**Title:** A ten-year community reporting database reveals rising coyote boldness and associated human concern in Edmonton, Canada

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**ABSTRACT**

In cities throughout North America, sightings of coyotes (*Canis latrans*) have become common. Reports of human-coyote conflict are also rising, as is the public demand for proactive management to prevent negative human-coyote interactions. Effective and proactive management can be informed by the direct observations of community members, who can report their interactions with coyotes and describe the location, time, and context that led to their interactions. To assess the predictors of human-coyote conflict, we used a web-based reporting system to collect *N* = 9,134 community-supplied reports of coyotes in Edmonton, Canada, between January 2012 and December 2021. We used a standardized ordinal ranking system to score each report on two indicators of human-coyote conflict: the actual risk of negative interactions, as indicated by coyote boldness, and the perceived risk of such interactions, reflected in human concern about coyotes. We assigned greater conflict scores to behaviours that included a, b, c, and perceptions that included d, e, f. Using ordered logistic regression and chi-square tests, we compared conflict scores for each response variable to spatial, temporal, and contextual covariates. . Our analysis showed that coyotes were bolder in less developed open areas and during the pup rearing season, but human concern was highest in residential areas and during the dispersal season. Reports that mentioned pets or children were more likely to describe greater boldness by coyotes and negative perceptions by people. Coyote boldness and human concern both increased over the 10 years of reporting..

**Keywords:** Human-coyote conflict, community science, *Canis latrans*, urban

**INTRODUCTION**

Coyotes (*Canis latrans*) are a common example of an urban-adapted species and in the largest carnivore that is common in cities across North America (Schell et al. 2020). Coyotes thrive in urban areas largely by avoiding interactions with humans (Mowry et al. 2020, Drake et al. 2021) while benefitting from reduced competition with other predators (Prugh et al. 2009), less human persecution in urban compared to rural areas (Collins and Kays 2011), and abundant urban food resources such as rodents, garbage, compost and fruit trees (Fedriani et al. 2001, Murray et al. 2015a, Sugden et al. 2021). Coyotes in urban areas potentially improve human quality of life by regulating populations rodents, hares, insects, and smaller predators (Crooks and Soule 1999), supporting a sense of of connection with nature, and providing aesthetic enjoyment that are often inherent in seeing wild animals (Soulsbury and White 2015, Cox and Gaston 2018). For these reasons, many people living in cities tolerate, and even appreciate, urban coyotes (Soulsbury and White 2015, Sponarski et al. 2018). However, over the past two decades, there have been increasing reports of bold and aggressive interactions between urban coyotes and people that are indicative of human-coyote conflict and reduce the tolerance of people for populations of urban coyotes (Baker and Timm 2017, Poessel et al. 2017). A better understanding of the circumstances associated with conflict could inform approaches to public education and coyote management to support human-coyote coexistence in urban areas.

The level of conflict between humans and coyotes can be assessed in two broad ways; presence of coyote behaviours, such as boldness, associated with conflict and human perception of conflict, such as fear. The risk of conflict that coyote behaviour presents to people or pets is often studied retroactively based on attacks (White and Gehrt 2009, Baker and Timm 2017). Coyote attacks on pets are usually attributed to predation or the defense of territories or dens (Gehrt et al. 2013, Poessel et al. 2017, Nation and St. Clair 2019). Attacks on humans are rare, but typically generate substantial media attention and degrade public tolerance (Alexander and Quinn 2011, Draheim et al. 2019). These attacks are often preceded by increasingly bold or aggressive behaviour, which is frequently caused by increasing coyote habituation to people (Baker and Timm 2017) and associated food conditioning (refs). To date, no analysis has examined the correlates of bold behaviour by urban coyotes as reported by members of the public. .

Human perceptions of coyotes may be positive, neutral or negative, with negative perceptions typically relating to fear of harm to themselves, children, or pets when they see or interact with a coyote. Negative perceptions of coyotes with fear of conflict may not align with the actual risk of injury, but still reduce public tolerance of coyotes, and, consequently, public attitudes towards various forms of wildlife management and policy (Sponarski et al. 2018; Draheim et al. 2019). When attacks on people occur or attacks on pets are prevalent, public demand for lethal management typically increases and targeted removals of problem individuals can rapidly reduce public perceptions of conflict nd (Breck et al. 2017), These circumstances make the perception of risk by the public an informative metric for coyote management and one for which correlates might also be studied to guide proactive, non-lethal management efforts to minimize potential conflict.

