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Citizen Science Project on Urban Canids Provides Different Results From Camera Traps but Generates Interest and Revenue

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CITIZEN SCIENCE PROJECT ON URBAN CANIDS PROVIDES DIFFERENT

RESULTS FROM CAMERA TRAPS BUT GENERATES

INTEREST AND REVENUE

by

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ABSTRACT

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Camera Traps but Generates Interest and Revenue

by

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Utah State University, 2024

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As urbanization progresses, wildlife increasingly encounters people. Coyotes (*Canis latrans*) and red foxes (*Vulpes vulpes*) are two canid carnivores that have readily adapted to urban environments causing them to come into conflict with people and their pets. Citizen science has emerged as a low-cost method of collecting data on urban-adapted species that can provide benefits to management agencies but may provide different results than traditional methods. We analyzed data collected by citizen scientists and data collected via motion-triggered camera traps to see how each relates to the anthropogenic features of distance to roads, building density, and median household income and the habitat feature of distance to water. We also investigated the potential benefits of advertising the citizen science project on social media. We used occupancy models with data from a grid of 67 cameras across the city of Wichita, Kansas, USA, during March 2023 to February 2024. We used generalized linear models to evaluate data collected simultaneously from a website we created and advertised on social media where members of the public could report sightings of urban canids. The camera-trap occupancy models suggested that red fox occurrence was not related to any of our variables and coyote occurrence was only related negatively to building density. The citizen science models suggested that sighting reports of both species were more likely closer to roads, at intermediate building densities, and in high income neighborhoods. Additionally, coyotes and red foxes were both most likely to be detected by people during crepuscular periods but most likely to be detected by cameras at night. We also found that in addition to increasing the reports of sightings from the public, the advertisements generated six times as much revenue for the wildlife agency than was spent. Our study suggests that citizen science data differs from camera-trap data by human activity patterns and distribution, but citizen science projects can provide other benefits such as generating revenue for management agencies.

(48 pages)

PUBLIC ABSTRACT

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Neville. F. Taraporevala

As more people live in cities, wildlife increasingly encounters people. Coyotes (*Canis latrans*) and red foxes (*Vulpes vulpes*) are two carnivores that have easily adapted to urban environments causing them to come into conflict with people and their pets. Citizen science, where members of the community aid scientists in the collection of data, has emerged as a low-cost method of studying these species that can provide benefits to management agencies but may provide different results than traditional methods. We analyzed data collected by citizen scientists and data collected via motion-triggered camera traps to see how each relates to distance to roads, building density, median household income, and distance to water. We also investigated the potential benefits of advertising the citizen science project on social media. To evaluate differences between the two methods, we used data from a grid of 67 cameras across the city of Wichita, Kansas, USA, between March 2023 and February 2024 and data collected simultaneously from a website we created and advertised on social media where members of the public could report sightings of urban coyotes and foxes to determine canid distribution. The camera-trap models suggested that red fox occurrence was not related to any of our variables and coyote occurrence was only related negatively to building density. The citizen science models suggested that sightings of both species were more likely closer to roads, at intermediate building densities, and in high income neighborhoods. Additionally, coyotes and red foxes were both most likely to be detected by people during crepuscular periods but most likely to be detected by cameras at night. We also found that in addition to increasing the reports of sightings from the public, the advertisements generated six times as much revenue for the wildlife agency than was spent. Our study suggests that citizen science data differs from camera-trap data by human activity patterns and distribution, but citizen science projects can provide other benefits such as generating revenue for management agencies.

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CHAPTER 1

INTRODUCTION

More than half of the world's human population lives in urban areas (United Nations 2018), and this trend is even stronger in the United States (over 70%, U.S. Census Bureau 2010). Urban expansion, driven by increases in human settlements and density in localized areas, reduces habitat previously occupied by wildlife. While some wildlife populations may decline or go extinct with human expansion, others take up residence alongside humans.

Wildlife can benefit greatly from living in cities, but they also face many consequences. Urban areas provide year-round anthropogenic food sources and green spaces that benefit wildlife (Bateman and Fleming 2012; Lowry et al. 2012; Oro et al. 2013). They also offer refuge from large predators such as wolves (*Canis lupus),* mountain lions (*Puma concolor),* and bears (*Ursus* spp.), which typically avoid urban areas (Bateman and Fleming 2012; Nicholson et al. 2014), although exceptions exist (Beckmann and Berger 2003; Riley et al. 2021). Negative impacts include habitats fragmented by busy roads resulting in reduced gene flow and vehicle-wildlife collisions (Underhill and Angold 1999; Baker et al. 2007; Beaudry et al. 2008; Adducci et al. 2010; Taylor and Goldingay 2010; Conover 2019; Miles et al. 2019), concentrated pollution (Noyes 2009; Mario et al. 2014), and lethal removal when individuals and species are considered a threat (Hadidan 2015). High occupancy of species such as carnivores in cities can create problems and cause conflict with people. Some small and medium-sized carnivores live in cities by taking advantage of these benefits while minimizing risk by avoiding humans.

Coyotes (*Canis latrans*) and red foxes (*Vulpes vulpes*) are two carnivores that have readily adapted to urban environments. These two canids have resided in cities for decades, with reports of both coyotes and red foxes in U.S. cities since at least the middle of the 20th century (Fichter and Williams 1967; Timm and Baker 2007). Urban canids have successfully colonized cities due to their ability to exploit anthropogenic food sources while mostly avoiding direct contact with humans (Gehrt and Riley 2010; Gehrt et al. 2011). In urban areas, canids have adapted to avoid people, including becoming more nocturnal to decrease interactions with diurnal humans (McClennen et al. 2001; Riley et al. 2003) and decreasing road crossings during the day and evening to avoid cars (Tigas et al. 2002; Baker et al. 2007). In fact, coyotes and red foxes both prefer to use green spaces (e.g., parks, golf courses, and forest preserves) even when their home ranges contain few of these features (Gese et al. 2012; Mueller et al. 2018). However, these adaptations are not sufficient to avoid humans altogether.

In areas where wild canids and humans overlap, conflict may arise since canids can be a threat to humans and their pets. Canids can indirectly impact humans because they harbor and transmit diseases such as rabies, mange, and Lyme disease (Sidwa et al. 2005; Baneth 2014; DeCandia et al. 2019). Coyotes and foxes may directly threaten communities through attacks on humans and pets which, although rare, are increasing in frequency (Lewis et al. 1993; Gehrt and Riley 2010; Plumer et al. 2014; Baker and Timm 2017). These instances, in turn, contribute to a fear of canids among a significant proportion of the U.S. population (Lawrence and Krausman 2011; Elliot et al. 2016; Nardi et al. 2020). Wildlife managers are tasked with managing these species to mitigate conflict, habitat loss, and the spread of diseases, so research that informs management is important to maintain coexistence between people and urban canids.

