



Public perception of urban wildlife during a COVID-19 stay-at-home quarantine order in Chicago

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Abstract

Reduced human activity to mitigate the spread of the COVID-19 pandemic was accompanied by reports of unusual wildlife sightings in highly developed areas. Such experiences with urban nature may have helped residents cope with the stress of the pandemic and increased public interest in urban wildlife; however, this may depend on the species residents encountered. In this study, we surveyed Chicago, Illinois, USA residents during a stay-at-home order to understand if residents in more affluent or greener neighborhoods saw more wildlife species. We also evaluated whether encounters with pest and non-pest species were associated with residents' values about wildlife. Of 593 responses included in our analyses, respondents in higher-income and greener neighborhoods were more likely to perceive increased wildlife sightings and respondents in higher-income areas reported observing a higher number common birds and mammals. Support for seeing wildlife in residential areas was associated with seeing passerine birds and not seeing rats during the stay-at-home order. Our results suggest that perceived increases in wildlife sightings were common during a stay-at-home order, especially for affluent residents, and that residents' perceptions depended on the species encountered. Understanding how changes in human behavior modifies human-wildlife interactions can help mitigate human-wildlife conflict and foster positive engagement with local wildlife.

Keywords COVID-19 pandemic · Wildlife values · Survey · Biodiversity · Environmental equity · Human-wildlife interactions

Introduction

Policies to mitigate the spread of the COVID-19 pandemic had diverse and unexpected outcomes for wildlife, particularly in urban areas. Reductions in human activity, including local and international travel, known as the “Anthropause” (Rutz et al. 2020), were accompanied by changes in animal

behavior (Derryberry et al. 2020) and wildlife sightings (Vardi et al. 2021) in highly developed areas. These shifts incited a flurry of interest in urban wildlife (Zellmer et al. 2020), which may have been due to increased wildlife activity but also human behavior. For example, residents may have had more time or opportunity to observe wildlife in their own yards, neighborhoods, and urban parks during lockdowns (Basile et al. 2021; Vardi et al. 2021). Concurrently, sightings of synanthropic urban exploiters such as rats increased in cities worldwide, purportedly following restaurant closures (Parsons et al. 2020). The spring of 2020, which saw many cities enact stay-at-home orders to curb the spread of COVID-19, may have been an unusual period of human-wildlife interactions with important consequences for human well-being and support for urban conservation.

A growing body of work documents positive associations between human exposure to biodiversity and physical health (Hartig et al. 2014), mental health (Wood et al. 2017), and happiness (Methorst et al. 2021), all of which

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may help urban residents cope with pandemic-related stressors. Throughout Japan and Europe, residents expressed that urban nature helped them cope with pandemic lockdowns, especially those with access to green spaces (Pouso et al. 2020; Soga et al. 2021). While observing wildlife might benefit health, residents may have had different experiences with wildlife during the pandemic based on the ecological and socioeconomic characteristics of their neighborhood. There are significant disparities in biodiversity among neighborhoods in cities (Aronson et al. 2014; Fidino et al. 2020). These disparities often correlate with income, such that areas with higher incomes tend to have more access to greenspace, a phenomenon known as the “luxury effect” (Hope et al. 2003; Leong et al. 2018). Further, affluent residents may have had more time to spend observing wildlife, for example if they had job flexibility that allowed them to work from home during the pandemic or to spend time outdoors. Understanding differences in residents’ experiences with wildlife during pandemic restrictions can help identify inequities for communities with less access to urban greenspace.

In addition to human benefits, frequent wildlife sightings may promote greater interest in urban ecosystems and their conservation (Prévot et al. 2018). For example, public interest in national parks declined during pandemic-associated park closures (Souza et al. 2021) while use of urban parks increased during the pandemic (Venter et al. 2020). However, these positive outcomes may depend on the species residents encountered. For example, backyard passerine birds are generally well-liked and may inspire positive perceptions of wildlife (Bjerke et al. 2003; Cox and Gaston 2015) while more frequent interactions with pest species, such as rats, may have the opposite effect. Therefore, while residents may have had increased interactions with wildlife during the pandemic, they may have encountered different wildlife communities based on neighborhood income and access to greenspace, leading to divergent perceptions of urban wildlife. To untangle these effects, understanding variation in public perception of wildlife is critical.

One way to measure public perception of urban wildlife is through assessing wildlife value orientations (Fulton et al. 1996), patterns of basic beliefs relevant to wildlife such as using lethal wildlife management for human benefit or placing importance on seeing wildlife in the community. Wildlife value orientations are predictive of the acceptability of different management actions (Jacobs et al. 2014), and can thus be useful for gauging support for urban wildlife presence. The pandemic and associated stay-at-home orders in 2020 provided an opportunity to measure how large-scale changes in human activity affect human-wildlife interactions and support for urban wildlife. However, these stay-at-home orders were time sensitive, limiting opportunities

for traditional survey methods such as paper mail. To gather public perceptions during this unique time, we distributed an online survey through community groups to understand residents’ experiences with urban wildlife during this unique time.

In this study, we surveyed Chicago city residents to understand their perceptions of urban wildlife during a stay-at-home order in late March – early June 2020. Our first goal was to test whether residents in greener and/or more affluent neighborhoods would be more likely to perceive increased wildlife activity and report observing more species during the stay-at-home order. We predicted that residents in greener and more affluent neighborhoods would be more likely to report an increase in wildlife sightings and report observing more species from a list of common birds and mammals during the stay-at-home order. Our second goal was to test whether residents’ wildlife value orientations were associated with the type of wildlife they observed, specifically pest or non-pest species, during the stay-at-home order. We predicted that residents who observed more rats during the stay-at-home order would express values in favor of wildlife management while residents who observed birds would express values in support of urban wildlife. Our results clarify the implications of changes in human behaviour for human-wildlife interactions, which may vary among neighborhoods based on disparities in income and green space. Our results also demonstrate how experiences with pest and non-pest species can shape human perception and support for wildlife in human-dominated landscapes.

Methods

Survey distribution

We gathered information about Chicago residents’ experiences with wildlife during the stay-at-home order using an online survey and the following cross-sectional study design. We collected survey responses via SurveyMonkey (SurveyMonkey Inc., San Mateo, California, USA) to ensure rapid distribution of surveys, which would have been impossible using paper surveys. The survey was available from April 27 – June 6, 2020 during Chicago’s stay-at-home order, which was in effect between March 21 and June 3, 2020. During the stay-at-home order, the City of Chicago requested that all residents stay at home except for essential needs and most indoor services such as dine-in service at restaurants were not permitted (Pritzker 2020).

