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Legacy effects of housing segregation on urban mammal communities in Washington, D.C., USA

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Abstract

Racist public policies in the US, like redlining, segregated many communities of color to resource poor and impoverished areas, and codified how resources were distributed to communities based on race. Redlining, a historic discriminatory housing policy used to value city neighborhoods by race has codified segregation in cities today. Research has shown how the practice of redlining has shaped the economic and social fabric of modern U.S. cities, but only recently have researchers explored how these discriminatory policies have influenced the ecology in cities. Here, we used camera trap data collected in the Washington, D.C. region to assess if historic redlining impacts medium-sized mammal diversity in present day. We found no significant difference in species richness or community composition among historic neighborhood classifications. We did find that urbanization alone had a significant negative correlation with the persistence of raccoon and occupancy of Virginia opossum, but these variables did not vary significantly between housing classifications for any species. Our study adds to a growing body of knowledge on how historic land use decisions affect biodiversity in cities, allowing managers to better understand where conservation and habitat improvements should be made to reduce nature inequalities.

Keywords Urban wildlife · Redlining · Social justice · Environmental justice · Urban ecosystem

Introduction

Historically, structural racism has shaped the economic, social, and ecological functions of cities in the United States (Rothstein 2017; Schell et al. 2020). The locations of where human communities have formed in U.S. cities has been decided by discriminatory land use and housing policies enacted at the federal, state, and private levels (Markley 2024). These decisions outlined through a mapping practice informally known as "redlining," codified the segregation of communities of color to resource impoverished areas (Rothstein 2017). Despite housing segregation being outlawed by the Fair Housing Act in 1968, the practice of redlining caused long-term segregation, creating a significant lack of generational wealth accumulation in communities of color resulting in social, environmental, and economic disparities that continue in cities today (Appel and Nickerson 2016). Residents of these historically redlined (segregated) neighborhoods are less likely to be college educated, have lower incomes, less access to health care, shorter overall lifespans and are at higher risk of violent crimes compared to other neighborhoods that were not redlined (Chandler 2020). Recent evidence has also found that redlined communities have less access to nature (Kephart 2022).

The Home Owners' Loan Corporation (HOLC) was established by the United States (U.S.) government and the Federal Housing Administration (FHA) in 1933 to assist struggling Americans during the Great Depression by offering low interest housing loans (Hillier 2003; Rothstein 2017). To create criteria for low interest lending, the HOLC and FHA each created neighborhood ranking maps for large U.S. Cities (Hillier 2005). While HOLC did not directly conduct lending using their maps, their maps influenced similar efforts to assess property values in cities like Washington, D.C. by the FHA (Woods 2012; Markley 2024). Mapping by both entities used color coding to value neighborhood investment risk based on racial make-up of each neighborhood. HOLC maps were color coded with red ("Hazardous") and green ("Best"). Red, known as redlined,

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neighborhoods represented area of cities that were considered unsafe to invest in and were often majority Black and non-U.S. citizens. Green neighborhoods were considered the safest neighborhoods for investments and were predominantly affluent white communities (Crossney and Bartelt 2005). Similarly, the FHA maps categorized neighborhoods A-H, with categories A-D being primarily white neighborhoods and E-H communities of color or immigrants (Markley 2024). While these valuation efforts did not create segregation – they mapped existing segregation – these maps codified the practice of valuing neighborhoods primarily based on class and race (Massey and Kanaiaupuni 1993). FHA valuation and lending, specifically, contributed to the displacement and segregation of thousands of people by ensuring that in Washington D.C., 98% of housing loans went to white borrowers from 1934 to 1962 (Blank et al. 2005; Jackson 1980). These decisions supported the accumulation of property and wealth by white families, and has shaped the neighborhood makeup, wealth distribution, environment, and, perhaps, the ecology of Washington D.C. (Blank et al. 2005; Rothstein 2017).