Research on urban canids often uses GPS collars and remotely triggered camera traps to monitor their space use and activity patterns. Occupancy models are a common tool for analyzing detection/non-detection data to estimate the likelihood that an area is occupied by a species given imperfect detection (Mackenzie et al. 2002). Occupancy models can be important to evaluate the attributes that make individuals of a population more or less likely to occupy regions. Similarly, activity patterns estimated from these methods can highlight when animals are most active and inform when people would be most likely to come into conflict with them (Grinder and Krausman 2001; McClennen et al. 2001). Occupancy studies can help managers determine where hot spots for conflict may arise and mitigate potential conflict.

Traditional methods, such as GPS collars and camera traps, are costly and labor-intensive, generating the desire for alternative methodology. An emerging tool for collecting data in urban areas is through citizen science (CS; *sensu* Cooper et al. 2021), where members of the public volunteer to collect data and contribute to scientific research (Bonney et al. 2009). CS projects can benefit both the local community and the scientific community. People who get involved in CS projects report improved well-being through increased awareness of and interaction with nature (Pocock et al. 2023; Butler et al. 2024). Research shows participants frequently increase their knowledge of the subject being studied (Jordan et al. 2011; Brossard et al. 2015; Greving et al. 2022), but evidence of behavior and attitude change are ambiguous (MacPhail and Colla 2020). Some studies find no change in participants' attitudes or behavior (Jordan et al. 2011; Brossard et al. 2015), while others find that CS promotes pro-nature attitudes and behavior (Hobbs and White 2015; Ballard et al. 2017; Asingizwe et al. 2020; Greving et al. 2022), and these changes can be seen equally across level of participation in the project (Greving et al. 2022). While research on the benefits of CS to the participants and wildlife have been well studied, little research exists about how CS projects can benefit management agencies directly beyond the collection of data (MacPhail and Colla 2020).

The use of CS data can be cost effective (Holck 2007; Gardiner et al. 2012; Encarnação et al. 2021) but may have limitations. For example, CS data are subject to reporting bias since contributions can only be made if community members have both necessary technology and spare time (Dickinson et al. 2010; Courter et al. 2012; Geldmann et al. 2016). Additionally, unstructured, contributory CS projects may be inadequate for measuring elusive species such as urban canids (Gehrt et al. 2011), since such CS methods require detection of wildlife by untrained members of the public (Mueller et al. 2019). Even so, the use of CS data has arisen independently for several urban areas (Co-Existing with Coyotes; Vancouver, BC; The Portland Urban Coyote Project; Portland, OR; UW Urban Canid Project; Madison, WI; The District Coyote Project; Washington, DC) as an attempt to map local canid space-use using information collected by volunteer members of the community. These maps are often created to aid in local management, allowing managers to detect patterns of human-canid interactions. But little is known about how the conclusions drawn from these data compare to data generated by other methods. Indeed, only one study has evaluated the efficacy of CS compared to traditional wildlife monitoring methods and found around 60% overlap between methods (Mueller et al. 2019). As a result, we know little about whether these different data collection methods provide equivalent information allowing CS methods to replace traditional field methodology for some questions and management needs.

Our study addresses this gap in knowledge by (1) evaluating how human influence affects data from a low-cost CS effort and the field methodology of camera traps, and (2) evaluating whether advertising a CS project on social media benefits a management agency. To address the first objective, we simultaneously conducted a camera trap and CS study on coyotes and red foxes in Wichita, Kansas, USA. We developed a website for community members to report their sightings of canids, monitored canid occupancy and activity patterns using a camera grid across the city. We then analyzed how each method varies with human influence. Based on previous research, we hypothesized that CS data will be significantly related to each of our variables of human influence. Specifically, we predicted that due to needing spare time and access to technology to report sightings, canid sighting submissions would be higher in wealthier areas compared with camera trap records. Additionally, sighting reports would be rare at low building density and farther from roads because of lower human traffic compared with camera trap records. To address the second objective, we advertised our project via social media and press interviews and collected metrics on engagement from the community. We predicted that reported sightings would increase during the time we advertised our project. This study is the first of its kind simultaneously evaluating whether volunteer-reported sightings and data collected from camera traps on urban canids are affected by human influence. Our study will help inform how useful CS studies are in this context and what other benefits can be gained from advertising such projects.

CHAPTER II

METHODS

Study Area

The study was conducted in the city of Wichita, Kansas, the 49th largest city in the United States, which is in Sedgwick County. Wichita currently has a stable population of about 400,000 people (U.S. Census Bureau 2020). Relative to the US, it has a below-average median income ($53,466, U.S. avg: ~$65,000; U.S. Census Bureau 2020) and home value ($138,100, U.S. avg: ~$230,000; U.S. Census Bureau 2020). Wichita also has a below-average amount of park land as a percentage of total land (4.7% of the city's total acreage is park land compared to a median of 8.2% for all major U.S. cities; Harnik et al. 2015). Just over half (55%) of the park land is designed (e.g. neighborhood parks, golf courses, cemeteries) and the remainder is designated as natural (Harnik et al. 2015).

The city is surrounded mostly by cropland and grasslands. East of Wichita is the Flint Hills, the largest area of remaining undeveloped tallgrass prairie in the U.S. (Towne and Craine 2016). Large predators such as wolves, mountain lions, and bears were extirpated from the state of Kansas by the early 1900s, and they are only beginning to return in small numbers over the last 15 years (Kansas Department of Wildlife and Parks). For the last 100 years, coyotes have served as the apex predator, feeding mostly on small mammals (Gier 1967). Red fox populations in Kansas have historically fluctuated, increasing significantly after their reintroduction for sport hunting in the 1930s (Zumbaugh and Choate 1985). The other carnivores in the area include gray foxes (*Urocyon cinereoargenteus*), swift foxes (*Vulpes velox*), bobcats (*Lynx rufus*), North

American river otters (*Lontra canadensis*), raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), and Virginia opossums (*Didelphis virginiana*).

The Animal Services Section of the Wichita City Police Department and licensed animal damage control businesses permitted by Kansas Department of Wildlife and Parks (KDWP) respond and remove coyotes and foxes deemed to be dangerous, sick, or causing property damage within Wichita. Outside of the city limits, coyotes can be hunted year-round and trapped during the legal furbearer harvesting season which generally runs from November to February. Red foxes can be taken during the legal furbearer harvesting season.

