non-Latino communities of color (Black, Asian, Native American), were within one SD of the metro-wide mean value. Our final experimental design included 38 sites, 10 sampled in June–September of 2019 (Lewis & Haight, 2022) and 28 sampled in June–September of 2021, with an income-ethnicity correlation of $r = -0.64$.

Camera methods

We sampled medium (2–5 kg) to large-bodied (>5 kg) wildlife species following common camera trap methods (Kays et al., 2020; Njoroge et al., 2009; Sollmann, 2018), using 38 non-baited, motion- and heat-activated wildlife cameras (Cuddeback black flash in 2019 and 2021; Bushnell Core low-glow in 2021) placed at locations where wildlife was likely to travel (signs of a natural pathway, scat, or tracks; Kays et al., 2020). Based on similar camera placement methods between survey years and similar camera trigger speeds, wildlife detection was estimated to be similar between years (Rovero et al., 2013). Each camera was secured to a tree at approximately knee height, and perpendicular to the expected wildlife path. Once triggered, cameras were programed to capture two photos with a 30-s quiet period between triggers (2019 cameras) or two photos with a 2-min quiet period (2021 cameras). Each animal observation was identified to species by two independent observers and an expert third observer to resolve discrepancies when necessary.

Social covariates

We utilized the average median household income and percent of Latino residents within a 1-km radius of each camera site as two continuous social covariates. Neighborhood income around our sites ranged from \$27,069 to \$130,221 (median = \$69,497), while neighborhood race/ethnicity ranged from 4% to 86% of residents who identify as Latino (median = 21%), and 7% to 88% who identify as White (median = 68%). We also evaluated the potential relationship between the social covariates and park size, and found no correlation between the variables (Appendix S1: Figure S1). We evaluated collinearity between variables and used a threshold of $r < 0.7$ for inclusion into occupancy models (Goad et al., 2014; Millar & Fox, 2003).