Public reports that describe coyote behaviour and human perceptions could both be examined with spatial, temporal and contextual variables via predictive models. . Spatial variables used to predict negative interactions between humans and wildlife must be measured at relevant scales to support management actions (Delsink et al. 2013, van Bommel et al. 2020). For example, knowing which areas have low, moderate or high probabilities of interactions between humans and black bears (*Ursus americanus*) allows for management resources to be more efficiently allocated to improve coexistence (Merkle et al. 2011). Temporal variables may apply to scales that range from diel, through seasonal, to inter-annual, again with a goal of predicting when negative encounters are most likely to occur (Morehouse and Boyce 2017, Soulsbury 2020) so that they can be mitigated more effectively. Additional information for predicting conflict includes contextual variables such as the presence of pets or children, off-leash dogs, and poor health of individual coyotes , which can influence each of coyote behaviour and human perceptions of it. .

The importance of spatial, temporal and contextual variables for predicting coyote behaviour and human perceptions could be advanced with large datasets collected by citizens on public reporting sites. Such databases allow researchers to gather information over many years and large geographic areas, while simultaneously engaging and educating members of the public (Weckel et al. 2010, Frigerio et al. 2018). Previous studies have collected voluntary reports of coyote activity using websites (Wine et al. 2015, Mowry et al. 2020), city reporting databases (Lukasik and Alexander 2011, Poessel et al. 2013), public surveys (Weckel et al. 2010), and cell phone apps (Mueller et al. 2019, Drake et al. 2021). Past analyses of these datasets have shown that reporting varies across development levels and land cover types, coyote seasons (e.g., breeding, denning, dispersal), and with household income and education (Weckel et al. 2010, Poessel et al. 2013, Wine et al. 2015, Mowry et al. 2020),. Lukasik and Alexander (2011) and Drake, Dubay and Allen (2021) demonstrated that bold coyote behaviour was most prominent in the coyote pup rearing season. These studies also found more negative interactions in areas where coyotes consume more anthropogenic food (Lukasik and Alexander 2011). Despite these advancements, we are not aware of any study that has comparatively assessed the factors that drive changes in both coyote boldness and human concern, or that has investigated changes in the nature of human-coyote interactions over time.

In this study, we used community science reports collected over 10 years from a website hosted by the Edmonton Urban Coyote Project (ref) in Edmonton, Canada to develop two indicators of human-coyote conflict: coyote boldness towards people or pets and the concern people expressed about coyotes. Then, we used spatial, temporal and contextual information in the reports to identify correlates of higher ordinal values for each of coyote boldness and perceived conflict.To our knowledge, our study represents the largest and longest-term community science-based study on human-coyote interactions. By revealing the variables that predict bold behaviour by coyotes and concern about human-coyote conflict for people, we hope to support proactive coyote management and effective public education. In turn, these tools could facilitate sustainable coexistence of humans and coyotes to maximize the ecosystem services, including public enjoyment, of urban coyote populations throughout North America.

**METHODS**

**Study area**

This study occurred in Edmonton, Alberta, Canada (53.54728oN, 113.50068oW), which has an area of684 km2) and a population of 976,223 (City of Edmonton 2019). A combination of large area and moderate population density makes Edmonton one of the most sprawling cities in North America with large areas of undeveloped land (ref). Edmonton has warm summers (Jun-Aug daily average = 16.7°C) and cold winters (Dec-Mar daily average = -9.7°C; Environment and Climate Change Canada 2018). The city is bisected by the North Saskatchewan River valley and several large ravines, which form a network of minimally developed natural areas that provide abundant habitat for coyotes and other wildlife (Figure 1).

**Report collection**

Beginning in September 2010, members of the public were able to voluntarily report coyote sightings or encounters through a web-based platform on the Edmonton Urban Coyote Project website (<https://www.edmontonurbancoyotes.ca/reportsighting.php>). We promoted the website opportunistically during media interviews, public lectures, and social media posts, as well as through word of mouth, on labels attached to wildlife cameras in the city, and via a link on the City of Edmonton website (<https://www.edmonton.ca/residential_neighbourhoods/pets_wildlife/Coyotes.aspx>) that was added in 2019.

When submitting a report, participants? were asked to provide the date, time of day, and nearest intersection of the report location. Time of day was submitted by reporters using a drop-down menu with the option to select either hourly times between 5 AM and midnight, or a general time window (dawn, morning, afternoon, evening, or night). Reporters were also asked to specify whether their report was a “sighting,” defined as an observation of a coyote at a distance with no interaction, or “encounter,” defined as an interaction with a coyote at close range. Reporters were invited to provide free-form comments as well as their name and contact information. For the *N* = 3,366 reports that did not include map coordinates, we determined them *post hoc* based on the reported nearest street intersection and other information in the comments (e.g., if a specific park or building was named). To encourage participation, no registration or login was required.