Camera Traps

To estimate occupancy and activity patterns of urban canids, we established a grid of motion-triggered camera traps throughout the city of Wichita. Cameras (n = 67, Strike Force Pro X, Browning Trail Cameras, Birmingham, AL, USA) were set up in a hexagonal grid spaced 3 km apart and placed within a 300-m buffer around the center of each grid cell (Fig. 1). This spacing created grid cells which were approximately half the size of coyote home ranges and twice the size of red fox home ranges in North America (Gosselink 2003; Gehrt and Riley 2010; Mueller 2018). Each camera was placed 0.5-1 m off the ground, secured on a tree or post using a security box and a cable lock, and angled at a trail or road if one was present. Cameras were set to take bursts of three pictures with a 30-second delay. Cameras were placed to avoid being seen and disturbed by humans, but cameras that were damaged or stolen (n = 7) during the study were redeployed in different locations within the same grid in hopes of minimizing repeated theft. Cameras were set for five weeks during each of four seasons: spring 2023 (May 13 - June 17), summer 2023 (July 1 - August 5), fall 2023 (September 30 - October 4), and winter 2023-24 (December 23 - January 27; Kays et al. 2020).

All camera images were processed with Microsoft MegaDetector v5 (Beery et al. 2019) to remove false detections. Images with an animal confidence score lower than 0.2 were removed. The remaining images were manually tagged by species using the image processing program Timelapse2 (Greenburg et al. 2023) and used to generate weekly detection histories for coyotes and red foxes.

Citizen Science

In March of 2023, we created a project webpage on the KDWP website (https://ksoutdoors.com/Wildlife-Habitats/Wildlife-Sightings/Wichita-Urban-Coyote-and-Fox-Project). The website allows members of the public to report their sightings of coyotes and red foxes in Wichita using Survey123 (Chivite 2016). We publicized this website by posting flyers in multiple languages (e.g. English, Spanish), notifying interested groups (e.g. City of Wichita, Sedgwick County, city-wide homeowners association governance board), and advertising on social media. On the website, volunteer community members were allowed to fill out a form with information about canid sightings including the specific location using both a GPS-based map with drag and pin locator along with a physical address if known, date, time, species, habitat, behavior, count, and how seeing the animal made the person feel.

Sightings were only kept for analysis if they met certain criteria. The criteria were: (1) they were located in our study area, defined by the area encompassing our camera grid; (2) the sighting was between the dates of 1 March 2023 and 29 February 2024, also matching our camera survey; (3) the species sighted was a coyote or red fox; and (4) the sighting was of a living animal. Sightings were also removed if they did not move the location marker on the map nor provide a sufficient description or address of the sighting for us to validate accuracy.

Model Covariates

We chose both anthropogenic and habitat covariates in our study area. Due to our hypothesis that human influence would be related to reporting of canids, three metrics of human influence were used to assess reported space-use of coyotes and red foxes. First, we measured the distance from each camera trap or CS sighting point to the nearest road using the Sedgwick County Geographic Information Services (SCGIS) road layer (Sedgwick County 2023). Second, we estimated building density around each camera trap or CS sighting point. Building density was calculated by determining the percentage of land covered by buildings within a 1-km radius of each point. Building footprints were given by the SCGIS building footprint layer (Sedgwick County 2011). Proximity to roads is assumed to reflect accessibility of an area to humans, whereas building density is assumed to indicate human density. Our third anthropogenic variable was median household income, which was taken from Esri Updated Demographics Variables 2023 (ESRI 2023). Income was calculated by averaging the median household income within a 1-km radius around each point and assumed to reflect likelihood of having the means of contributing to a CS effort. For habitat variables we identified water and green space as variables that may influence canid space use. However, occurrence of green space was correlated > 0.6 to building density and was therefore removed. We used distance to water given by the SCGIS lakes and hydrology layer (Sedgwick County 2023).

Statistical Analyses

To describe space-use by coyotes and red foxes from the camera traps, we used two single-species multi-season occupancy models (Mackenzie et al. 2003). We included building density and mean household income in a 1-km radius as well as distance to roads and distance to water as occupancy covariates. We allowed for a quadratic effect of building density. Additionally, we included three detection covariates: season, the number of days in a week the camera was active, and a categorical variable of whether the camera was pointed at a road (n = 5), trail (n = 31), open area (n = 34), or enclosed area (n = 4). We used a generalized linear model to analyze how the CS sightings differ from randomly generated background points. We generated an increasing number of random background points within our study area until model estimates remained consistent, which occurred around 1000 background points for each sighting. We used the same covariates as the occupancy covariates: distance to roads, a quadratic effect of building density within 1 km, and mean household income within 1 km.

Time of day patterns were created using kernel density functions applied to both the camera trap detections and CS sightings of each species. We further broke CS sightings into those in which the animal was detected on a remote camera vs. sightings of animals which were only detected in-person. Overlap in time-of-day patterns by species, method, and type of sighting were calculated. All analysis was done in RStudio v. 4.2.1 (R Core Team, 2022) with the package unmarked for occupancy models (Kellner et al. 2023), activity for activity plots (Rowcliffe 2023), overlap for calculating overlap (Meredith et al. 2024), lme4 for generalized linear models (Bates et al. 2015), and tidyverse for data organization and visualization (Wickham et al. 2019).

Benefits Of Citizen Science

We used CS data to address our second objective to evaluate the benefits to different stakeholder groups. To increase awareness about our project, we paid for advertisements on two social media platforms: Facebook and Instagram. The advertisements were set to run concurrently with our camera-trap sessions to maximize overlap, although we were unable to align dates exactly for logistical reasons. The advertisements ran in the spring (28 March – 27 April 2023), fall (2 October – 31 October 2023), and winter (22 December 2023 – 5 January 2024, and 25 January – 16 February 2024). We collected data on the amount of money spent per day, engagement measured as views and clicks, and amount of money raised through purchases of licenses or permits on the KDWP website. Additionally, the KDWP has been gathering data since 2011 on the number of calls they have received complaining about nuisance coyotes and red foxes and we tracked changes during the advertisement periods. We also summarized data collected from the remaining questions on the survey form (e.g. how the sighting made people feel, count of animals, etc.)

CHAPTER III

RESULTS

Camera Traps

We captured 780 pictures in 371 bursts of coyotes and 631 pictures in 274 bursts of red foxes from 67 cameras in 74 camera locations over 8190 trap nights. Occupancy was statistically significantly and negatively related with building density for coyotes ($\beta = -2.782 \pm 1.399$, $p = 0.047$, Table 1, Fig. 2) and was positively but not statistically significantly related with building density for red foxes ($\beta = 1.242 \pm 0.688$, $p = 0.071$, Table 1, Fig. 2). There was no statistically significant quadratic effect of building density for either species (coyotes: $\beta = -1.802 \pm 1.157$, $p = 0.119$, red foxes: $\beta = -0.184 \pm 0.345$, $p = 0.594$, Table 1, Fig. 2). Occupancy was not statistically significantly related to distance to roads (coyotes: $\beta = 0.518 \pm 0.486$, $p = 0.287$, red foxes: $\beta = -0.649 \pm 0.586$, $p = 0.268$, Table 1, Fig. 2), median household income (coyotes: $\beta = 0.770 \pm 0.457$, $p = 0.092$, red foxes: $\beta = 0.477 \pm 0.476$, $p = 0.316$, Table 1, Fig. 2), or distance to water for either species (coyotes: $\beta = 0.185 \pm 0.432$, $p = 0.669$, red foxes: $\beta = -0.433 \pm 0.445$, $p = 0.330$, Table 1, Fig. 2).