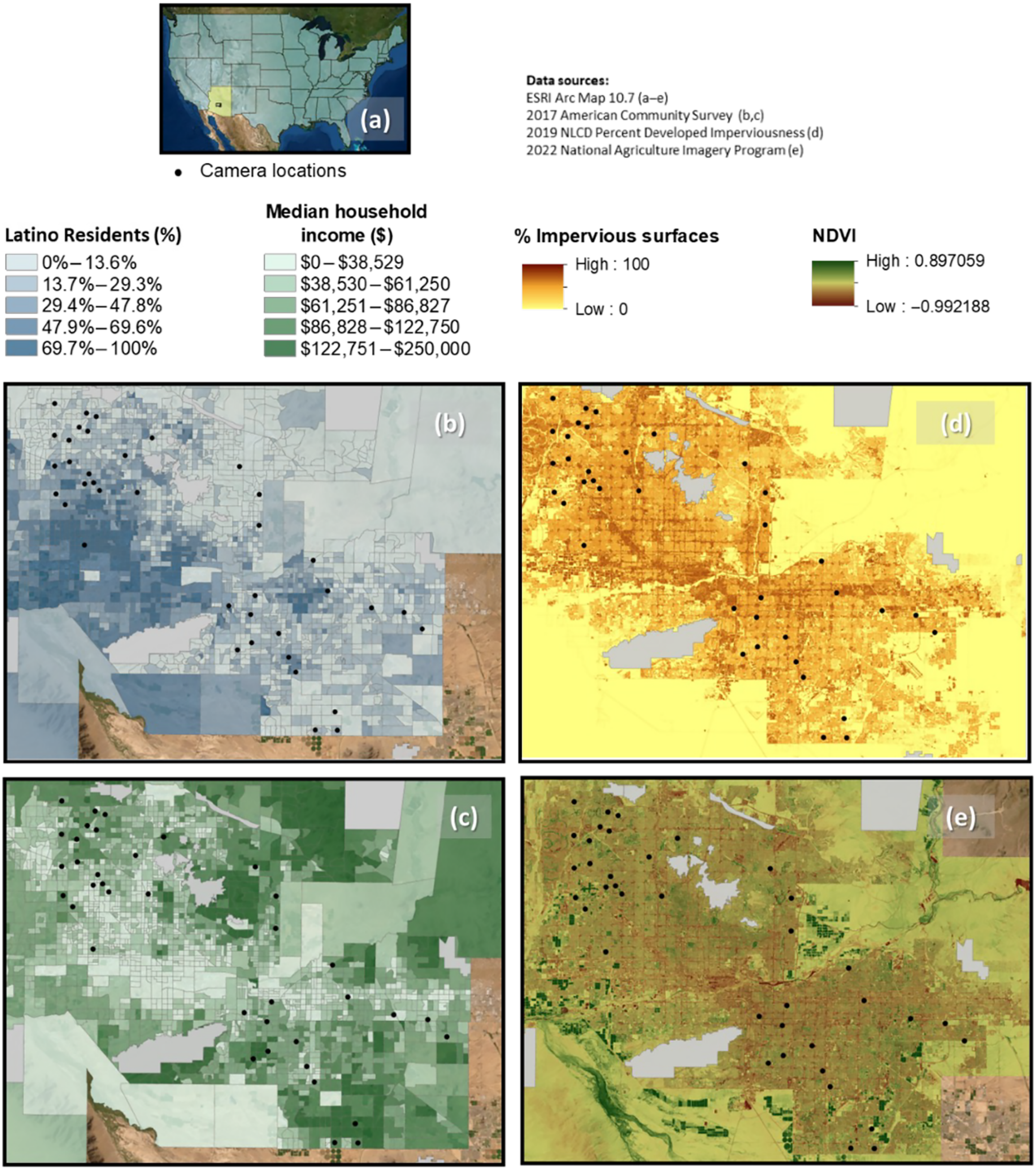

FIGURE 1 Map of sites used in this study, located within the (a) Central Arizona-Phoenix Long Term Ecological Research area (CAP LTER) in Maricopa County, AZ. Colors in panels (b, c) indicate sociodemographic data from census blocks, focusing on (b) the proportion of residents who identify as Latino and (c) median household income (American Community Survey, 2017; Brown et al., 2021). Circle symbols are camera locations. Panels (d, e) indicate the two environmental variables data, focusing on the (d) percentage of impervious surfaces and (e) the normalized difference vegetation index (NDVI) values. See Appendix S1: Figure S2 for an example of a camera location at a site.

Landscape covariates

We accounted for landscape features that are known to impact mammal distributions at geographic scales that encapsulate the varying land cover features surrounding the area of each site (McKinney, 2002). We estimated shrub and tree cover using NDVI, the extent of impervious surfaces, and the presence of or distance to a water feature (artificial or natural body of water, such as a pond, canal, or river). For NDVI and other impervious surfaces, we averaged continuous values at multiple buffer sizes around each site (125-, 250-, 500-, 750-, 1000-, 1500-, and 2000-m radii). We estimated mean impervious surface cover in ArcMap 10.7 with the National Land Cover "percent imperviousness" layer (Dewitz, 2021). We calculated NDVI utilizing the derived values from the CAP LTER NDVI layer (Sabu & Frazier, 2022) in ArcMap 10.7. We measured the closest distance to a water feature in Google Earth and determined the categorical presence of a water feature within multiple buffer zones (the same-sized buffer zones as impervious and NDVI) around each site using Google Earth.

To select the best scale of landscape covariates for the models, we evaluated the most supported buffer size for each species by comparing univariate occupancy models for each species and each covariate at different buffer sizes using Akaike information criteria corrected for small sample size (AIC_c) (Anderson & Burnham, 2002). We took a similar approach to determine the most supported measure of water availability (categorical presence vs distance to water). These analyses showed the strongest support for the categorical presence/absence of water features for all species, and one buffer size per covariate per species (Appendix S1: Tables S1–S3). We evaluated collinearity between the continuous covariates using Pearson's correlation and retained variables with $r < 0.7$ (Goad et al., 2014; Millar & Fox, 2003).

Occupancy modeling

Over a single season in the hot summer months of the Sonoran Desert (mean maximum temperatures for each month >37.8°C [>100°F], mean minimum temperatures for each month >25.6°C [>78°F]), we conducted single-species, single-season occupancy models on three mammal species that were commonly detected at our sites, including two native Sonoran Desert species (coyote and desert cottontail rabbit) and one non-native domestic species (domestic cat) (US Department of Commerce, NOAA, 2023). We estimated occupancy probability (psi) and detection probability (p) based on their association with social covariates (average neighborhood income and percentage Latino) and landscape covariates (percentage of impervious surface, NDVI, and water; MacKenzie et al., 2018). We evaluated detection (1) and non-detection (0) data for the metro Phoenix summer months (June 3–September 30) with ten 12-day occasions (MacKenzie et al., 2018; Sollmann, 2018). Occupancy analyses were executed in program R version 4.1.3 (R Core Development Team, 2013) using the "RMark" package (Laake & Rexstad, 2022) using program MARK (Laake & Rexstad, 2022). To determine whether detection probability was influenced by detection-related covariates, we evaluated the time-varying option in RMark (detection probabilities across occasions), effort days (number of sample days per camera), the intercept-only (dot) model, and all combinations of these covariates using AIC_c model selection. Of these, the dot model was most supported (lowest AIC_c) for detection probability of all species (Appendix S1: Table S4) and models within 2 ΔAIC_c of the dot model had beta estimates with CIs that overlapped zero. Thus, the dot model for detection probability was used in all subsequent model runs for occupancy. All continuous covariate values were standardized by subtracting the mean value and dividing by the SD (Schielzeth, 2010). We ran all possible combinations of the social and landscape covariate combinations on psi, resulting in 32 models per species. We interpreted the lowest AIC_c model per species to be the most supported and considered models to be informative if they performed better than the dot model and resulted in a ΔAIC_c value <2 (Burnham & Anderson, 2004; Lewis et al., 2021). Additionally, to provide further insight on each covariate's relationship to species occupancy, we calculated the variable importance values (VIV) by summing the Akaike weights for each covariate across all models (Anderson, 2008). We considered variables as having a relationship with occupancy if the 95% or 90% CI did not overlap 0.