To ensure that the survey was viewed by as many residents across the city as possible, we distributed a link to our online survey through community newsletters. We emailed a short explanation of our survey and a link, in English and

Spanish, to all 50 aldermanic offices (i.e. elected officials who represent city wards) and at least one community organization in all 77 Chicago community areas. These organizations were invited to share our survey in their community newsletters. This approach was used because we had no sampling frame of email addresses for Chicago residents. Of those invited, nine community organizations and 29 Aldermanic offices shared our survey. Of the organizations that participated, seven of the nine community organizations and 15 of the 29 Aldermanic offices were in the North Side of Chicago. Prior to distributing the survey, Lincoln Park Zoo volunteers (n=21) pilot tested potential questions and wording was refined to improve comprehension. These volunteers included Lincoln Park Zoo volunteers and community members who included a range of age groups, genders, and levels of formal education. The survey was advertised and made available in English and Spanish. Survey respondents were eligible if they were over the age of 18 and had lived in their current residence for at least six months. All survey participants anonymously provided written informed consent via checkboxes prior to taking the survey. The Lincoln Park Zoo Institutional Review Board approved our informed consent protocol and deemed this study exempt.

Respondent characteristics

To account for established demographic differences in wildlife perceptions (Zinn and Pierce 2002) and test whether residents in more affluent or greener areas were more likely to perceive more wildlife near their homes during the stay-at-home order, we included a small set of demographic and spatial questions. Specifically, we asked respondents to self-report their gender, age group (above or below median age of 45), children in the household (yes/no), type of housing, their neighborhood, and their closest major intersection. We categorized housing types into single-family homes and townhouses vs. apartment buildings because these building types are likely to differ in access to a yard or large patio. We also asked respondents to self-report the amount of time spent per week outside in the neighborhood because essential workers may have had less time to observe wildlife outside of the home. We did not ask respondents for their race and ethnicity or their income due to the sensitive nature of these questions in a particularly challenging time.

We also collected data on socioeconomic status and neighborhood greenness to test whether residents in more affluent and/or greener neighborhoods saw more wildlife or more species during the stay at home order. To do so, we queried the median household income of their census tract based on their closest major intersection (U.S. Census Bureau 2020). As a measure of neighborhood greenness, we included a vegetation index score (range=0–1, higher

values indicating more vegetation cover) calculated using normalized difference vegetation index (NDVI) data for each community area by the Chicago Health Atlas (CDPH 2020). We were interested in wildlife in residents' yards and neighborhoods and so we used the vegetation index score because it includes vegetation from yards in addition to urban green space. Although access to urban green space is significantly higher for majority-white and higher-income areas in Chicago (Liu et al. 2021), the vegetation index score was not significantly correlated with median household income across community areas ($R^2=2.4 \times 10^{-3}$, $F=0.018$, $df=1,76$, $p=0.89$) and so we included both income and greenness in our analyses.

Wildlife observations during stay-at-home order and neighborhood characteristics

The survey included questions designed to (1) assess which respondents noticed more wildlife around their home in the past month and (2) determine how many common urban bird and mammal species residents observed during the stay-at-home order. To assess perceived changes in wildlife activity, we asked respondents if they agreed or disagreed with the statement “In the past month, I have noticed more wildlife around my home” and “In the past month, I have noticed more wildlife around my neighborhood”. We asked respondents to reflect over the past month because (1) lockdown had been in place for a month before the survey was distributed, (2) we wanted respondents to reflect back over an objective and consistent timeframe, and (3) it allowed us to assess whether wildlife sightings changed from early to later on during the stay-at-home order. The responses were categorized on a 5-point Likert scale from “strongly disagree” to “strongly agree” (Supplemental file 1). We also asked respondents to indicate which species they observed during the past month from a list of seven common urban mammals (rat, *Rattus norvegicus*; coyote, *Canis latrans*; raccoon, *Procyon lotor*; Virginia opossum, *Didelphis virginiana*; striped skunk, *Mephitis mephitis*; bat (any species); and rabbit, *Leporidae*) and six common urban bird species (Canada goose, *Branta canadensis*; House sparrow, *Passer domesticus*; Pigeon, *Columba livia*; American robin, *Turdus migratorius*; Northern cardinal, *Cardinalis cardinalis*; European starling, *Sturnus vulgaris*) based on common names and photographs of each species (Supplemental file 1, Figure S3). The survey was conducted as part of a larger study exploring changes in residents' encounters with urban rats during the stay-at-home order (Murray et al. 2021). Because of the survey's focus on rats, we also asked if respondents observed more rats, fewer rats, or no change in rat sightings relative to a month prior.

To test whether residents in more affluent or greener areas were more likely to report increased wildlife sightings during the stay-at-home order, we used an ordinal regression with whether a respondent observed more wildlife around their home (ranging from strongly disagree to strongly agree) as the response variable. We used the `polr` function using the MASS package (v. 7.3–51.6) in R (v 4.0.0; Venables and Ripley 2002; R Core Team 2019) and the reference category was “strongly agree”. We included the following as explanatory variables: respondent age group and gender; time period when they took the survey (first 3 weeks ($n=352$) vs. last 3 weeks ($n=241$) of the stay-at-home order); housing type; time spent outside the home; median household income (of their census tract); and neighborhood greenness (vegetation index score of their neighborhood). Because respondents completed the survey at different times, we included the time period in which the survey was completed as a covariate in our analyses. We included the time period when they took the survey to account for expected changes in wildlife sightings from early to late spring (e.g. nesting birds). We compared a suite of candidate models that represented different hypotheses: (1) the luxury effect (income * greenness), (2) access to the outdoors (time outside + housing type), (3) luxury effect plus access to the outdoors, (4) demographics (age * gender), (5) season (date survey was taken), (6) null (intercept only), and (7) global model (all covariates). We ranked the models using Akaike Information Criterion (AIC) scores and considered models within $\Delta\text{AIC} < 2.0$ of the top-performing model to be competitive (Burnham and Anderson 2002).

We also tested whether residents in more affluent or greener areas were more likely to observe more species using binomial regression. The response variable was the number of species the respondent observed (successful trials) and the number of species they did not see in the species pool (number of failed trials). In this model, we included the following explanatory variables: respondent age and gender, time spent outside, housing type, neighborhood greenness, median household income, and survey date (first or last three weeks). For this analysis, we ran the global model with all covariates and interpreted the confidence intervals of individual covariates.