The average probability of detecting a coyote was 0.365 (Table 2), while the probability of detecting a red fox was 0.168 (Table 2). The location of the camera, number of days the camera was active, and season had no effect on detection probability for coyotes (Table 2). The same pattern was seen for red fox detection except in the fall; red foxes were more likely to be detected in the fall compared to the spring ($\beta = 1.034 \pm 0.449$, $p = 0.021$, Table 2).

Citizen Science

We received 2007 reports of wildlife sightings between March 2023 - February 2024. We removed 500 for having an unclear location or being outside of our study area, 22 because they were of a different species or it was not possible to determine the species, and 20 due to being reported as roadkill. Thus, we retained 1465 CS reports based on our criteria, of which 444 were reports of coyotes and 1021 were of red foxes. A higher proportion of coyote reports listed people reported being worried or scared and a smaller proportion listed feeling happy or lucky compared to red fox reports (Appendix Table 3). A summary of the remaining responses to the questions on our form can be found in the Appendix.

Both coyotes and red foxes were more likely to be reported close to roads (coyotes: $\beta = -0.221 \pm 0.052$, $p < 0.001$, red foxes: $\beta = -0.87 \pm 0.034$, $p < 0.001$, Table 1, Fig. 3). Coyote and red fox reported sightings were also both more likely in areas with a higher mean annual household income (coyotes: $\beta = 0.334 \pm 0.050$, $p < 0.001$, red foxes: $\beta = 0.256 \pm 0.035$, $p < 0.001$, Table 1, Fig. 3). Both species were also most likely to be reported at intermediate building densities; building density was statistically significant for both coyote and red fox sightings linearly (coyotes: $\beta = 0.558 \pm 0.082$, $p < 0.001$, red foxes: $\beta = 1.578 \pm 0.089$, $p < 0.001$, Table 1, Fig. 3) and quadratically (coyotes: $\beta = -0.881 \pm 0.089$, $p < 0.001$, red foxes: $\beta = -0.717 \pm 0.059$, $p < 0.001$, Table 1, Fig. 3). Reported coyote sightings peaked around 10% building cover whereas red fox sightings peaked around 15% building cover. Coyotes were more likely to be reported close to water ($\beta = -0.199 \pm 0.044$, $p < 0.001$), and red foxes were not ($\beta = 0.039 \pm 0.040$, $p = 0.342$).

Activity Patterns

Coyotes were most likely to be detected by camera traps during the night, between 21:00 and 06:00, with a peak around 01:00 (Fig. 4A). Red foxes were most likely detected by camera traps at night, between 19:00 and 06:00, with a primary peak at 04:00 and a secondary peak at 23:00 (Fig. 4A). Humans were most likely to be detected by camera traps during the day (Fig. 4A). People were most likely to report detecting both species around sunrise and sunset, with peaks around 21:00 and 07:00 (Fig. 4B). Canids were least likely to be detected on cameras or by people during daylight hours, between 09:00 and 17:00 (Fig. 4B). This differed by type of sighting. Canid sighting reports from remote cameras peaked during the night and were least likely during the day, whereas canid reports from in-person sightings showed two distinct peaks around sunrise and again around sunset (Fig. 4C-D).

Daily activity of coyotes and red foxes showed low overlap by type of data and high overlap by species. There was high overlap between coyote sighting report activity and red fox sighting report activity ($\Delta_4 = 0.919$). Similarly, coyotes were photographed on camera traps at similar times to red foxes ($\Delta_4 = 0.855$). However, for both coyotes and red foxes, CS sighting reports and detections on camera had lower overlap (coyotes: $\Delta_4 = 0.690$; red foxes: $\Delta_4 = 0.656$). Additionally, in-person coyote sighting reports had high overlap with in-person red fox sighting reports ($\Delta_4 = 0.904$), and coyote sightings detected by remote cameras had high overlap with red fox sightings detected by remote cameras ($\Delta_4 = 0.919$). However, in-person sightings had low overlap with sightings from remote cameras for both species (coyotes: $\Delta_4 = 0.708$; red foxes: $\Delta_4 = 0.725$).

Benefits Of Citizen Science

Over the course of the study, $4561.13 was spent advertising the project over 119 days, an average of $38.33 per advertisement day. Advertisements were highly related to increases in sightings; the days with advertisements averaged 9.59 reported sightings compared to 3.27 sightings on days when advertisements did not run (Fig. 5). KDWP received $27,578 in revenue directly from the advertisements, an average of $231.75 per day (Fig. 5). On average the return on investment was $6.05. KDWP also received a total of 2.28 million impressions and 3486 website page views directly from the advertisement links.

During 2011 - 2022, the KDWP received an average of 8.3 nuisance coyote calls and 3.5 nuisance red fox calls per year. In 2023, the first year of our project, this number was 15 for coyotes and 9 for red foxes. During the first four months of 2024, KDWP received 8 calls for coyotes and 15 calls for red foxes.

CHAPTER IV

DISCUSSION

Our study found that CS data was statistically related to all our anthropogenic variables, and camera trap data was not significantly related to most of our variables. Additionally, we found that CS programs can provide other benefits for managers and the community. Coyote and red fox presence models based on the CS sighting reports related to distance to roads, building density, and income. This contrasted with occupancy models from camera trapping, where canid occupancy was not related to distance to roads or income and only related to building density for coyotes. We found that advertising the project increased the number of reported sightings, connected concerned community members with the proper resources and managers to address their concerns, allowed managers to learn how interactions with urban canids makes people feel, and directly generated revenue for a state agency. In turn, CS data provided information on human-carnivore interactions for urban wildlife managers with the state agency.

Our camera-trap results suggest the distribution of urban canids is not strongly influenced by the variables we chose related to human development. There were no statistically significant relationships between the probability of occurrence of red foxes and any of our anthropogenic covariates from our camera-trap data. Red fox presence may be positively associated with building density, but that finding was not statistically significant. This is in line with other studies which have found red foxes do not respond negatively to increased urbanization (Mueller 2018; Alexandre et al. 2019; Handler et al. 2019). For coyotes, no covariates were statistically significant except for a negative linear relationship between building density and coyote occupancy. These results suggest coyotes tolerated human activity and human structures to some threshold but preferred lower levels of urbanization. This aligns with previous research that found coyote but not red fox occurrence is negatively correlated with urbanization (Gehrt et al. 2011; Gese et al. 2012; Hursh et al. 2023). While median household income is usually related to green space in cities and that can increase the presence of urban canids (Magle et al. 2016), our camera trap data does not suggest that canids were selecting for areas of higher income. This may be because there was a low correlation between income and distance to greenspace in Wichita. Overall, our camera trap results suggest that foxes are relatively unaffected by the human disturbance related variables we investigated here, while coyotes are sensitive to increased building density.