Daily activity patterns

We evaluated how daily activity patterns of coyotes, desert cottontail rabbits, and domestic cats overlapped between categories of income and ethnicity. We divided neighborhoods by their 1-km averaged median household income ("higher income" vs. "lower income") and percentage of Latino residents ("higher Latino" vs. "lower Latino"; Appendix S1: Table S5). We used the package "overlap" in R to calculate the coefficient of activity overlap (0 = no overlap; 1 = total overlap) and 95% CIs (Ridout & Linkie, 2009). We optimized the coefficient estimate and CIs by using 10,000 bootstrap simulations and created overlap density plots using the von Mises kernel approach for circular data that correspond to the time of day (Ridout & Linkie, 2009). We followed small sample recommendations when there were less than 50 detections in either category (Ridout & Linkie, 2009). To ensure independent animal detections, we only included photos that were greater than 30 min apart (Sollmann, 2018). Each of the species evaluated had at least 20 detections and at least five sites in each income or ethnicity category, and visual inspection of results indicated sufficient sample sizes to estimate activity patterns (Lewis et al., 2021). We concluded that the daily activity patterns of a species shifted in the higher-versus-lower income or the higher-versus-lower percentage Latino neighborhoods if the upper limit of the 95% CI of overlap was <0.90 (Lewis et al., 2021).

RESULTS

Occupancy of wildlife and domestic animals across neighborhoods

We detected 28 species in total across all animal taxa and 13 mammal species from 49,360 photos over 122 sample days across our 38 camera sites from June to September (Cocroft & Hall, 2022; Lewis & Haight, 2022). The dataset for our target species included 208, 2744, and 2549 detections of coyotes, desert cottontail rabbits, and domestic cats, respectively. Occupancy and detection probability for the three focal species ranged from 0.21 to 0.71 and 0.34 to 0.74, respectively (Table 1).

The significance and direction of the variables varied for each species evaluated. Along with landscape covariates, both median household income and percentage of Latino residents in neighborhoods surrounding our sites were negatively and significantly associated with the occupancy probability of coyotes (Table 2). The percentage of Latino residents appeared in coyote and cottontail top models and were negative and significant (Figure 2; Appendix S1: Tables S6 and S7). For domestic cats, neither of the social covariates appeared in the top model (Appendix S1: Table S8). For coyotes, there was a positive significant relationship with NDVI and occupancy (but not the other variables). For cottontail rabbits, there was a positive significant relationship with water. For cats, there was a positive significant relationship with percentage of impervious surface, NDVI, and water. In the lower ranked models (Akaike weight <0.06), the sign of the beta estimates switched in models for income and NDVI depending on the presence of other covariates, suggesting that collinearity may be present for these two variables (although below our threshold of $r < 0.7$) (Appendix S1: Tables S6–S8). Specifically, in the lower ranked models for coyote and desert cottontails (two of 32 models, Akaike weight ≤0.03) and domestic cats (three of 32 models, Akaike weight ≤0.06) the sign of the beta estimate for income switched from negative to positive depending on whether percentage of Latino residents was included. NDVI switched from positive to negative for domestic cats in three of 32 models when associated with other variables (Latino, water, income; Appendix S1: Table S7c).

TABLE 1 Number of detections, occupancy (psi), and detection probabilities (p) and CIs of the intercept-only (dot models) for three mammal species across the 38 sites in metro Phoenix, Arizona, USA, from June to September 2019 and 2021.

			Psi		p	
Species	No. detections	No. sites ($n = 38$)	Estimate	95% CI	Estimate	95% CI
Coyote	208	19	0.51	(0.35, 0.67)	0.34	(0.28, 0.42)
Desert cottontail rabbit	2744	9	0.21	(0.11, 0.37)	0.74	(0.62, 0.82)
Domestic cat	2549	29	0.71	(0.55, 0.83)	0.69	(0.63, 0.74)

Note: Estimates reported are the real estimates of occupancy and detection probabilities.