Wildlife value orientations and species observed during the stay-at-home order

To test whether perceived changes in wildlife sightings or encounters with pest or non-pest species during the stay-at-home order were associated with wildlife values, the questionnaire included previously validated wildlife value orientation scales from Fulton et al. (1996). Wildlife value orientations are measured by quantifying respondent

agreement with a series of statements pertaining to different belief domains (Fulton et al. 1996). In our study, we included twelve statements relevant to four wildlife value orientations: wildlife use, which reflects the belief that wildlife should be managed for human benefit; wildlife rights, which reflects the belief that wildlife are deserving of rights and protection from lethal management; residential wildlife experience, which reflects the importance of wildlife around residents’ homes and neighborhoods; and recreational wildlife experience, which we modified to reflect the importance of wildlife to recreation in urban parks (Table S1). For example, we asked respondents whether they agreed with statements such as “Humans should manage wild animal populations so that humans benefit” and “I enjoy seeing wildlife around my home” (Table S1). For each statement, the response could range from 1 (strongly disagree) to 5 (strongly agree), resulting in a score for each respondent ranging from 3 to 15 for each of the four wildlife value orientations.

To test whether wildlife value orientations pertaining to wildlife management or enjoyment were associated with encountering particular species, we calculated scores for each of the four wildlife value orientations (Fulton et al. 1996). We calculated the internal consistency of respondent scores within each of the four wildlife value orientation scales using Cronbach’s Alpha (Cronbach 1951). We then used exploratory and confirmatory factor analysis to identify how many latent factors were associated with our data (Fulton et al. 1996). Factor analysis of wildlife value orientation scores indicated two latent factors, one associated with positive scores for wildlife residential experience and wildlife recreational experience (i.e. enjoying seeing wildlife in recreational or residential settings) and the other associated with positive scores for wildlife use (i.e. support for wildlife management) and negative scores for wildlife rights (i.e. wildlife should have rights that protect them from lethal management) (Figure S1). Confirmatory factor analysis determined that two factors provided a good fit to the data (Tucker Lewis Index = 1.00, Comparative Fit Index = 1.00; Figure S1). We then used a Principal Components Analysis (PCA) to reduce the dimensionality of the four wildlife value orientation scores. We retained Principal Component 1 (PC1) as our measure of wildlife-friendly values in our models because it explained 57% of the variance in responses and because PC1 was positively correlated with the wildlife use dimension and negatively associated with the wildlife rights, recreational experiences, and residential experiences dimensions, aligning with the latent factors in our factor analysis (Figure S2).

To test our hypothesis, we included PC1 scores as the response variable in a linear regression with the following explanatory variables: binary variables for whether or not

the respondent had observed each of the 13 common species; along with age, gender, and children in the household. We also ran a separate model to test if PC1 scores were associated with a change in wildlife sightings around the home during the stay-at-home order, age, gender, children in the household, median household income, and neighborhood greenness.

In all analyses, all continuous variables were centered and scaled (i.e. mean subtracted, divided by standard deviation) prior to analysis. We confirmed normality of all continuous variables prior to analysis using the `find_skewness` function of the `dlookr` package in R (Choonghyun 2021) and log-transformed variables if necessary. We also checked the normality of linear regression model residuals using QQ plots.

Results

Respondent characteristics

In total, we received 835 surveys that were at least partially completed and all were completed in English. We received 593 surveys with responses to all variables in this analysis and so this was our sample size. All surveys received were completed in English. Most respondents indicated that they had heard of the survey from their Alderman/city council member (47%), from a community organization (17%) or from social media (17%). Relative to the total sample ($n = 835$), respondents with data for all variables and included in our analysis ($n = 593$) were slightly more likely to identify as female (54% vs. 68%) and not have children in the home (23% vs. 28%). Of responses included in our analysis, 406 (68%) identified as female, 177 (30%) identified as male, 5 (1%) identified as non-binary and 6 (1%) preferred not to say, while 54% and 25% of total respondents identified as female and male, respectively. When including gender as a covariate in generalized linear models, we were only able to include respondents who identified as male or female to have adequate statistical power. The responses in our analysis included representation of all age groups, while there were fewer respondents in the 18–24 category (3%) relative to other categories (16–23%) and this distribution was similar to the total sample. Compared to Chicago's total population, respondents were more likely to identify as female (51% of censused residents vs. 68% of respondents) and as property owners (45% of censused residents vs. 66% of respondents) but there was no significant bias in age class (Table S2).

We received responses from 106 neighborhoods, mostly in the North side of the city (Fig. 1). We received more responses from community areas with higher incomes

($\beta_{\text{Income}} = 8.36 \pm 2.39$ SE, $t = 3.49$, $p = 0.001$; model adjusted $R^2 = 0.43$, $F(2,50) = 20.63$, $p = 2.93 \times 10^{-7}$). Based on census tract data, the average median household income for respondents who provided their closest major intersection was $\$82,888 \pm 34,182$ (mean \pm S.D.; range: $\$16,953 - \$168,352$; all Chicago census tracts: $\$57,632 \pm 32,361$). In terms of urban green space, the average vegetation index value for respondent community areas was 0.24 ± 0.04 (range: 0.14–0.39, Chicago = 0.28 ± 0.07).

Wildlife observations during stay-at-home order and neighborhood characteristics

When we asked if respondents had observed more wildlife around their home during the stay-at-home order relative to the month prior to the survey period, 42% of respondents agreed or strongly agreed while 20% disagreed and 38% neither agreed nor disagreed. We found a similar pattern of responses for changes in wildlife sightings in the neighborhood (42% agreed or strongly agreed, 19% disagreed or strongly disagreed, 39% neither agreed nor disagreed) and so we only analyzed sightings around the home. We ranked candidate models to test whether residents in greener or higher income areas were more likely to observe more wildlife around their home and found two competitive top-performing models: the model representing access to the outdoors and the model representing access to the outdoors and the luxury effect ($\Delta\text{AIC} < 2.0$; Table 1). Based on the model representing access to the outdoors and the luxury effect, respondents were significantly more likely to observe more wildlife around their home during the stay-at-home order if they spent more time outdoors in their neighborhood ($\beta_{\text{Time outside}} = 0.48 \pm 0.22$, $t = 2.20$, $p = 0.03$; Table 2; Fig. 2a). There was also a significant interaction between income and greenness such that wildlife sightings increased with income in greener neighborhoods but decreased with income in grayer neighborhoods ($\beta_{\text{Income*Vegetation index}} = 0.33 \pm 0.15$, $t = 2.17$, $p = 0.03$; Table 2; Fig. 2b).