The CS sightings showed statistically significant relationships between coyote and red fox presence and our three covariates. Coyote and red fox sighting reports increased closer to roads. People may be more likely to see animals close to roads because they are likely driving on or walking next to roads and roads provide long stretches of open land, allowing for easier sightings at greater distances (Mueller et al. 2019). Other studies have similarly found roads to be a source of bias with CS data being disproportionately closer to roads (Mair and Ruete 2016; Tiago et al. 2017; Cretois et al. 2021). Sighting reports were also higher in areas with higher median household incomes. CS reports of canids in areas of higher income may be due to people with higher incomes being more likely to report sightings, as has been found in previous research which showed that people with higher incomes are more likely to participate in CS projects (Pateman et al. 2021; Mahmoudi et al. 2022; Carlen et al. 2024). Both species were detected by people at intermediate building densities. Previous research into the effect of building density on CS data has produced mixed results since some species select against urban areas (Kelling et al. 2015; Walter et al. 2018; Petrovan et al. 2020; Tang et al. 2021). Coyote sightings peaked at a lower building density than red foxes, consistent with the camera-trap data and previous research which show coyotes avoid urbanization more than red foxes (Hursh et al. 2023), but both species were unlikely to be reported at very low building densities. There are likely fewer opportunities for CS sightings in areas with lower building density because these areas are less likely to have people present. Overall, these results largely differed from the data collected by our camera traps.

We found differences between the two methods for estimating how species occurrence related to the three covariates for both species. There were more reported CS sightings for both species closer to roads, while there was no relationship between distance to roads and camera-trap occupancy estimates. Building density was quadratically related to reported CS sightings of both species, whereas on cameras, it was negatively associated with coyotes and not related to red foxes. Income was not significantly related to coyote or red fox occupancy from the camera-trap data. Reported CS sightings, on the other hand, were related to income for both species. We used different methods of analysis and therefore cannot compare the results directly, but note that different results from each of our two methods suggests caution should be taken in the interpretation of results from a single method.

The time of day of the reported sightings and the camera images also differed. On camera, canids were most likely to be detected during the night, but canids were most likely to be detected by people around crepuscular periods (sunrise and sunset). This is likely due to people being more diurnal and therefore having both an increased ability and opportunity to sight wildlife during the day. This is shown by the difference between in-person sightings and those from remote cameras. Most reported in-person sightings occur during the overlap in human and canid activity which occurs around sunrise and sunset, while CS sighting reports from remote cameras were mostly during the night, similar to the camera trap detections. Previous research has found similar patterns; CS reports of urban canids peak in the morning and again late in the evening (Walter et al. 2018; Wilkinson et al. 2023), even though urban canids are most likely to be active at night (McClennen et al. 2001; Riley et al. 2003).

Both camera traps and CS projects can provide biased results and there are numerous tools to account for such biases. Camera trap data may be biased as they are novel objects which emit infrared light which animals may avoid (Brooks et al. 2023), and variation in camera models and placement may affect results (Caravaggi et al. 2020). To mitigate these effects, we used the same camera model throughout the project and accounted for camera placement as a detection covariate. Additionally urban canids are bolder than their rural conspecifics, so they are less likely to be disturbed by novel objects (Breck et al. 2019; Morton et al. 2023). However, we were limited in the number of camera traps we could deploy and therefore our analysis was limited in its statistical power. CS data can be biased due to volunteers collecting the data solely through self-reporting incidental encounters as is done in most CS urban canid projects in North America. But, bias in CS projects can be reduced by directed and repeated sampling (van Strein et al. 2013; Mondain-Monval 2024). Additionally, expected biases can be accounted for during the data analysis process (Backstrom et al. 2024). Finally, both can be used simultaneously as CS can complement data from professional studies (Ruiz-Gutierrez et al. 2021; Stuber et al. 2022; Stillman et al. 2023).

While the results of the reported sightings did not match the results of the camera traps, we found other benefits of creating the CS project. Paid advertisements increased the mean number of sighting reports on days the advertisements were run. In addition, more people reached out to the agency to address concerns about urban canids than in previous years, allowing the management agency to reach concerned members of the public. These projects can increase complaints to agencies as community members become more aware of wildlife issues. This can simultaneously create the false appearance of increased conflict, while providing a resource to people dealing with conflict that they may not have previously known about. These projects also provide information on how people feel about human-canid interactions which managers can use to better educate members of the public on coexistence. An unexpected result of advertising the project was that this project generated revenue for the KDWP. Some people clicked on the link in our advertisement, visited the state agency's website, and made a purchase. These purchases were not related to the urban canid study; our advertisements were solely dedicated to generating sightings for our project and did not ask for any monetary contribution. Yet, the agency generated over six times as much money as they spent on the advertisements. Previous research has demonstrated how participation in CS projects can increase donations towards conservation organizations (Toomey and Domroese 2013; Peter et al. 2021), but this is the first study to document monetary benefits to a management agency. These benefits suggest that advertisements in citizen science projects can be used to generate both interest and revenue.

Our study shows how caution must be applied when interpreting results from CS data because it may not provide data consistent with other methods. CS is a combination of studying people and wildlife. However, CS projects can have many positive effects such as educating people about wildlife, connecting community members with managers, and generating revenue for management agencies.

TABLES

Table 1. Occurrence estimates from occupancy models and generalized linear models for coyotes (*Canis latrans*) and red foxes (*Vulpes vulpes*) in Wichita, Kansas, USA, from March 2023 to February 2024. 95% confidence values are in parentheses, statistically significant values are in bold.

Occurrence Covariate	**Sightings (Presence)**		**Cameras (Occupancy)**	
	Coyotes	**Red Foxes**	**Coyotes**	**Red Foxes**
Intercept	**-6.48 (-6.62, -6.34)**	**-7.16 (-7.27, -7.06)**	-0.46 (-1.61, 0.69)	-0.88 (-2.00, 0.25)
Distance to Roads	**-0.22 (-0.32, -0.12)**	**-0.49 (-0.55, -0.42)**	0.52 (-0.44, 1.47)	-0.65 (-1.80, 0.50)
Building Density	**0.56 (0.40, 0.72)**	**1.58 (1.41, 1.76)**	**-2.78 (-5.52, -0.04)**	1.24 (-0.11, 2.59)
Building Density^2	**-0.88 (-1.06, -0.71)**	**-0.72 (-0.84, -0.61)**	-1.80 (-4.07, 0.46)	-0.18 (-0.86, 0.49)
Income	**0.33 (0.24, 0.43)**	**0.26 (0.19, 0.32)**	0.77 (-0.12, 1.67)	0.48 (-0.46, 1.41)
Distance to Water	**-0.20 (-0.28, -0.11)**	0.04 (-0.04, 0.12)	0.19 (-0.66, 1.03)	-0.43 (-1.30, 0.44)

Table 2. Detection estimates from the camera-trap occupancy model for coyotes and red foxes in Wichita, Kansas, from March 2023 to February 2024. 95% confidence values are in parentheses, statistically significant values are in bold.