TABLE 2 Summary of occupancy probability beta estimate direction and significance for each species.

	Occupancy beta				
Species	Income	Latino	Impervious	NDVI	Water
Coyote	−**	−**	−**	+**	NS
Cottontail	NS	−**	NS	NS	+*
Cat	NS	NS	+**	+*	+*

Note: The direction of the beta estimate relationship is represented by + (positive) or − (negative) for models that were most supported. Beta estimates that were significant in many of the models at the 95% and 90% intervals are denoted by **. Beta estimates that were significant at the 90% CI are denoted by *. Beta estimates that were not significant at the 95% or 90% CI are denoted by NS.

Abbreviation: NDVI, normalized difference vegetation index.

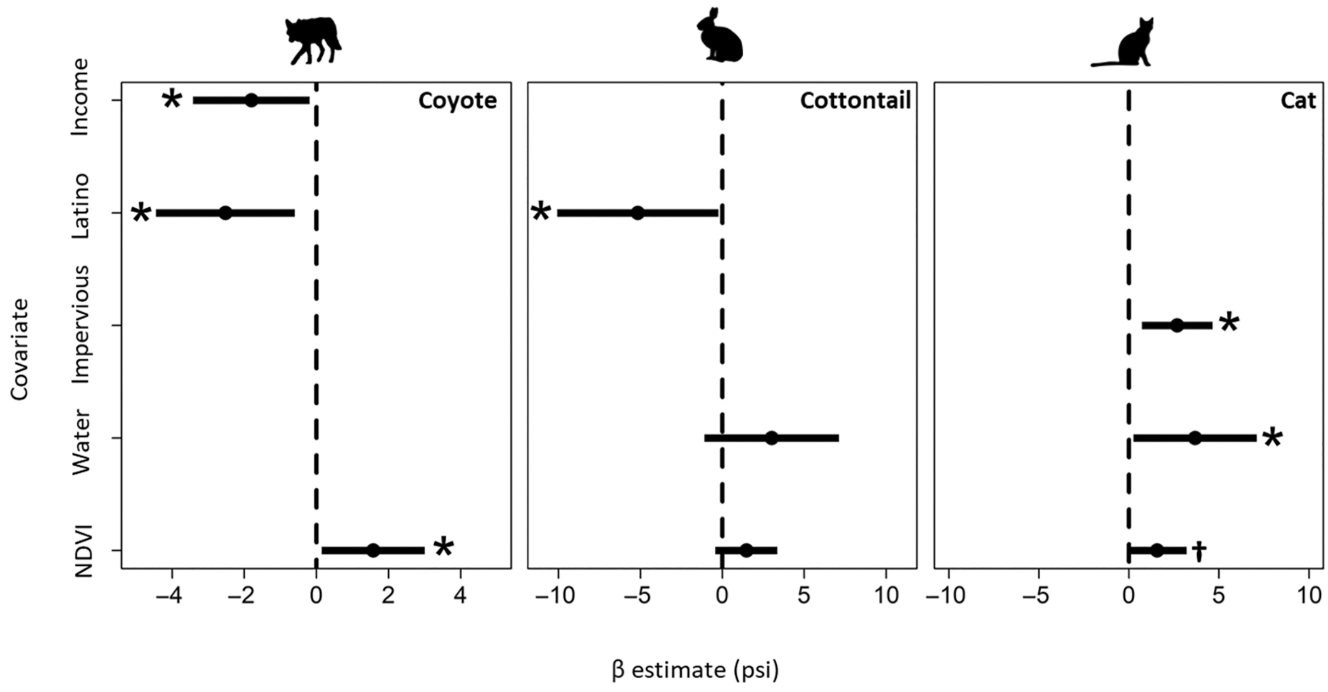

FIGURE 2 Beta estimates and 95% CIs for the top model (lowest corrected Akaike information criterion) for coyotes, desert cottontail rabbits, and domestic cats in this study in the metro Phoenix area. Asterisks (*) denote that the 95% CI of the estimate does not overlap zero. A dagger (†) indicates that the 90% confidence level does not overlap 0. NDVI, normalized difference vegetation index.

VIV showed that ethnicity was more important for coyotes and cottontails, and less so for cats. Combining the weights of all models, neighborhood ethnicity was more important (VIV) than landscape variables or income for occupancy of native mammals. For domestic cats, ethnicity was a more important covariate than income, but both social variables were less strongly associated with cat distribution than amount of impervious surface in neighborhoods (VIV = 0.95; Figure 3).