We used binomial regression of species sightings to test whether residents in greener and higher-income areas observed more species of common birds and mammals during the stay-at-home order. We found that respondents in higher-income census tracts observed significantly more species relative to respondents in lower-income areas ($\beta_{\text{Income}} = 0.09 \pm 0.03$, $z = 3.13$, $p = 1.76 \times 10^{-3}$; Table 3; Fig. 3). Contrary to our predictions, we found that respondents in greener neighborhoods saw significantly fewer species relative to respondents in grayer neighborhoods, although the effect size was small ($\beta_{\text{Vegetation index}} = -0.11 \pm 0.04$, $z = -2.77$, $p = 5.54 \times 10^{-3}$; Table 3; Fig. 3). Respondents reported approximately one fewer species

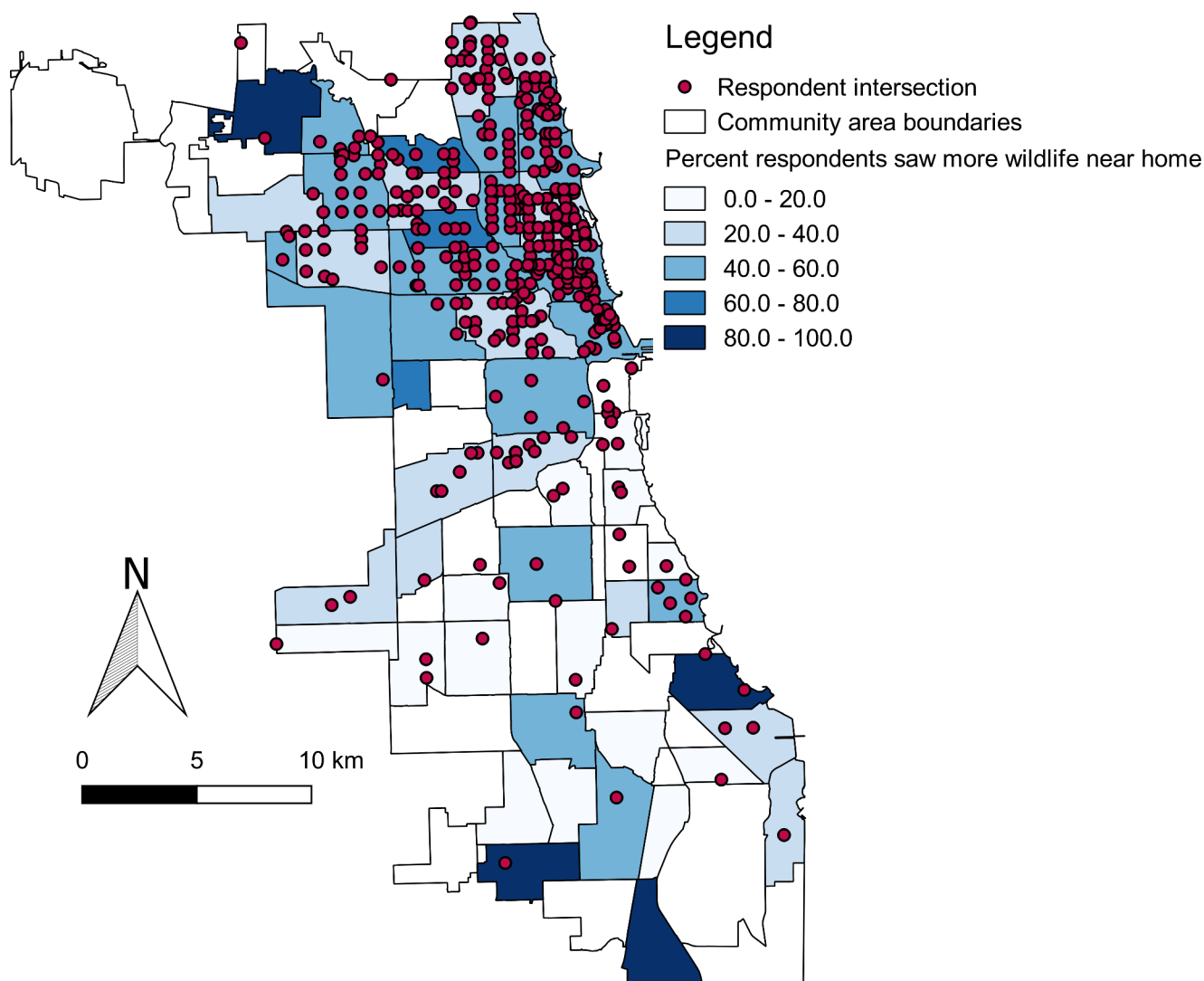


Fig. 1 Map of Chicago showing community area boundaries and the locations of survey respondents. Community areas are shaded based on the percentage of respondents who self-reported their neighborhood of residence and agreed that they observed more wildlife around their homes during the stay-at-home order relative to a month prior

($n=740$). Red circles indicate the closest major intersection reported by respondents ($n=627$). The locations of respondent intersections were offset by a random distance within a 500 m buffer to maintain respondent privacy

with a 20% increase in greenness or a \$100,000 decrease in income.

Wildlife value orientations and species observed during the stay-at-home order

We quantified respondents' values about wildlife using previously validated wildlife value orientation scales about wildlife use, wildlife rights, residential experiences, and recreational experiences with wildlife. The scores for these four scales ranged from 1 to 15 (1 = all "strongly disagree", 15 = all "strongly agree") and the internal consistency of each scale was high (Cronbach's alpha for recreational experiences = 0.836, residential experiences = 0.926, wildlife

use = 0.802, wildlife rights = 0.863). On average, respondents ($n=658$) agreed they enjoyed seeing wildlife in urban parks (recreational experiences mean = 12.7 ± 2.3) or in their neighborhood (residential experiences mean = 11.7 ± 3.0). Specifically, 87% said they enjoyed seeing wildlife in urban parks, 59% agreed that one of the reasons they visit parks is to see urban wildlife, 74% of respondents said they enjoyed seeing wildlife in their neighborhood, 76% of respondents agreed that they enjoyed seeing wildlife around their home. Respondents had on average lower score for lethal wildlife management (wildlife use = 9.3 ± 2.8) and support for wildlife rights (8.5 ± 3.0).