Detection Covariate	**Coyote**	**Red Fox**
Intercept (Open, Spring)	-0.55 (-1.2, 0.1)	-1.6 (-2.6, -0.6)
Fenced Area	-0.08 (-0.87, 0.71)	-0.24 (-1.64, 1.16)
Path	-0.25 (-0.66, 0.15)	0.28 (-0.21, 0.77)
Road	0.56 (-0.31, 1.42)	0.43 (-0.57, 1.43)
Days Camera Active	-0.03 (-0.1, 0.03)	0.03 (-0.06, 0.12)
Summer	-0.24 (-0.84, 0.36)	-0.69 (-1.62, 0.24)
Fall	0.14 (-0.49, 0.78)	**1.03 (0.15, 1.91)**
Winter	0.26 (-0.41, 0.94)	0.88 (-0.08, 1.84)

FIGURES

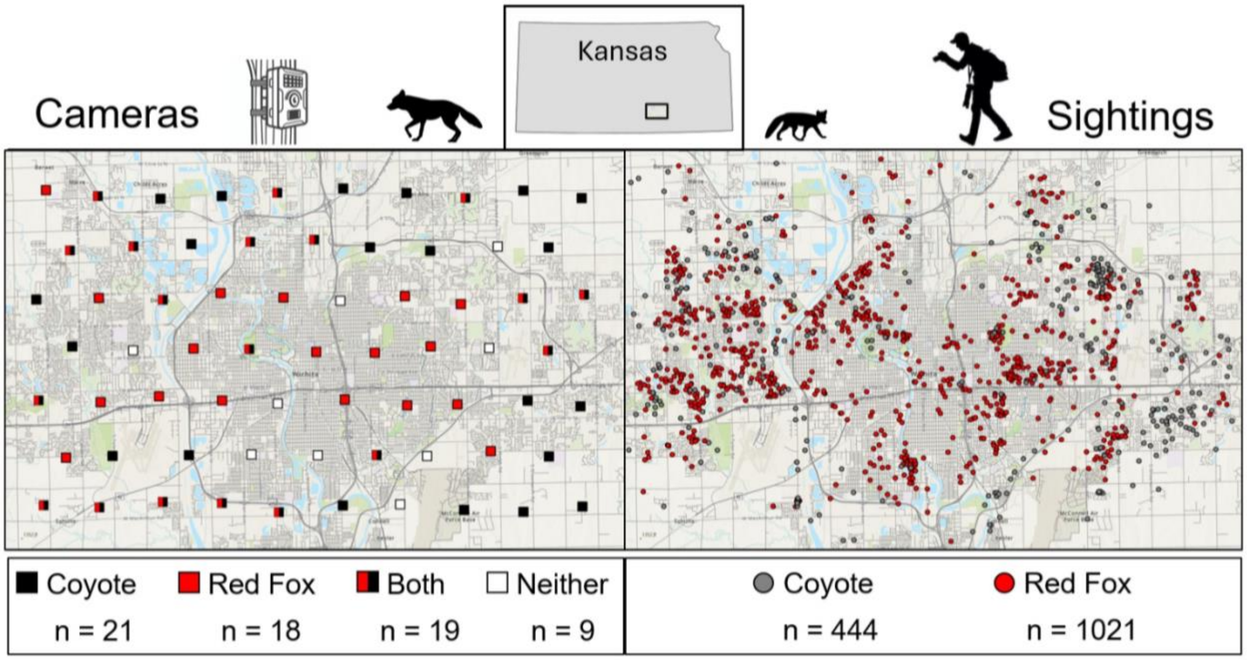

Figure 1. Locations of camera traps and citizen science sightings across Wichita, Kansas, from March 2023 to February 2024. Cameras and sightings of coyotes are in black and gray, respectively. Cameras and sightings of red foxes are in red in both panels.

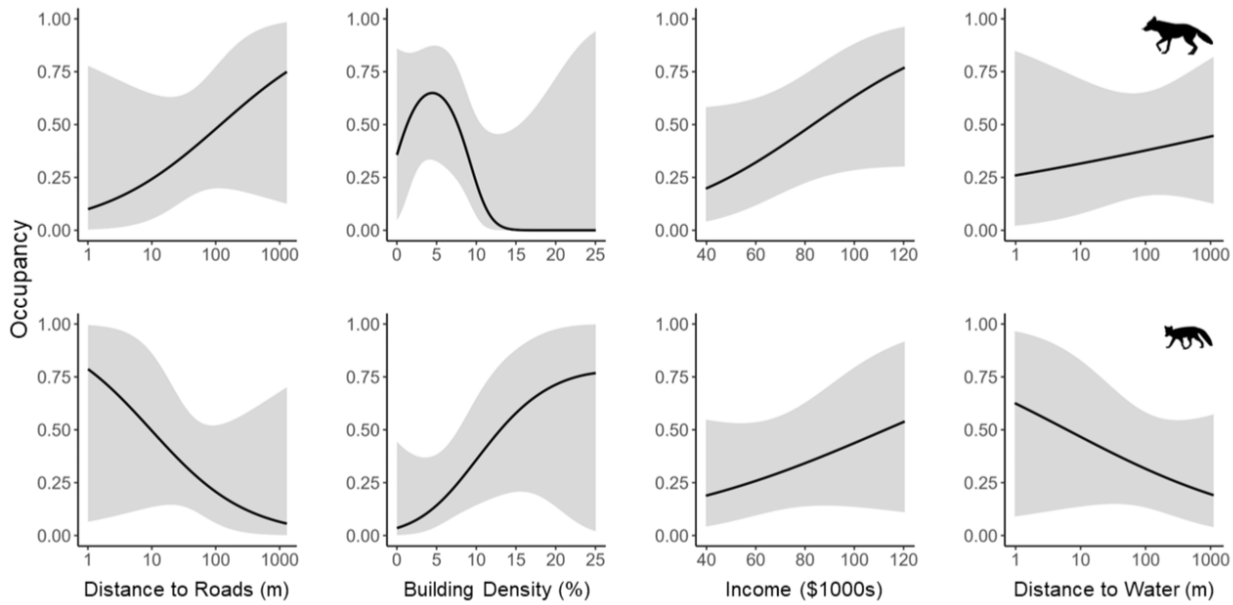

Figure 2. Occupancy probability in relation to distance to roads, building density, and median household income from detection histories created from camera-trap data for coyotes (top) and red foxes (bottom) in Wichita, Kansas, from March 2023 to February 2024. Gray shading indicates 95% confidence interval.