Daily activity patterns in neighborhood categories

Daily activity patterns shifted for coyotes, but not for the other species. Daily activity patterns of coyotes shifted between neighborhoods with higher and lower proportions of Latino residents (Figure 4). In the higher Latino neighborhoods, coyotes started their activity later in the evening and remained more active into the early morning than in lower Latino neighborhoods (overlap estimate of 0.72 and a 95% CI of 0.55–0.88; Figure 4; Appendix S1: Table S9). In contrast, the temporal activity patterns of coyotes and domestic cats were not influenced by neighborhood income (Figure 4). Desert cottontail rabbits were detected too infrequently across sites in lower income or higher Latino neighborhoods to be modeled (Appendix S1: Table S9). Daily activity patterns of domestic cats did not appear to vary with neighborhood income or ethnicity (overlap estimate of 0.87 [±0.81 to 0.92 95% CI] and 0.89 [±0.84 to 0.95 95% CI], respectively; Figure 4; Appendix S1: Table S9).

DISCUSSION

By integrating a broader set of social variables into ecological models beyond income, our study provides insights into key patterns that shape biodiversity across diverse neighborhoods (Des Roches et al., 2021; Wilson, 2023). We found evidence that neighborhood ethnicity was negatively related to occupancy probability of native mammals. Income was informative for coyotes but was less supported than the % Latino covariate. Furthermore, we found inverse associations between income and occupancy for the three species in this study. But the CIs for income and occupancy overlapped zero for two of the three species, indicating little confidence in the relationships. This adds nuance to the luxury effect described in previous studies (e.g., neighborhood wealth is positively associated with mammal species richness; Magle et al., 2021) as individual species relationships to wealth may vary from relationships with species richness. Our study adds evidence to the growing call to include additional social variables into social-ecological research, as well as an acknowledgment of the influence of negative

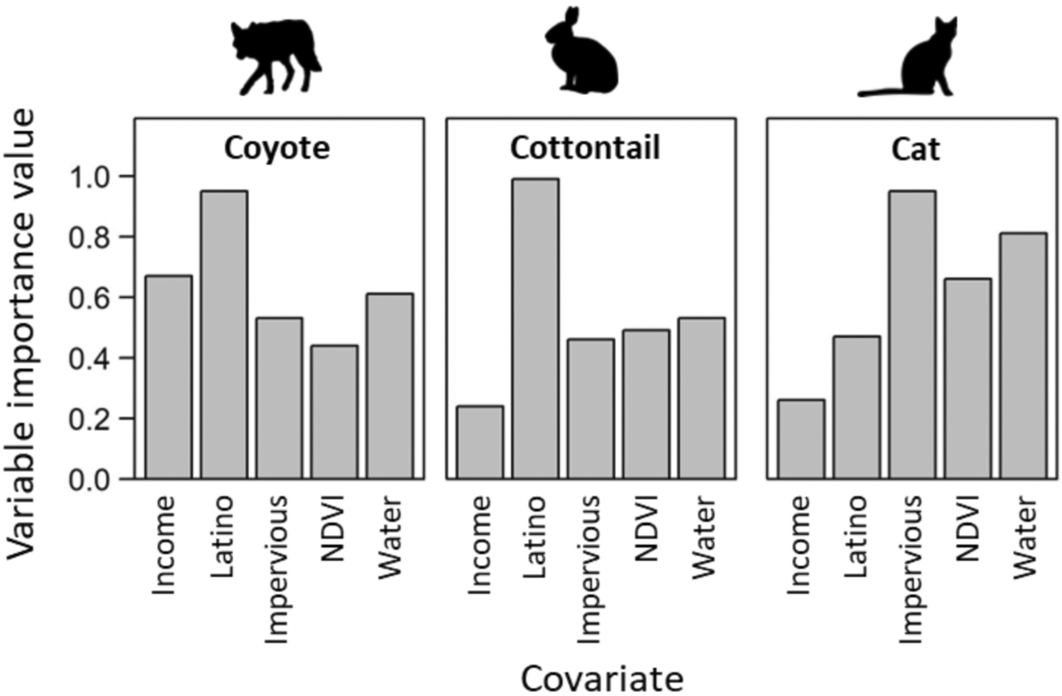

FIGURE 3 Variable importance values for native species (coyote and desert cottontail rabbit) and non-native domestic cat in the metro Phoenix area. NDVI, normalized difference vegetation index.

human histories (e.g., segregation, environmental injustices) on landscape patterns (Gadsden, 2022; Gadsden et al., 2023).