We defined wildlife-friendly values as higher scores in agreement with wildlife rights and enjoyment of seeing

Table 1 Comparison of candidate models of predictors of respondent response to “In the past month, I have noticed more wildlife around my home”. The reference category for ordinal regression was “strongly agree”

Model	Model description	Deviance	AIC	ΔAIC
Access	Time outside + Housing	1453.55	1469.55	0
Luxury effect and access	Income*Greenness + Housing + Time outside	1448.52	1470.52	0.97
Global	Age*Gender + Housing + Time outside + Income*Greenness + Date	1446.98	1476.98	7.43
Luxury effect	Income*Greenness	1466.69	1480.69	11.14
Season	Date	1472.5	1482.5	12.95
Demo-graphics	Age*Gender	1472.37	1486.37	16.82
Null	Intercept	1800.12	1808.12	338.57

wildlife in recreational and residential settings and lower scores for wildlife use/lethal management (i.e. lower PC1 scores). More wildlife-friendly values were significantly associated with lower incomes, being under 45, identifying as female, not having children in the home, and observing more wildlife around the home during the stay at home order (Fig. 4; Table 4). We then tested whether encounters with desirable species (i.e. backyard birds) would be positively associated with values in favor of seeing urban wildlife, while encounters with pest species (i.e. rats) would be

associated with values in favor or lethal wildlife management. In support of our prediction, wildlife-friendly values were significantly positively associated with observing robins, house sparrows, and starlings (Fig. 4b; Table 4, Figure S4) while wildlife-friendly values were negatively associated (i.e. higher scores for wildlife use/lethal management) with observing more rats during the stay-at-home order (Fig. 4c; Table 4).

Discussion

In this study, we surveyed Chicago residents during the COVID-19 stay-at-home order to understand resident perceptions of wildlife during the stay-at-home order. We tested whether residents in more affluent or greener areas were more likely to observe more wildlife and tested whether residents’ wildlife value orientations were associated with the type of wildlife they observed during the stay-at-home order. More respondents perceived more wildlife around their home or neighborhood than otherwise, especially those who spent more time outside or live in higher income neighborhoods. Respondents in higher income areas were also more likely to observe more species of common birds and mammals relative to respondents in lower-income areas. Interestingly, respondents in greener neighborhoods were more likely to observe more wildlife but fewer species. Observing more wildlife during the stay-at-home order

Table 2 Ordinal regression output of the top-performing models associated with respondents observing more wildlife around their homes during the spring 2020 stay-at-home order in Chicago. The reference level was the response “strongly agree” to the statement “In the past month, I have noticed more wildlife around my home”

Model	Term	Estimate ± S.E.	t	p
Access	Housing (house)	0.16 ± 0.16	0.98	0.33
	Time outside (linear)	0.49 ± 0.21	2.28	0.02
	Time outside (quadratic)	-0.09 ± 0.18	-0.48	0.63
	Time outside (cubic)	0.03 ± 0.14	0.22	0.82
	Intercept (Strongly disagree Disagree)	-3.45 ± 0.27	-12.64	1.23 × 10 ⁻³⁶
	Intercept (Disagree Neither agree nor disagree)	-1.37 ± 0.14	-9.95	2.47 × 10 ⁻²³
	Intercept (Neither agree nor disagree Agree)	0.41 ± 0.12	3.35	8.10 × 10 ⁻⁴
	Intercept (Agree Strongly agree)	2.19 ± 0.16	13.47	2.21 × 10 ⁻⁴¹
	Access and luxury effect	Income	0.23 ± 0.14	1.69
Greenness (vegetation index)		0.21 ± 0.14	1.50	0.13
Housing (house)		0.13 ± 0.16	0.79	0.42
Time outside (linear)		0.48 ± 0.22	2.20	0.03
Time outside (quadratic)		-0.08 ± 0.18	-0.45	0.65
Time outside (cubic)		0.04 ± 0.14	0.29	0.77
Greenness * Income		0.33 ± 0.15	2.17	0.03
Intercept (Strongly disagree Disagree)		-3.67 ± 0.30	-12.28	1.10 × 10 ⁻³⁴
Intercept (Disagree Neither agree nor disagree)		-1.58 ± 0.18	-8.74	2.25 × 10 ⁻¹⁸
Intercept (Neither agree nor disagree Agree)		0.21 ± 0.17	1.26	0.21
Intercept (Agree Strongly agree)		2.00 ± 0.20	10.26	1.12 × 10 ⁻²⁴

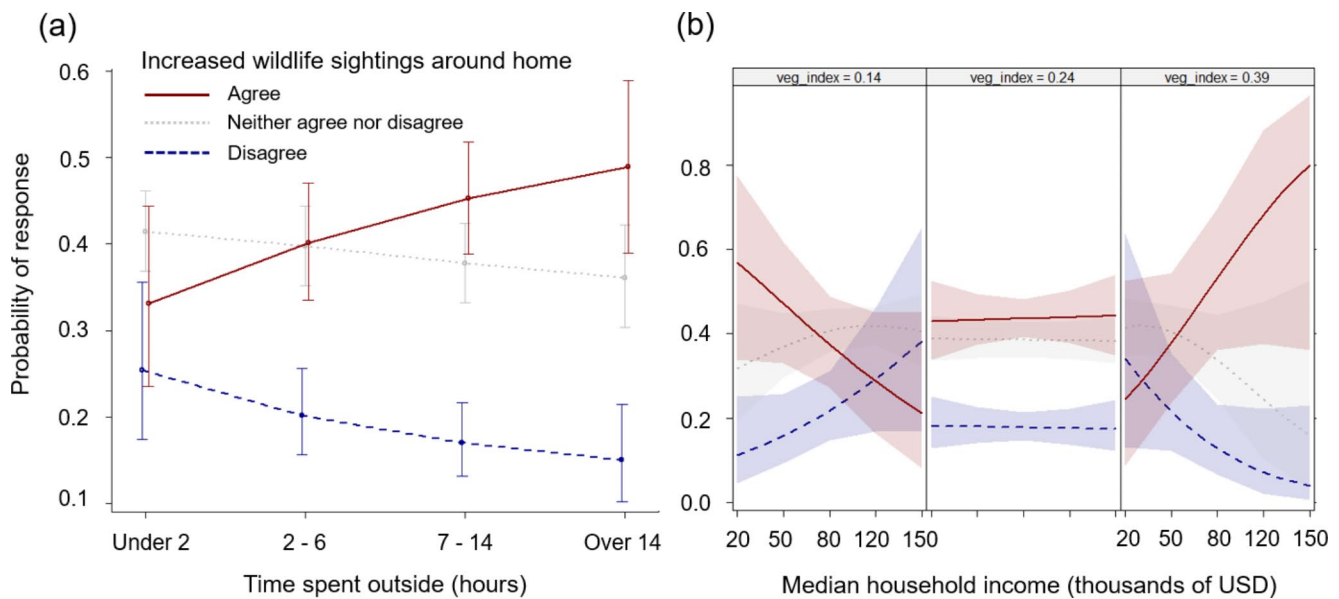


Fig. 2 Characteristics of survey respondents who saw more wildlife around their homes during a COVID-19 stay-at-home order in Chicago. Lines show the probability of a survey respondent agreeing/strongly agreeing (red), disagreeing/strongly disagreeing (blue), or neither (gray) to the statement “In the past month, I have noticed more wildlife around my home.” We included all five response types in our

analysis but collapsed “strongly agree” with “agree” and “strongly disagree” with “disagree” here for visual clarity. Sub-panels in (b) show the relationship between the likelihood of response type and income for three representative levels of neighborhood greenness, measured as a vegetation index based on NDVI (min of 0.14, median of 0.24, and max of 0.39). Vertical error bars (a) and shaded regions (b) show 95% confidence intervals