Urban segregation and redlining has been heavily studied in regard to economics (Mentias et al. 2023; Aaronson et al. 2021) and social vulnerability (Noelke et al. 2022; Lynch et al. 2021), but only recently has research began to explore the connection between historic redlining and the environment (Estien et al. 2023, 2024; Locke et al. 2021). The luxury-effect hypothesis states that more affluent areas tend to have more green spaces and higher vegetation diversity; thus, more wildlife habitat (Hope et al. 2003; Schell et al. 2020), and connections between the luxury effect theory and housing segregation have been made by researchers (Hoffman et al. 2020; Wood and Esaian 2020; Schell et al. 2020). For example, Locke et al. (2021) found that tree canopy, an important asset to cities as trees help abate the urban heat island effect, was significantly lower in historic redlined neighborhoods (23%) compared to wealthy neighborhoods (43%). Hoffman et al. (2020) found that of 108 historically redlined cities, neighborhoods with the lowest ranking grades were up to five degrees hotter on average than historically wealthy neighborhoods, and subject to higher heat extremes during warm seasons. Additionally, the environmental trajectories created by historic city design have also affected urban biodiversity (Herrera et al. 2024). In Los Angeles, California (USA), a higher diversity and abundance of forest dwelling birds was found in neighborhoods historically categorized as "Best" by HOLC (Wood et al. 2024). Whereas redlined areas were dominated by birds with generalist habitat requirements, due to higher urbanization (e.g., impervious surface) and a less green space (Wood et al. 2024). Ellis-Soto et al. (2023) also found that historic records of bird species were lower in redlined neighborhoods across 195 U.S. cities. These recent studies support the notion that redlined communities have lower biodiversity and thus less access to nature.

Here, we studied the legacy effects of redlining on mammalian species in the Washington, D.C. metropolitan region. Using field collected wildlife observations and historical FHA maps our objective was to assess whether there was a difference in mammalian species richness and community composition between historically redlined neighborhoods and non-redlined neighborhoods. Following, the luxury-effect hypothesis we hypothesized that species richness (a-diversity; Whittaker 1972) and habitat use (occupancy) of mammals would be lower in redlined communities compared to non-redlined communities. Due to potential differences in habitat availability, we also hypothesized that community composition (b-diversity; Whittaker 1972) would be different among neighborhood classification (Wood et al. 2024; Honda et al. 2018). Understanding the lasting effects of urban planning decisions can inform modern day planning and enhance justice-centered management by identifying and prioritizing restoration needs in areas that have been historically marginalized.

Methods

Study area

Our study took place within the Washington, D.C. metropolitan region, which includes Washington D.C., Prince George's, and Montgomery Counties, in the state of Maryland, and the City of Alexandria, Arlington County, and Fairfax County, in the state of Virginia (Fig. 1). Washington, D.C. is the sixth largest metropolitan area by population density within the U.S. (Smega et al. 2020). Washington, D.C. maintains segregated neighborhoods as a byproduct of the assignment of historic racial covenants and neighborhood grading by the FHA starting in the 1930s (Chandler 2020). 67% of neighborhoods are still considered racially segregated as of 2017, including most Black neighborhoods located east and northeast of the Anacostia River, and white dominant neighborhoods in Northwest D.C. spanning into Montgomery County, Maryland (Chandler 2020).

Ecologically, the climate in the Washington D.C. region experiences all four seasons, and averages 1120 mm of precipitation annually (NOAA, 2022). The Washington D.C. region contains a geological fall line, separating the city and surrounding lands into two distinct ecoregions, the Appalachian Piedmont region to the west, and the Mid-Atlantic coastal plain to the east (District of Columbia Department of Energy and Environment, 2015). This geological split diversifies the regions habitats including woody wetlands,