Consistent with our predictions, occupancy of native mammals (coyotes and cottontail rabbits) was inversely associated with the proportion of Latino residents in neighborhoods. However, the underlying drivers of these associations are unclear. Because the demographics of residents within neighborhoods can shift more quickly than ecological or built infrastructure, associations between current race/ethnicity and historic environmental patterns are unclear. That said, redlining and discriminatory housing practices were prevalent in the metro Phoenix area in the 1930s, leading to racial segregation and environmental inequities in Phoenix's early development (Bolin et al., 2005). Latino and Black residents of the metro Phoenix area were the most affected groups by racist housing practices such as unregulated land construction in minority neighborhoods (Bolin et al., 2005). Additionally, many Mexican residents faced discrimination and exclusion in many economic sectors (Bolin et al., 2005). These practices resulted in fragmented land uses and zones of disamenities in lower income and minoritized neighborhoods, primarily in South Phoenix (e.g., Tessum et al., 2019; Wen et al., 2013; York et al., 2014) that may be associated with wildlife habitat quality. For example, minoritized neighborhoods can have less tree cover and ecosystem service provisioning, and are more susceptible to the urban heat island effect (Dialesandro et al., 2021; Grove et al., 2014; Hsu et al., 2021), which may influence the presence of, or habitat use, by wildlife. A recent study has even identified direct relationships between birds and redlined boundaries in Los Angeles. Specifically, populations of birds that are associated with dense urban features were more prominently common in Latino neighborhoods (Wood et al., 2023).

Another possible driver of the wildlife–ethnicity association may be related to decisions or activity at the residential parcel or neighborhood levels (Arreola, 2012; Grove et al., 2006; Larson, Casagrande, et al., 2009). The presence of vegetative cover or particular plant species in private yards may influence mammal activity as it can provide habitat connectivity, food resources, or protection (Grade et al., 2022; Van Helden et al., 2020). Free-roaming wildlife may be influenced by movement access such as fences or gates, the presence of anthropogenic food sources, or the presence and timing of people in parks (Lewis et al., 2021; Murray & St. Clair, 2017). Additionally, wildlife movement may be influenced by interactions with domestic species such as free-roaming or outdoor domestic dogs (Hansen et al., 2020; Kays, 2014), which may themselves be related to cultural or historical practices within neighborhoods. Neighborhood-scale decisions that impact wildlife habitat are also likely impacting the habitat for mammal species.