Table 3 Binomial regression output of demographic, environmental, and socioeconomic factors associated with the number of seven mammal and six bird species observed during the spring 2020 stay-at-home order in Chicago

Variable	Estimate \pm S.E.	z value	p value
Intercept	-0.11 \pm 0.06	-1.67	0.09
Gender (Male)	-1.20 $\times 10^{-3}$ \pm 0.07	-0.02	0.99
Age (under 45)	-0.05 \pm 0.06	-0.83	0.40
Housing (house)	-2.70 $\times 10^{-4}$	-0.01	0.99
Time outside (linear)	1.14 \pm 0.07	2.074	0.04
Time outside (quadratic)	0.03 \pm 0.06	0.55	0.58
Time outside (cubic)	-0.03 \pm 0.45	-0.75	0.45
Median household income	0.09 \pm 0.03	3.13	1.76 $\times 10^{-3}$
Greenness (vegetation index)	-0.11 \pm 0.04	-2.77	0.01
Date (last 3 weeks)	0.02 \pm 0.11	0.16	0.87

was also associated with wildlife-friendly values (i.e. enjoy seeing wildlife in residential contexts, not in favor of lethal management) and respondents were especially likely to express wildlife-friendly values if they observed passerines and had not observed more rats during the stay-at-home order. Our results suggest that while restrictions to mitigate the COVID-19 pandemic may have promoted wildlife sightings for a large proportion of urban residents, residents’ experiences with wildlife were associated with the affluence

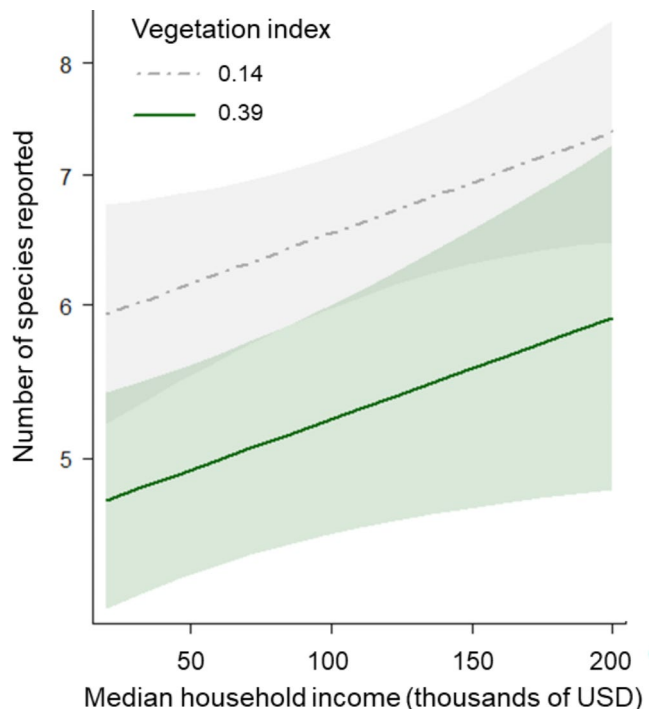


Fig. 3 Relationship between the number of species seen during the stay-at-home order, income, and neighborhood greenness for relatively vegetated (solid) and less vegetated (dashed line) neighborhoods in Chicago. Survey respondents were asked how many species they observed from a list of common urban birds and mammals. Neighborhood greenness was measured using NDVI values from the Chicago Health Atlas

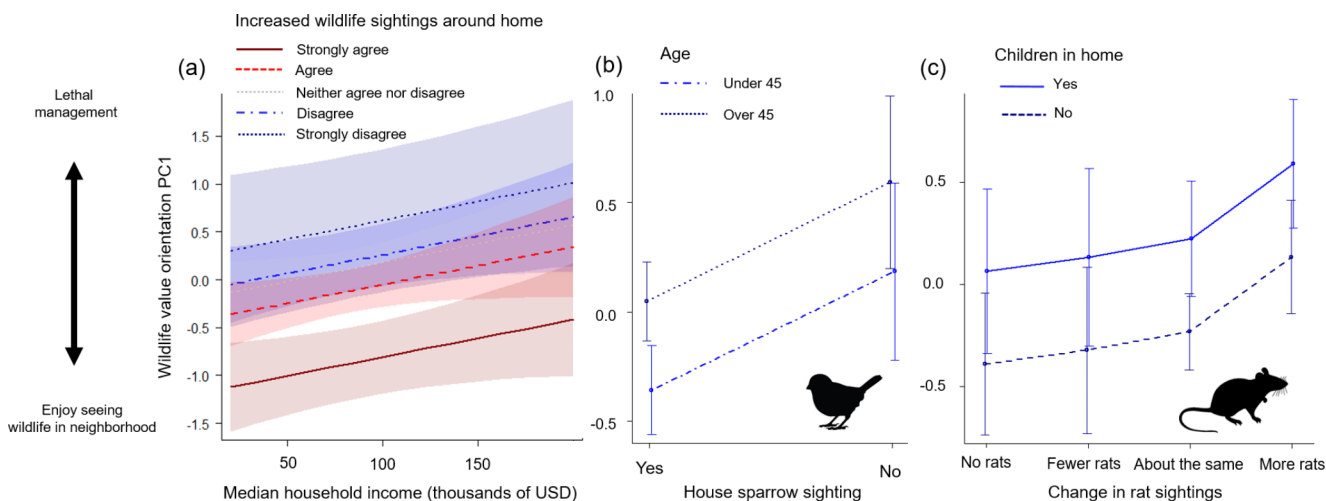


Fig. 4 Relationships between wildlife value orientations and (a) reported changes in wildlife sightings during a stay-at-home order and income, (b) whether or not the respondent observed house sparrows and respondent age, and (c) reported changes in rat encounters and children in the home, with no rats indicating no rat sightings before

and during lockdown. We collapsed wildlife value orientation scores using Principal Components Analysis. More negative PC1 scores are associated with higher scores for enjoying seeing wildlife in residential or recreational contexts and wildlife rights, while more positive scores are indicative of higher scores for lethal management. Shaded bands (a) and vertical error bars (b, c) show 95% confidence intervals

and greenness of their neighborhood and values about wildlife were associated with the species they encountered.