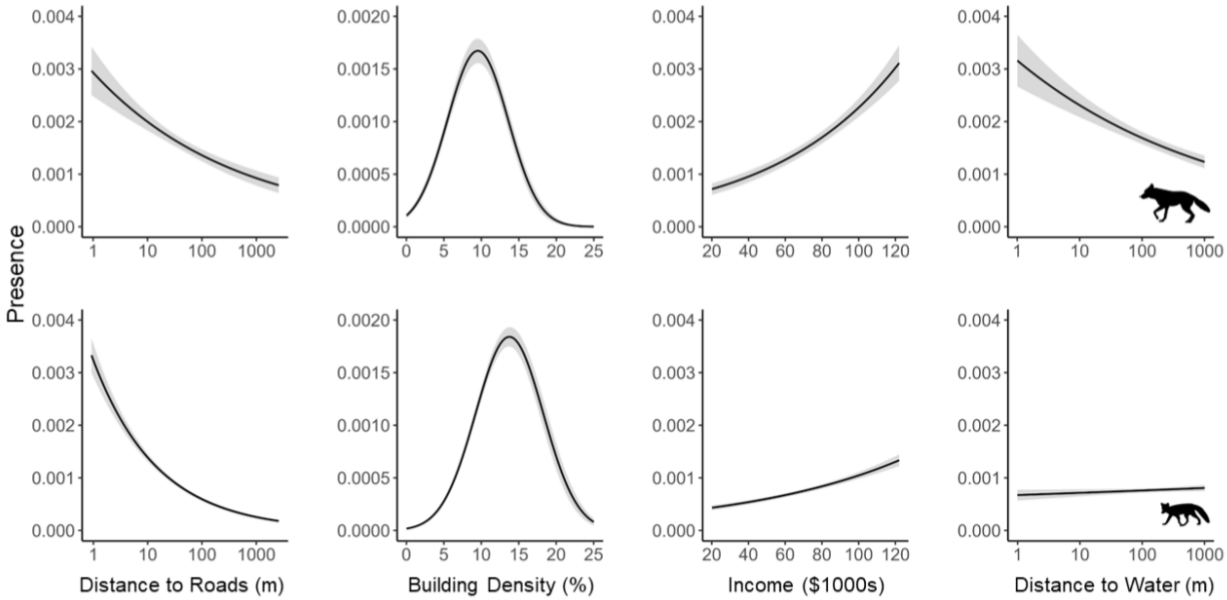

Figure 3. Probability of presence of citizen science sightings in relation to distance to roads, building density, and median household income for coyotes (top) and red foxes (bottom) in Wichita, Kansas, from March 2023 to February 2024. Gray shading indicates 95% confidence interval.

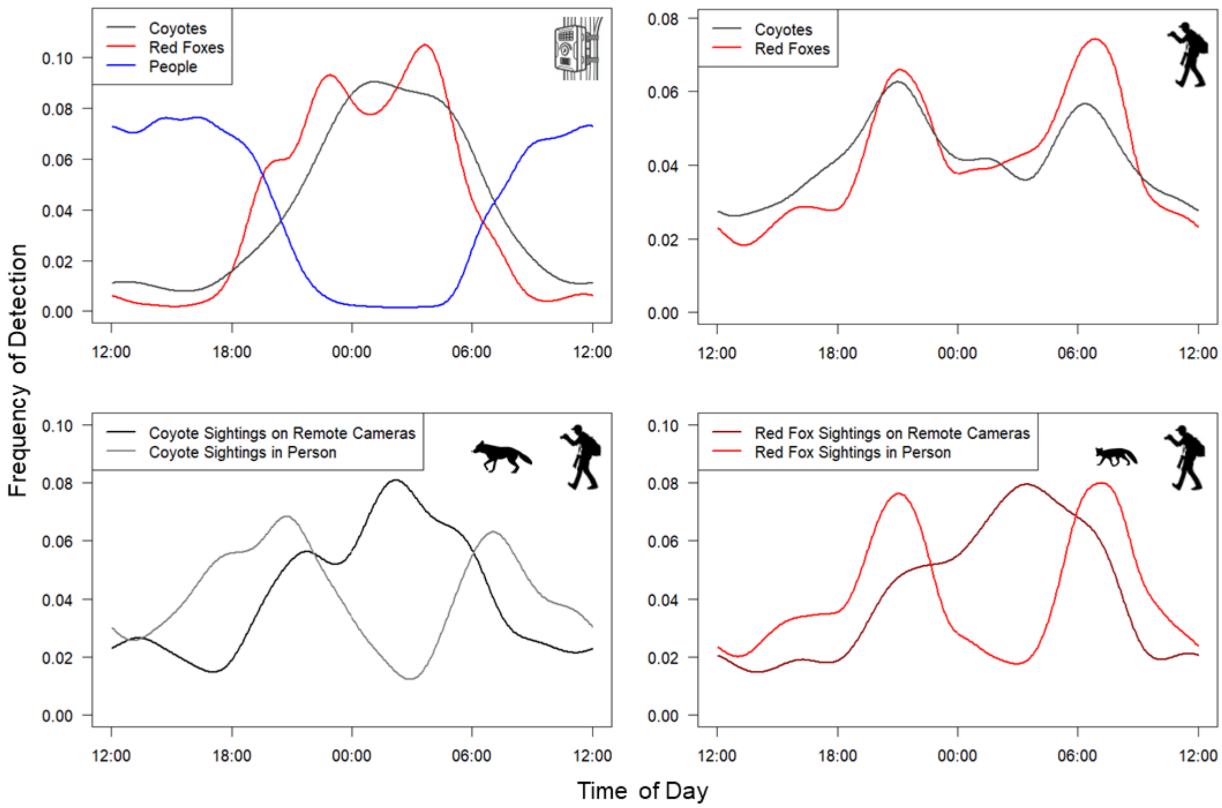

Figure 4. Daily activity of coyotes, red foxes, and people detected by camera traps and CS in Wichita, Kansas, from March 2023 to February 2024. (A) Activity of coyotes, red foxes, and people detected by camera traps. (B) Activity of coyotes and red foxes detected by CS sighting reports. (C) Activity of reported coyote sightings in person and on remote cameras. (D) Activity of reported red fox sightings in person and on remote cameras.