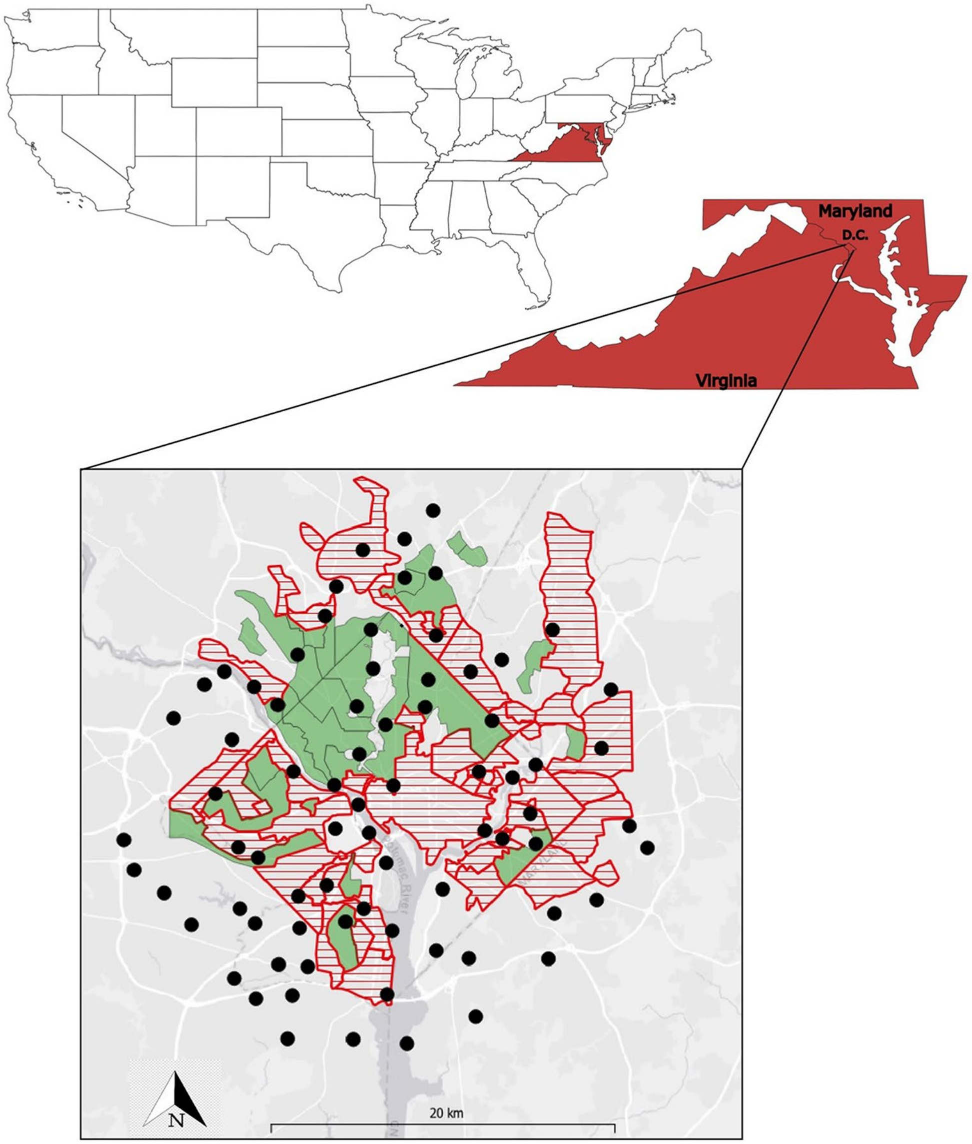

Fig. 1 A map of seventy-five sampling sites (black dots) located in red (red hatched polygon), green (green polygon), and unclassified neighborhoods used to study mammal richness, diversity, and habitat use in the Washington, D.C. region, USA

coastal plain swamps, upland floodplain forests, ruderal grasslands, and open riverine habitats (District of Columbia Department of Energy and Environment, 2015). Our study area lies in the ancestral homeland of the Nacochtank (also called Anacostan) and Piscataway people (Tayac 2009).

Wildlife data collection

We overlaid an initial 24×24-km spatial grid of 163 points on our study area where each point was 2 km apart. To identify sampling sites, we randomly chose 75 points from this initial grid, and the nearest greenspace to each selected point was identified as a sampling location (Fig. 1). Greenspaces were chosen from a comprehensive list of federal, state, and municipal lands, public and private golf courses, and public and private cemeteries. The final list of study sites included public parks ($n = 69$), private golf courses ($n = 3$), and cemeteries ($n = 3$). All public parks within our study area are used daily by people and many include or are adjacent to playgrounds, parking lots, biking trails, public restrooms, and athletic recreation areas. Sampling sites were established within each greenspace at a location that maximized detection probability of wildlife species (e.g., heavily vegetated areas, animal trails, gravel roads, fence lines, etc.).

We deployed one unbaited remotely triggered trail camera at each site for approximately 30 days, four times per year (January, April, July, and October) from January 2021-February 2023. Cameras were active an average of 29.4 days per season. Three models of trail camera were used: Reconyx Hyperfire 2 (Reconyx, Holmen, WI, USA), Bushnell Trophy Cam HD Aggressor, and Bushnell Trophy Cam HD (Bushnell Corporation, Overland Park, KS, USA). We placed cameras on trees approximately 1.5 m from the ground using nylon straps. We deployed cameras at the same location each sampling season. We selected camera locations at each site in a location that maximized detection probability of wildlife species (e.g., heavily vegetated areas, animal trails, gravel roads, fence lines, etc.). We set cameras to take one photo every trigger with a 15 s rest period between triggers. Photos were uploaded to the Urban Wildlife Information Network online database (Magle et al. 2019) and animals in photos were identified by trained individuals to the lowest taxonomic level possible.