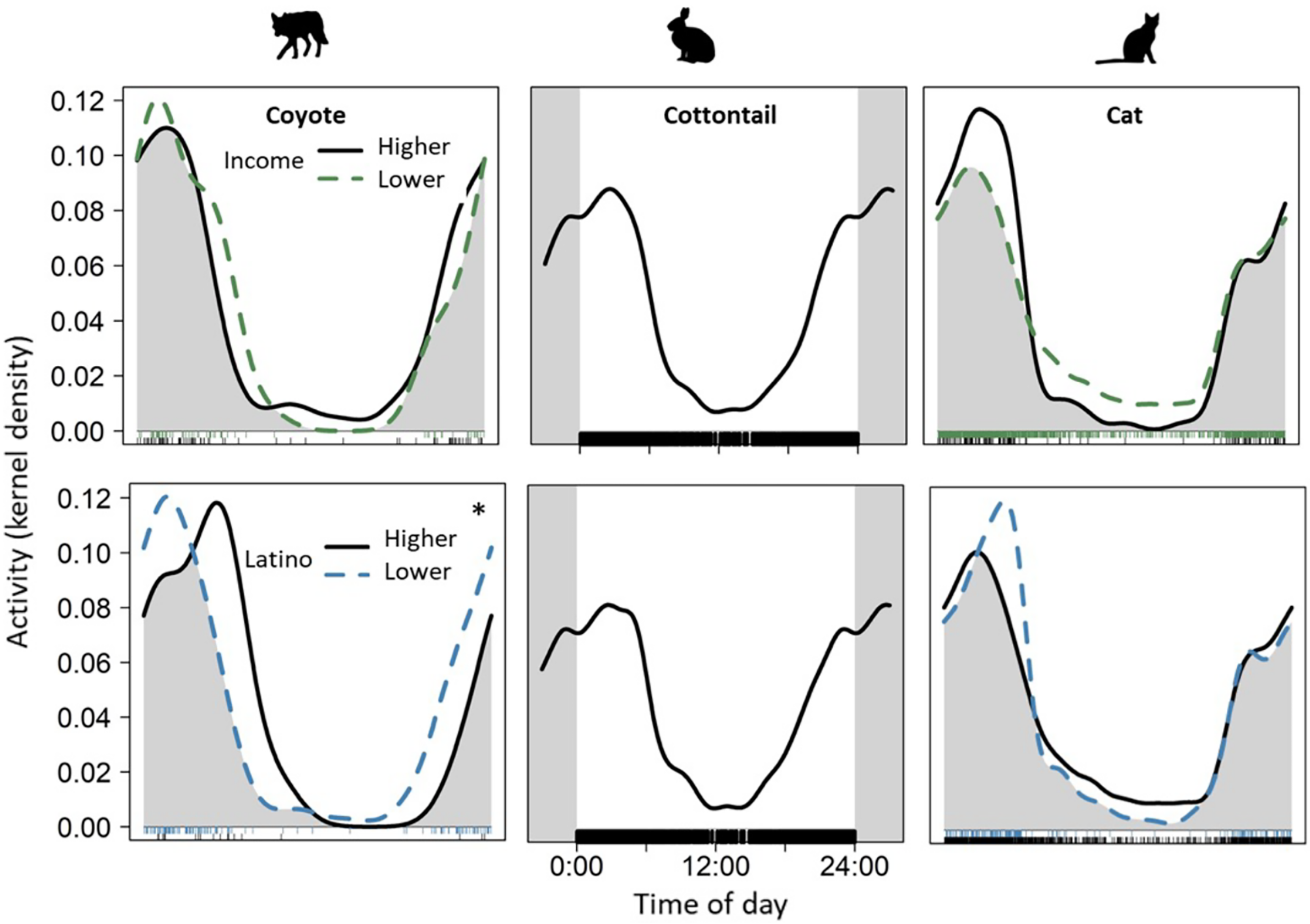

FIGURE 4 Daily activity patterns of coyotes, desert cottontail rabbits, and domestic cats across categories neighborhood income and neighborhood proportion of Latino residents within the metro Phoenix area. Solid lines are activity in higher income or higher Latino neighborhoods, and dotted lines are activity in lower income or lower Latino neighborhoods. An asterisk (*) in the upper right corner of the panel denotes that daily activity was shifted in lower versus higher income/ethnicity categories (upper 95% CI < 0.90).

Neighborhood homeowner associations (HOAs), and the potential cultures and costs associated with those institutions, can control aspects of residential landscapes and pest control, which may influence the presence of coyotes and rabbits (Hadidian, 2015; Lerman et al., 2012). For example, neighborhoods in metro Phoenix with HOAs have more diverse native bird and plant species than non-HOA neighborhoods (Lerman et al., 2012). Further, some residents are inclined to value and steward wildlife populations, while other residents are indifferent to wildlife (Larson et al., 2023), highlighting the variable views of wildlife by residents within the metro Phoenix area specifically.

Consistent with previous studies, NDVI was an important covariate for occupancy of the mammals studied, as NDVI is associated with the presence of cover and resources (McCleery, 2010; McKinney, 2002). NDVI was positively associated with occupancy for all species, but the CIs overlapped zero for cottontails. Coyotes commonly utilize moderately dense neighborhoods, but they avoid spaces with high levels of impervious surfaces and instead, use corridors such as washes and small patches of open space within their large home ranges (Atwood et al., 2004; Gehrt et al., 2009; Gese et al., 2012). Domestic cats are likely utilizing the open spaces within neighborhoods when allowed to freely range.

Domestic cats are widespread across the globe and are facilitated by humans in urban and urbanizing areas where they devastate native species populations. Free-roaming cat populations prey upon billions of mammals and birds each year (Elizondo & Loss, 2016; Loss et al., 2013, 2022), which has contributed to the extinction of native species (McGregor et al., 2020; Molsher et al., 1999). Domestic cats also impact wildlife communities through injury, disease transmission, and indirectly create an "ecology of fear" in other species such as lagomorphs (Elizondo & Loss, 2016; Loss et al., 2013; Loyd et al., 2017). In our study, domestic cats were common across the metro Phoenix area, and the neighborhood percentage of Latino residents was positively related to cat occupancy, but CIs overlapped zero and thus weakening our confidence in the relationship. Some research suggests that ownership and ownership practices are associated with ethnicity (Faver & Cavazos, 2008; Schoenfeld-Tacher et al., 2010). Contrary to our results, people who identify as White are more likely to own a pet, while Latino residents are less likely to have cats (Risley-Curtiss et al., 2006). Preliminary findings from the metro Phoenix area suggest that residents who are Latino are more likely to own a dog than a cat; and if they have a pet, they report that their pet spends more time outside than White residents (unpublished Phoenix Area Social Survey; Larson & Andrade, 2017). The ability to confirm free-ranging cat ownership is beyond the scope of this study, but it is also likely that many of the cats we detected were feral.