Respondents in higher-income areas had increased wildlife sightings and saw more species during the stay-at-home order relative to less affluent areas (Figs. 2 and 3). This pattern supports more general trends of inequity in biodiversity among urban neighborhoods known as the luxury effect (Hope et al. 2003; Leong et al. 2018). Given the health benefits associated with biodiversity exposure (Hartig et al. 2014), this relationship may exacerbate other existing inequities in health and well-being between residents in high- vs. low-income neighborhoods, particularly during the pandemic. For example, residents in lower-income neighborhoods were hit harder by unemployment in 2020, had less access to health care, and more cases of COVID-19 relative to more affluent communities (Mackey et al. 2020; Galea and Abdalla 2021). Our results highlight that residents within the same city can have very different experiences with wildlife, which may have implications for their physical and mental health.

The luxury effect is typically focused on inequities in greenspace with income, but another important aspect is the luxury of time to observe wildlife. During the pandemic from April – June 2020, some 56% of Americans were able to work safely from home – compared to 5% prior to 2020 (Templeman and Reid 2020) – while essential service workers were required to work from their typical workspaces. Although essential workers leave the house for work, those working from home may have had more time to walk in their neighborhood, recreate in their yards or on their patios, or simply view wildlife from windows. These differences

in work flexibility may have contributed to disparities in wildlife sightings with income because many essential and especially frontline workers (e.g., grocery store workers) have low-wage jobs (Blau et al. 2020). Future studies could examine disparities in residents' access to urban nature based on the availability of time to use these spaces based on employment (e.g. working from home, shift work, multiple jobs, unemployed), safety (e.g. perceived safe and unsafe times to use green spaces) or accessibility (e.g. are green spaces accessible without a vehicle or by public transit).

Resident experiences with urban wildlife appear to have been impacted by the stay-at-home order, which may increase support for urban wildlife conservation. Respondents who observed more wildlife during the stay-at-home order, and specifically those who saw passerine birds, expressed more enjoyment with seeing wildlife in urban parks and neighborhoods (Fig. 4). In Europe, online searches for nature-related terms increased significantly during pandemic restrictions in the spring of 2020, especially the topic of "Birds" (Rousseau and Deschacht 2020). Residents also used parks more often than usual during the pandemic to recreate safely (Geng et al. 2020; Rice and Pan 2020; Venter et al. 2020). All of these trends could indicate greater public interest in urban wildlife or urban green spaces. This is important because an appreciation for wildlife or their habitats may lead to interest in urban conservation such as backyard habitat programs or urban greening. Indeed, public awareness is often an important determinant of policy changes (Burnstein 2003) and so greater awareness of urban birds, through either media or more frequent bird sightings as in our study, may garner increased support for urban

Table 4 Linear regression output of factors associated with wildlife value orientations, collapsed into two axes using Principal Component Analysis. Positive PC1 scores were associated with values in favor of lethal wildlife management for human benefit and negative PC1 scores were associated with values in favor of wildlife rights and seeing wildlife in recreational or residential contexts

Model	Variable	Estimate \pm S.E.	t value	p value	
Neighborhood	Intercept	-0.28 \pm 0.41	-0.68	0.50	
	Greenness (vegetation index)	0.46 \pm 1.60	0.29	0.77	
	Median household income	0.13 \pm 0.07	1.94	0.05	
	Gender (Male)	0.36 \pm 0.14	2.53	0.01	
	Children (Yes)	0.51 \pm 0.15	3.50	5.18 $\times 10^{-4}$	
	Age (under 45)	-0.26 \pm 0.13	-1.95	0.05	
	Time outside (linear)	0.26 \pm 0.25	1.01	0.31	
	Time outside (quadratic)	0.09 \pm 0.21	0.42	0.68	
	Time outside (cubic)	0.02 \pm 0.17	0.13	0.89	
	Change in wildlife sightings (linear)	-1.00 \pm 0.28	-3.62	3.22 $\times 10^{-4}$	
	Change in wildlife sightings (quadratic)	-0.25 \pm 0.24	-1.06	0.29	
	Change in wildlife sightings (cubic)	-0.25 \pm 0.18	-1.39	0.17	
	Change in wildlife sightings (\wedge^4)	2.97 $\times 10^{-3}$ \pm 0.13	0.02	0.98	
	Species seen	Intercept	-0.05 \pm 0.39	-0.12	0.90
		Gender (Male)	0.57 \pm 0.18	3.15	1.75 $\times 10^{-3}$
		Children (Yes)	0.45 \pm 0.15	3.12	1.90 $\times 10^{-3}$
		Age (under 45)	-0.31 \pm 0.16	-1.98	0.05
Time outside (linear)		0.14 \pm 0.18	0.75	0.45	
Time outside (quadratic)		-0.03 \pm 0.15	-0.19	0.85	
Time outside (cubic)		-0.11 \pm 0.12	-0.99	0.32	
Coyote		0.24 \pm 0.17	-1.34	0.18	
Raccoon		0.10 \pm 0.17	0.58	0.56	
Opossum		0.19 \pm 0.17	1.74	0.08	
Skunk		-0.24 \pm 0.21	-1.13	0.26	
Bat		-0.30 \pm 0.20	-1.50	0.14	
Rabbit		0.01 \pm 0.18	0.07	0.94	
Goose		0.06 \pm 0.14	0.45	0.66	
Sparrow		-0.52 \pm 0.21	2.46	0.01	
Pigeon		0.25 \pm 0.17	1.45	0.15	
Robin		-0.49 \pm 0.21	2.28	0.02	
Cardinal		-0.22 \pm 0.17	1.33	0.18	
Starling		-0.36 \pm 0.14	-2.50	0.01	
Change in rats (linear)		0.37 \pm 0.15	2.42	0.01	
Change in rats (quadratic)		0.15 \pm 0.15	0.97	0.33	
Change in rats (cubic)	0.06 \pm 0.16	0.36	0.72		

biodiversity conservation. More frequent interactions with nature can increase motivation to protect biodiversity either by placing a higher value on urban nature (Tyrväinen and Väänänen 1998) or feeling more connected with nature and motivated to protect it (Whitburn et al. 2019). Thus, certain types of marketing and public engagement about urban green space could be especially salient and effective at this time. However, it is unclear whether any changes in public awareness of nature during the pandemic will be long-term.