Neighborhood classifications

The FHA categorized Washington, D.C.'s neighborhoods as A-H with A being the best neighborhoods to invest in and H considered areas to avoid investments (Weimer 1937; Table 1). We collapsed the FHA categorization into two categories for our analyses based on grade descriptions: we categorized E-H as "red" neighborhoods, A-D as "green" neighborhoods (Weimer 1937; Table 1), and ungraded areas as "unclassified".

Digital maps of the historic FHA maps for the Washington, D.C. region are provided by the Prologue DC and Mapping Segregation Washington, D.C. project (Prologue 2020). We divided our 75 sampling sites into "green" ($n=22$) or "red" ($n=20$) based on the FHA reclassification of the neighborhood in which each sampling site was located (Fig. 1). Camera sites that did not fall within an FHA categorized neighborhood are categorized as "U" or uncategorized ($n=33$). We used the uncategorized areas as a reference category, as these neighborhoods were not historically categorized due to low population density at the time (Swope et al. 2022). However, at the time of this study, uncategorized areas had high population densities and would be considered urban sections of the Washington, D.C. region.

Table 1 Neighborhood grade descriptions by the Federal Housing Administration, divisions of Economics and Statistic, created in 1937 to categorize loan and investment risk across the Washington, D.C. metropolitan region, USA. Categories A-D were considered minimal risk for investment due to being white residency areas, and categories E-H were considered highest risk for investment due to being occupied by black communities. Dollar amounts are in year 1936 dollars

Recategorized to "green"		Recategorized to "red"	
FHA Grade	Description	FHA Grade	Description
A	White Residency, Upper Class, High Income, Property value of \$15K+	E	Middle Class, mixed racial, lower income, property values at \$5K or less
B	White Residency, Upper Class, High Income, Property value of \$10K+	F	Black residency, residential homes declining to slums, low business investment areas
C	White Residency, Upper Middle Class, Property value of \$7K+	G	Black residency, poor streets, little resources, property values \$700
D	White Use, Transitional with some properties being converted from family homes to businesses	H	Areas meant for Black people only, no resources nearby, most homes equivalent to temporary shacks

Urban index

To control varying levels of urbanization, we calculated an index of urbanization by extracting mean percent canopy cover, mean percent impervious surface cover, and human population density within a 1-km buffer around each site. These three variables were chosen because tree cover and impervious cover represent the conversion of natural habitats to impervious surfaces (Grimm et al. 2008), and population density represents the inherent human characteristic of urban environments (Foley et al. 2005; Grimm et al. 2008). A 1-km fixed radius buffer was used because it exceeds the home range of most mammals used in this analysis except for coyote (*Canis latrans*) and red fox (*Vulpes vulpes*; Gehrt et al., 2010).

To calculate tree and impervious cover we used the Chesapeake Bay Conservancy 2017/2018 1-m resolution Land Cover data representing year 2017 and 2018 conditions (CBPO 2022; Pallai and Wesson 2017). To calculate tree cover, we calculated the proportion of each 1-km buffer that was covered in cells categorized as Tree Canopy. To calculate impervious cover, we calculated the proportion of each 1-km buffer that was covered in Impervious Structures, Other Impervious, Impervious Roads, Tree Canopy Over Impervious Structures, Tree Canopy Over Other Impervious, or Tree Canopy Over Impervious Road. To calculate population density, we extracted total population of the census block that overlapped the 1-km buffer from the 2020 U.S.Census (Census Bureau, 2020) using the tidycensus (Walker 2023) package in R. When a census block did not overlap a buffer completely, we used a crosswalk approach and divided the population data by the proportion of the respective census block that was within the spatial buffer (Goodchild et al. 1993). These analyses were done using the sf (Pebesma 2018) and terra (Hijmans et al. 2015) packages in R ver 4.1.2 (2022). We used a principal component analysis (PCA) to reduce the dimensionality of these three variables and used the first principal component as our index of urbanization. The first principal component accounted for 77.92% of data variation. PCA results indicated that negative values of the first principal component equate to a higher rate of urbanization (greater impervious surface and greater population density) and positive values equate to lower urbanization (higher percentage of tree canopy). For easier interpretations, we multiplied the first principal component by -1 so that higher values indicated higher urbanization, and lower values indicated less urbanization.