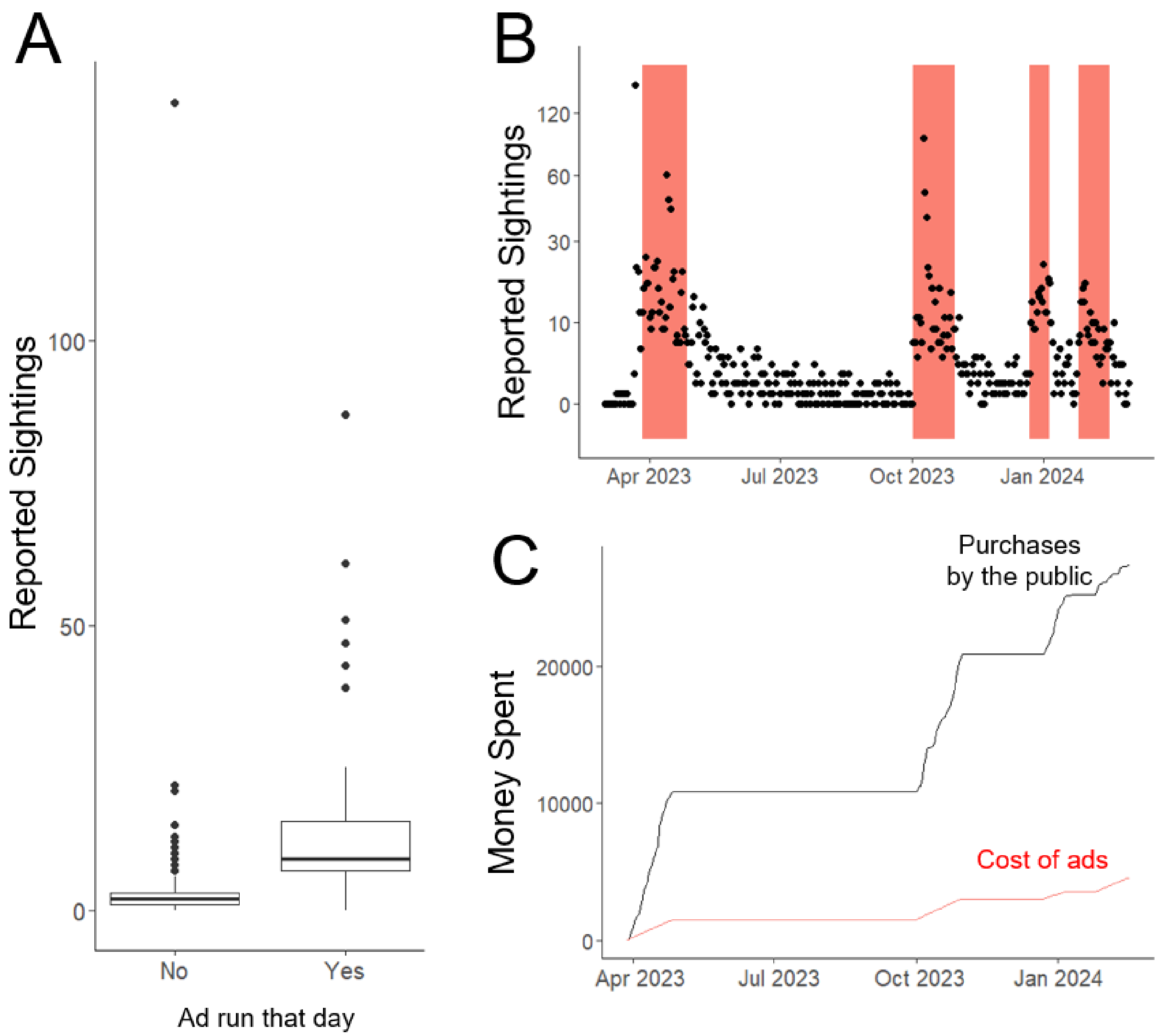

Figure 5. (A) Number of CS sightings on days the advertisements were or were not run in Wichita, Kansas, from March 2023 to February 2024. (B) Number of CS sightings across time. Red lines indicate periods when the advertisements were run. (C) The number of United States Dollars (USD) spent on the advertisements (red) vs. money generated by purchases on the KDWP website by members of the public (black).

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APPENDIX

SUMMARY OF SIGHTING FORM RESPONSES

Table 3. Results of responses to survey form. (n = 1485)

Question Asked	Species	Response Given	Count of Responses	Proportion of Respondents
What was the animal doing?	Coyote	Moving Slow	162	0.364
		Moving Fast	188	0.422
		Mostly Stationary	50	0.112
		Vocalizing	49	0.11
		Hunting/Eating	20	0.0449
		Interacting with human/pet	38	0.0854
		Roadkill/Dead	1	0.00225
		Other	46	0.103
	Red Fox	Moving Slow	436	0.419
		Moving Fast	374	0.36
		Mostly Stationary	174	0.167
		Vocalizing	124	0.119
		Hunting/Eating	31	0.0298
		Interacting with human/pet	46	0.0442
		Roadkill/Dead	19	0.0183
		Other	127	0.122
Please describe the habitat.	Coyote	Street/Sidewalk	96	0.216
		Residential Areas (yards etc.)	209	0.47
		Parking Lot	9	0.0202
		Wetlands (In/around lakes, rivers, etc.)	56	0.126
		Forested Area	38	0.0854
		Neighborhood Park, Open Field, Golf Course, etc.	123	0.276
		Other	74	0.166
	Red Fox	Street/Sidewalk	322	0.31
		Residential Areas (yards etc.)	727	0.699
		Parking Lot	56	0.0538
		Wetlands (In/around lakes, rivers, etc.)	44	0.0423
		Forested Area	38	0.0365

		Neighborhood Park, Open Field, Golf Course, etc.	109	0.105
		Other	72	0.0692
How many animals of this species did you see in total?	Coyote	1	337	0.757
		2	62	0.139
		3+	46	0.103
	Red Fox	1	872	0.838
		2	99	0.0952
		3+	69	0.0663
Were there any offspring present?	Coyote	No	429	0.964
		1	1	0.00225
		2	2	0.00449
		3+	3	0.00674
		Yes, but did not count how many	10	0.0225
	Red Fox	No	959	0.922
		1	18	0.0173
		2	16	0.0154
		3+	35	0.0337
		Yes, but did not count how many	12	0.0115
Seeing this animal made me feel:	Coyote	Happy	72	0.162
		Lucky	64	0.144
		Scared	48	0.108
		Worried	141	0.317
		Indifferent	109	0.245
		Angry	14	0.0315
		Other	82	0.184
	Red Fox	Happy	511	0.491
		Lucky	355	0.341
		Scared	44	0.0423
		Worried	170	0.163
		Indifferent	160	0.154
		Angry	20	0.0192
		Other	129	0.124