On the other hand, respondents who had observed an increase in rat sightings during the stay-at-home order expressed values in support of lethal wildlife management, suggesting that not all residents had positive experiences with wildlife during this period. This relationship suggests that encountering pests may negatively influence public attitudes about urban wildlife presence. Rat sightings increased in cities in multiple countries in the spring of 2020, potentially due to shifts in resource availability following restaurant closures (Parsons et al. 2020). Because of their role

as a carrier of zoonotic pathogens (Himsworth et al. 2013; Murray et al. 2020), an increase in rat sightings in residential neighborhoods may be of concern for public health if sightings reflect an increase in rat activity in proximity to homes. In a concurrent study, we found that approximately 20% of residents observed more rats than usual during the stay-at-home order, especially if they lived in restaurant-dense areas, suggesting that restaurant closures may have affected rat distributions (Murray et al. 2021). Future studies on public perceptions of species considered pests or nuisance wildlife could help to understand the consequences of negative human-wildlife interactions on public support for urban wildlife conservation. Understanding these changes in encounters with particular species can help encourage connections with urban nature or anticipate human-wildlife conflict.

Respondents' values about wildlife were also associated with demographic characteristics, namely gender and children in the home (Fig. 4). Respondents with children in the home were more likely to express support for wildlife management. This aligns with previous research in which parents generally show greater concern for environmental risks (the "parental role hypothesis", Davidson and Freudenberg, 1996). In terms of risks from urban wildlife, residents with children in the home expressed greater concern about being attacked by urban mountain lions (Zinn and Pierce 2002). We also found that younger respondents expressed more support for wildlife in residential contexts. This aligns with nationwide work in the United States showing consistent changes in public values away from utilitarian and domination views of wildlife toward more mutualism and protectionist values (Manfredo et al. 2003; Manfredo et al. 2020). Taken together, young urbanites may be especially likely to support urban wildlife conservation, however perception of risk for themselves or their families may mediate that support.

Rats notwithstanding, observing more wildlife during the stay-at-home order may have been an enjoyable and unexpected benefit to an otherwise stressful and challenging time. The majority of respondents - especially those who had observed more wildlife during the stay-at-home order - expressed that they enjoyed seeing wildlife in residential or recreational contexts. Several studies documented that observing or connecting with nature helped residents cope with pandemic lockdowns (e.g. Ma et al. 2021; Pouso et al. 2020; Samuelsson et al. 2020). However, access to green space was limited for some communities (Honey-Roses et al. 2020), suggesting compounding harms for communities that are under-resourced; lower-income communities were typically hardest hit by unemployment, COVID rates, and the inability to access greenspace in their neighborhoods. These patterns underscore the importance of equitable

access to urban nature in both space and time, particularly during stressful periods.

As with most survey data, our results are correlational and should be interpreted with caution. For example, we found that wildlife-friendly values were associated with observing more wildlife during the stay-at-home order and seeing birds in particular. Residents who saw birds could have subsequently expressed wildlife-friendly values; however, residents with more wildlife-friendly values could be more likely to actively look for and notice wildlife in their surroundings. Future work could help elucidate whether changes in wildlife activity leads to changes in human attitudes by surveying residents before, during, and after events likely to increase human exposure to biodiversity such as urban greening initiatives or community science bioblitzes (e.g. the City Nature Challenge). Also, due to the time-sensitive nature of the stay-at-home order, we used an online survey rather than a mailed survey. This approach limited our sample to residents with internet access. In addition, the responses were mainly from the relatively affluent North Side of Chicago, in large part because of a bias in which community organizations shared our survey but also because more affluent residents may have had more time to answer the survey. Residents in less affluent areas of the city may not have responded because those individuals or their community organizations had other priorities during the pandemic. This bias may have increased the proportion of respondents who perceived more wildlife during the stay-at-home order. Our dataset was also biased toward female-identifying respondents, a trend that has been observed in other research about online surveys (Smith 2008) and potentially because of gender differences in community engagement or interest in urban wildlife. It is also important to consider that this survey was marketed mainly as a survey about rats. This may have led to a bias in who was motivated to take the survey; for example, residents who have had problems with rat infestations. This potential bias in who responded to our survey may in part explain why so many respondents did not notice more wildlife around their homes. If the survey had been advertised as a survey about changes in wildlife sightings during the pandemic, our results may have differed. Lastly, our results reflect the experiences of survey respondents in Chicago, a large city with high numbers of COVID cases and stringent COVID policies during the stay-at-home order. In the future, multicity studies (Magle et al. 2019) could help elucidate how different municipal policies in response to the COVID-19 pandemic influenced residents' experiences with urban wildlife.

Understanding how changes in human behavior modify human-wildlife interactions is useful for devising potential avenues for conservation, management, and education. For

example, educational campaigns could capitalize on many people's newfound appreciation for urban greenspaces as a refuge and a place to safely gather. Our results can help anticipate how large-scale behavioural change may mediate or exacerbate human-wildlife conflict and demonstrates that these impacts vary based on socioeconomic and landscape factors. Specifically, reduced human activity appears to have increased human-wildlife interactions for residents in higher-income and greener neighborhoods while residents' perceptions depended on the species they encountered. Beyond the pandemic, many aspects of human disturbance can vary on a daily, seasonal, or annual basis such as human activity in urban parks, vehicular traffic, wildlife tourism, and the frequency of garbage collection. Such fluctuations can be routine or governed by larger phenomena such as economic recessions. All of these factors may have profound consequences for wildlife activity and human-wildlife interactions by changing resource availability, mortality risks, or fear dynamics (Gallo et al. 2019). Anticipating wildlife responses can help prevent negative human-wildlife interactions while promoting positive experiences with wildlife, for example by educating the public about reducing unintentional attractants for species perceived as pests.

In conclusion, our results suggest that large-scale reductions in human activity can promote wildlife observations for urbanites, particularly for those living in greener neighborhoods and those that can spend time outside in their neighborhood. Our results also suggest that encountering desirable species may increase support for urban wildlife while encounters with pests may erode such support. Understanding the links between experiences with particular species and environmental values, for example how the public categorizes species as desirable vs. undesirable or if pests are considered wildlife, could help bolster public support for urban conservation. Further, a better understanding of which species are encountered by low- vs. high-income residents can help tailor wildlife management and urban greening policies to the needs of individual communities. More broadly, understanding the role of human activity in shaping human-wildlife interactions can inform the development of interventions aimed at improving human cohabitation with urban wildlife in a changing world.

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Authors' contributions MHM, KB, SBM, and DG designed the study; JB assisted with data collection and study design; MHM and MF analyzed the data; MHM wrote the first draft and all authors edited the manuscript; all authors approved of the final version of the manuscript.

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Data Availability A summarized version of the dataset will be made available upon reasonable request.

Code Availability Not applicable.

Declarations

Ethics approval This study was exempted from Human Subjects approval by the Lincoln Park Zoological Society Institutional Review Board.

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Consent to participate Informed consent was obtained from all individual participants included in the study.

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