Multi-species occupancy model and derived diversity parameters

To estimate species richness while also accounting for imperfect detection we formulated a Bayesian multi-species dynamic occupancy model (Mackenzie et al., 2006; Dorazio et al. 2010). This model considers the detection probability of each species and helps account for species that may have been present but were completely undetected in our study period by using data augmentation (Royle et al. 2007). Dynamic occupancy models estimate initial occupancy (Ψ; the probability that a site is occupied in the first time period of sampling), colonization (g; the probability that a site is occupied in time period *t* given it was unoccupied in time period *t*-1), and persistence (r; the probability a site is occupied in time period *t* given it was previously occupied in time period *t*-1) as a function of covariates. Using our estimated latent state (that a site was occupied by each species) we were also able to derive a-diversity (site-level species richness) of medium-sized mammal species and b-diversity (community composition) between the different neighborhood housing grades using Jaccard's similarity index (Real and Vargas 1996). A Jaccard's index of one indicates mammal communities are the same, and an index of zero indicates no shared species at sites.

Model formulation and estimation

We kept the formulation of this model simple, for each species we included only the categorical variable of neighborhood classification and the site-level urban index on initial occupancy, colonization, and persistence. Posterior distributions of model parameters were estimated using a Markov chain Monte Carlo (MCMC) algorithm in JAGS with the package runjags in R ver. 4.3.1 (Denwood 2016; R Studio Team, 2022). Eight parallel chains were run from randomized starting values for 75,000 iterations with a thinning rate of 10. The first 25,000 iterations were discarded as burn in. Thus, we retained 50,000 samples. Model convergence was evaluated by checking that the Gelman-Rubin statistic for each parameter was < 1.1 (Gelman and Rubin 1992) and by visual inspection of all trace plots. We considered model parameters to be significant if the 95% credible intervals did not overlap 0.

Fig. 2 Histograms of median values of species richness across historic neighborhood grades in Washington, D.C. metropolitan region, USA from Jan 2021-Feb 2023. Bars represent the estimated frequency (y-axis) of observing the respective number of species across all sites and sampling seasons (x-axis)

Results

Between January 2021-February 2023, 198,700 photos of twenty mammal species, not including humans, were captured across nine sampling seasons. We included detection data for 10 species: coyote (*Canis latrans*), domestic cat (*Felis catus*), Eastern chipmunk (*Tamias striatus*), Eastern cottontail (*Sylvilagus floridanus*), Eastern gray squirrel (*Sciurus carolinensis*), raccoon (*Procyon lotor*), red fox (*Vulpes vulpes*), Virginia opossum (*Didelphis virginiana*), white-tailed deer (*Odocoileus virginianus*), and woodchuck (*Marmota monax*) in our model. We augmented our model with an additional 10 "hypothetical" species (Mackenzie et al., 2006; Dorazio et al. 2010) to account for species that we observed but did not have enough detections to include in our model.

Mammal Diversity and Habitat Use between Historic Neighborhood Grades.

We found no significant difference in a-diversity across neighborhood categories. Our model estimates that red and green neighborhoods are most likely to have one to two species present 15–20% of the time across all sites and sampling seasons, with a low probability of having all ten species present (5%) at a site during any given season. Uncategorized neighborhoods had an 18% chance of having one species present at a site during any given season, and an equally low chance (5%) of having more than one species present (Fig. 2).

Similarly, there was no significant difference in b-diversity between categorizations across the nine seasons of our sampling period. Jaccard's Similarity Indices between both unclassified neighborhoods and green neighborhoods and between redlined neighborhoods and green neighborhoods were > 0.5 indicating sites shared more than half the number of species (Fig. 3).

We also found similar mammal communities in the three categories. The top mammal community in historically redlined neighborhoods and uncategorized neighborhoods were white-tailed deer, red fox, and Virginia opossum. In