Like the significant relationship between neighborhood ethnicity and native mammal occupancy, activity pattern analyses showed shifts in coyote daily activity between neighborhoods that include a higher and lower proportion of Latino residents. Mammals often change their daily activity patterns in human-disturbed environments (Gallo et al., 2022; Lewis et al., 2021; Łopucki & Kiersztyn, 2020). Numerous ecological factors influence daily activity of species, but in human-dominated landscapes, species can exhibit increased nocturnality to avoid conflict (Gaynor et al., 2018; Suraci et al., 2019). For example, coyotes decrease crepuscular activity to avoid humans, and in urbanized areas they often have larger home ranges to do so (Gese et al., 2012). Also, because coyotes will exploit human food sources in neighborhoods (Murray & St. Clair, 2017), the time of day these food sources are available may lead to modification in coyote daily activities (Fedriani et al., 2001; Hansen et al., 2020; Kays, 2014). Although not measured in this study, wild mammals will also avoid fenced yards with dogs (Kays, 2014), and the time-of-day that pets are outside may be influencing the activity of coyotes as well.

While we found strong evidence between mammal occupancy and neighborhood social variables, study design limitations suggest numerous directions for future research. We did not estimate the importance of species interactions in our findings, although we captured photos of gray fox (*Urocyon cinereoargenteus*), racoons (*Procyon lotor*), javelinas (*Pecari tajacu*), bobcats (*Lynx rufus*), several species of squirrels (*Sciuridae* ssp.), and ground-dwelling birds in addition to our three targeted species. We did not have enough data to conduct occupancy analyses on the non-targeted mammal species. Although beyond the focus of this study, future research could evaluate interactions among coyote, cats, and cottontails, as other studies have found that cat abundance is higher in residential yards that do not have coyotes, and domestic cats can prey on lagomorph species (Kays et al., 2015; McGregor et al., 2020; Paul & Friend, 2020). Additionally, other research has found that mesopredators do not change temporal or spatial activity in response to predators like coyotes when humans are present, indicating that humans play a "predator"-like role in urban systems similar to our study area (Moura et al., 2022). We placed our cameras in locations to avoid human detections, but we captured photos of people at all locations. Activity patterns of people within our sites could influence animal activity and could be evaluated in future studies (Gámez & Harris, 2021; Li et al., 2020). Additional environmental variables that we did not measure may also influence animal occupancy and activity patterns, such as habitat-connecting corridors like washes (Beier & Noss, 1998). We evaluated occupancy and activity only in the metro Phoenix warm season (June–September), but future studies could analyze data across multiple seasons to evaluate temporal variability in our findings. Our study design focused on including landscape variables already known to impact mammal distribution. This allowed us to determine whether ethnicity was as good, or a better, predictor of mammal distribution than other variables. Future studies could include variables related to the parks and study area that have less clear connections with mammal distributions, like the park's size, open spaces, presence of built features (like sports facilities), and characteristics of private yards of residents within neighborhoods that may influence wildlife patterns. For example, Latino residents often use their yards as cultural landscapes to enhance the aesthetics and cultural expression within neighborhoods (Arreola, 2012). Finally, life experiences or cultural norms of residents may influence the use of open spaces in neighborhoods; recursively, open spaces and the presence of wildlife may influence residents' experiences related to nature-connectedness or nature's value (Soga & Gaston, 2016). Future research about the use and quality of neighborhood open spaces across diverse neighborhoods, and their influence on wildlife perceptions, could better inform the underlying drivers of neighborhood ethnicity–wildlife correlations.

This study provides a novel insight into the drivers of social-ecological system dynamics within a major metropolitan area. Our results provide support that neighborhood ethnicity was negatively related to the occupancy of two native species, which furthers the notion that ecological patterns in cities may be influenced by variables beyond measurements of wealth (Schmidt & Garroway, 2022). The United States is becoming more ethnically diverse (Frey, 2021b) at the same time that rapid environmental change is threatening the local livelihoods of both people and native wildlife (United Nations, 2018).

Discerning patterns that link social and cultural factors with wildlife distributions will become increasingly important to improve human connections to nature (Miriti et al., 2023; Soga & Gaston, 2016; Wilson, 2023). Future investigations of the mechanisms of biodiversity patterns associated with race/ethnicity independent of income would advance our understanding of the complex social-ecological feedback of systemic social forces like racism and classism on the well-being of people and nature.

AUTHOR CONTRIBUTIONS

Alexandreana Cocroft and Sharon J. Hall conceived the project and led the manuscript writing with editorial contributions from the other authors. Jeffrey Clark, Alexandreana Cocroft, Sharon J. Hall, and Jesse S. Lewis led the experimental design and methods development. Jeffrey Haight and Zachary Snyder helped with the data and occupancy modeling analyses, and both Susannah B. Lerman and Jeffrey Clark guided project conceptualization. Data collection in 2019 was led by Jesse S. Lewis and Jeffrey Haight.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data (Cocroft & Hall, 2022; Lewis & Haight, 2022) are available from the Environmental Data Initiative's Data Portal: https://doi.org/10.6073/pasta/14de8990cfad18c5b0f89a9c895d0f09, https://doi.org/10.6073/pasta/40583b26b0eb0947b3e5c581dadad00e.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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