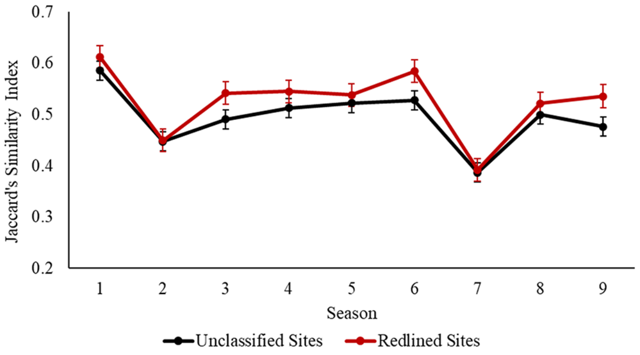

Fig. 3 Jaccard's similarity indices comparing the community composition of historically redlined sites to green sites and the community composition of unclassified sites to green neighborhoods in the Washington, D.C. metropolitan region, USA. Green neighborhoods are set to the reference category and are the assumed "background" of the graph. Data is from camera trap data across nine seasons, Jan 2021-Feb 2023. An index of one indicates mammal communities are the same, and an index of zero indicates no shares species at sites

green neighborhoods white-tailed deer, red fox, and woodchuck were the most common species across all seasons. Species-specific initial occupancy, colonization, and persistence did not differ between housing grades for any species (Fig. 4, Table S1).

Urbanization

Urbanization had a negative effect on the probability of initial occupancy of Virginia opossum (b = -0.53, 95% CI = -1.06 - -0.07; Fig. 5, Table S2) but did not have a significant association with initial occupancy of any other species. Urbanization also had a negative relationship with raccoon persistence (b = -0.59, 95% CI = -0.94 - -0.30; Fig. 5) but was not correlated with probability of persistence for any other species (Fig. 5, Table S2). We found correlation between urbanization and colonization probability of any species in our study.

Discussion

Urban ecology research is just beginning to explore the effects of historic urban planning decisions on wildlife communities. Here, we assessed mammalian richness, community composition, and habitat use across neighborhoods once valued by the U.S. Federal Housing Administration based on race and class to understand if the racist practice of redlining, and associated land management decisions, influenced modern-day assemblages of medium-sized mammals. Contrary to our hypothesis and what has been found in similar multi-city studies, we found no correlation between

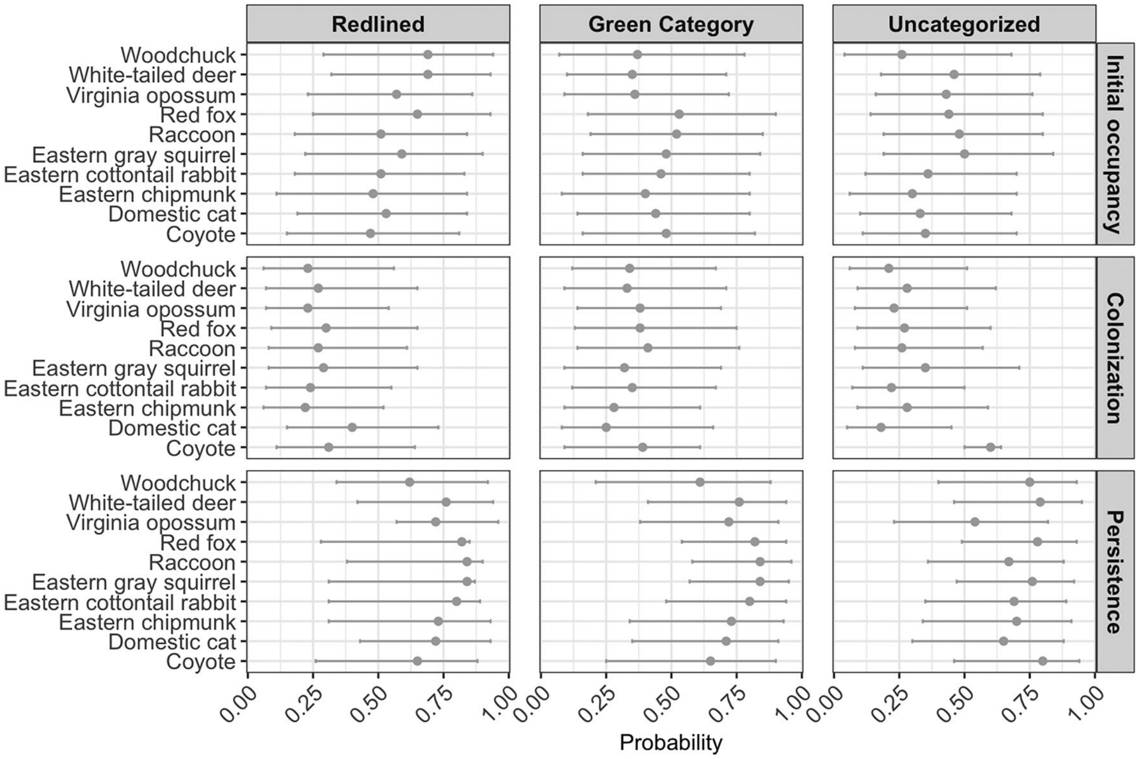

Fig. 4 Points represent that median model coefficients and bars represent the 95% credible intervals for the correlation of historic housing grade with species-specific initial occupancy, colonization, and persistence across the Washington, D.C. metropolitan region, USA. No significant relationship between housing grade and occupancy, persistence, or colonization was found

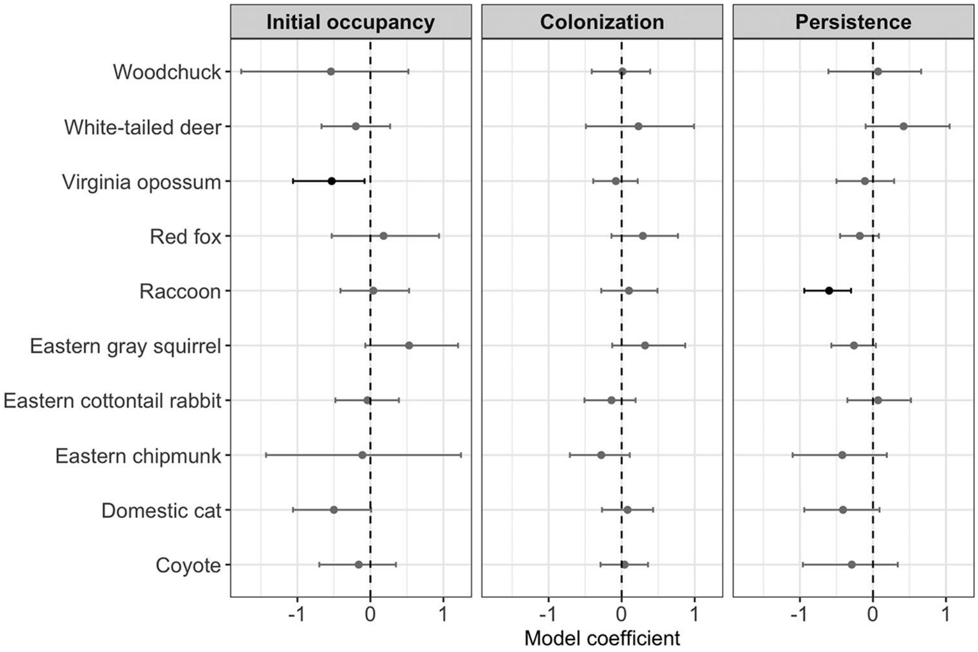

Fig. 5 Points represent the median model coefficients and bars represent the 95% credible intervals for the correlation of urbanization with species-specific initial occupancy, colonization, and persistence across the Washington, D.C. metropolitan region, USA. Black points and credible intervals indicate 95% CI that did not overlap zero

historic redlining and modern-day mammal species richness and no difference among mammal communities across the different neighborhood categorization. These results suggest that more single-city studies are needed to understand how city-specific nuances of historic land use practices correlate to modern day species assemblages. However, to directly compare cities, similar methodology will need to be used.

Species richness and community composition

The most common community make up across all our sites was white-tailed deer, red fox, Virginia opossum, and woodchucks. These species are urban adapters or urban exploiters (Chatelain and Szulkin 2020; Shochat et al. 2006; McKinney 2002) and can easily make us of anthropogenic structures and associated food or habitat resources. Therefore, one explanation for these similarities is that the common mammal communities in our study area may have already been filtered by the urban landscape to only include generalist species (Aronson et al. 2016).

Wildlife species that have more general habitat and dietary needs and can exhibit behavioral plasticity are able to exist near humans and these tend to be the species that persist in cities (Ducatez et al. 2018). White-tailed deer, red fox, and Virginia opossum – three of the most common species in our study – benefit from the supplemental resources such as food (Batemen & Fleming, 2012) and den sites (Wright et al. 2012) that humans directly or indirectly provide. These species also often lack natural predators in cities (Blanchong et al. 2013), and can therefore thrive in urban environments. It is likely that these common mammal species occur across all neighborhood grades due to their plastic biological and behavioral traits regardless of historic land use differences between neighborhoods. It is not clear why woodchucks are a common species in neighborhoods categorized as green, but not in redlined or uncategorized neighborhoods. Little research has been conducted on urban woodchuck habitat use, but woodchucks prefer habitat along forest edges and are known to use manicured fields and residential lawns (Hellgren and Polnaszek 2011; Armitage 2003). Our results could therefore be evidence of a luxury effect (Hope et al. 2003) where more affluent neighborhoods have more vegetation and therefore more habitat for woodchuck (Clark et al., 2013; Aznarez et al. 2023). However, more information is needed to better understand woodchuck habitat use in cities before making this inference.

Urbanization effects on mammal occupancy, colonization, and persistence

While multi-city studies suggest that urbanization can affect colonization or persistence of mammal species in the U.S. (Magle et al. 2021), we did not find this trend in Washington, D.C. The only species in our study that had a correlation between persistence and urbanization was raccoon, which had a higher probability of persistence at less urban sites, and opossum, which had lower probability of initial occupancy at more urban sites. Mesopredator response to urbanization and human development is complex and can result in a variation of occupancy and behavioral patterns (Veon et al. 2023). Raccoons and Virginia opossums are known to be adaptable urban exploiters that can live in highly urban areas (Veon et al. 2023; Rodriguez et al. 2021; Fidino et al. 2016). However, Washington, D.C. maintains the highest proportion of parkland of any major U.S. city at 21.9% of total land cover (Cohen et al. 2017). In our specific study area, racoons may persist less, and opossums may have lower initial occupancy in the urban core since higher quality habitat is available across the city. No effect on persistence or colonization of opossums may translate to the generalist nature of opossums seen in other urban species, including the exploitation of human provided resources such as food, water, and denning sites regardless of urbanization levels (Veon et al. 2023; Larson et al. 2020).

Future work and management implications

There have been several multi-city studies published on the relationship between historic urban planning, income, and biodiversity in cities (Ellis-Soto et al. 2023; Estein et al., 2023; Magle et al., 2023) but few have focused on this relationship in a single city (however, see Wood et al. 2024). These multi-city studies have created a baseline of generalizations to help guide research. However, as cities across the U.S. can vary in historic timelines, culture, policy, and natural environments it is crucial – from a conservation and management perspective – to conduct single city studies to understand the context of these variables within an individual city. The results of this study demonstrate the importance of single city studies, as our results in Washington, D.C. did not follow the general trends found in previous multi-city analyses (Ellis-Soto et al. 2023; Magle et al. 2021; Eistein et al., 2023). This could be due to several factors, including the FHA classes used in our study versus the HOLC classification system used in other studies, differences of human population densities within studied cities, or a difference in species composition, among others, but this does not undercut the importance of better understanding how historic urban planning can affect current environmental conditions in cities.

While this study did not find evidence of a strong relationship between historic housing grades and mammal diversity in Washington, D.C., we did not directly analyze habitat connectivity, or wildlife population health – key factors in wildlife conservation and management. Unlike birds, mammals have a much more limited capacity to move through the urban matrix without adequately connected habitat (Bierwagen 2007). Lack of connectivity may cause genetic isolation (Schmidt et al. 2022). Further, given known differences in human health outcomes in historically redlined communities, mammals could serve as environmental sentinels, or “proxies” for human health in these communities (García-Fernández et al. 2020). Future studies should consider these factors and take a One Health approach to better understand the potential relationships between historic urban planning, biodiversity, and human health.

Conclusion

Managing urban wildlife for conservation and for human well-being can be challenging. Thus, it is paramount to create a comprehensive and interdisciplinary understanding of how historic urban planning, including social inequities, have shaped native biodiversity distribution and habitat use (Schmidt et al. 2022; Schell et al. 2020). Single city studies that piece apart the long-term ecological effects of discriminatory practices such as redlining, can assist managers in creating and managing green spaces that are ecologically sound and accessible to all. Further, single city studies like ours show that not all cities follow the same patterns. Historical timelines, policy, and green space composition vary city to city, likely causing variation in mammal communities between and among cities. This variation is likely influenced by factors not limited to historic housing segregation alone, including movement capacity, population health, and habitat quality. Furthering work on the ecological connection to environmental inequities can inform justice-centered biodiversity conservation in cities (Schell et al 2020).

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Author contributions M. Collins led the study conception. Material preparation, data collection and analysis were performed by T. Gallo and M. Collins. The first draft of the manuscript was written by M. Collins. Both authors have read and approved the final manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors declare no competing interests.

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