**Extraction of response variables and contextual variables from reports**

Most reports (96.8 %, *N* = 8,859) included optional comments with further details about the human-coyote interaction including information on coyote behaviour, human perceptions, and various contextual variables. We groomed the database to remove duplicate entries and spam reports, removed the names and contact information of reporters, and then recruited a team of 30 volunteers and undergraduate students who read and classified the comments in each report following a standardized protocol (Appendix 1). For reports with comments that described coyote behaviour, volunteers assessed the degree of boldness on an ordinal scale from one (ran away) to nine (made physical contact with pets or people). We later simplified these categories into a four-point scale defining as avoidance, indifferent, bold, and aggressive behaviours (Table 1). We coded human perception related to the coyote on a three-point ordinal scale based on the explicit presence of words that conveyed positive (e.g., beautiful), neutral (e.g., curious or not scared), or negative (e.g., scared) emotions or attitudes (Table 2).

We coded report comments for the presence of five contextual variables including (1) the human activity occurring at the time of the report (e.g., walking, cycling, driving), (2) the presence or mention of vulnerable individuals (children, dogs or cats), (3) if dogs present were leashed or off leash, (4) the number of coyotes observed, and (5) any mention of coyote health status (e.g., mangy). To assess the repeatability between report classifiers, one author (JJF) randomly selected and re-classified 100 reports for each volunteer. We assessed inter-observer differences by calculating the percentage of reports that generated a different classification for each of the five variables.

**Spatial and temporal variable collection**

To quantify the geospatial setting of each report, we imported report locations into ArcGIS Pro v2.7 (Figure 1). We excluded reports that were located outside of Edmonton city limits or in recently annexed but undeveloped rural land, and we identified our study area by generating a minimum convex polygon around the remaining report locations. Land cover types within our study area were classified using geospatial data from the City of Edmonton Urban Planning Land and Vegetation Inventory (uPLVI) database, a high-resolution database that uses remotely sensed imagery and Softcopy photogrammetry to identify land cover types for urban land use decisions (City of Edmonton 2018). For our study, we binned uPLVI land cover classifications into six land cover types representing various degrees of human development and coyote habitat quality (Table 3). These land cover types were comparable to those used in similar studies in the American cities of New York (Weckel et al. 2010), Denver (Poessel et al. 2013), and Atlanta (Mowry et al. 2020).

Because coyote boldness and human concern may be affected by a combination of site-specific conditions (van Bommel et al. 2020) and broader landscape characteristics (Murray et al. 2015b, Wine et al. 2015), we measured land cover at five different scales; within 100, 200, 400, 800 and 1600 m radii of each report. Land cover was calculated as the proportional area of each land cover type within the circular area defined by each scale. Proportional land cover measurements were then centered and log-ratio transformed to minimize autocorrelation (Quinn et al. 2019). To compare the distribution of reports across different land cover types (see below), we also assigned a single land cover category to each report based on the category with the greatest proportional area within a 100-meter radius of the report.

Building density and road distance have previously been associated with human-coyote encounters (Wine et al. 2015, Drake et al. 2021); therefore, we determined building density based on the proportional area of building footprints within each of the five scales around each report (Statistics Canada 2019). We also measured the distance from each report to the nearest road from the single line street network geospatial database from City of Edmonton. For road distance, we applied an exponential distance decay function (*e*-*0.002d*, where d = meters to the nearest road) to confine values between zero (far from road) and one (on road; Nielsen et al. 2009). All spatial variables were measured in raster format with a 10 x 10-meter cell size.

To support temporal analyses, we measured changes in reporting, coyote boldness, and human concern across years, months, and time of day, as well as across the coyote breeding, pup rearing and dispersal seasons. We manually categorized time of day into either day (after sunrise and before sunset) or night (before sunrise or after sunset). Sunrise and sunset times were specific to Edmonton and were adjusted for seasonal variation. Biologically defined seasons were classified based on the month in which the report was submitted (Morey et al. 2007): breeding (January 1 – April 30), pup rearing (May 1 – August 31), or dispersal (September 1 – December 31).

**Statistical methods**

We began by categorizing our spatial, temporal and contextual patterns in report submissions. For land cover types, we estimated the expected number of reports based on the total proportion of that land cover type within the study area. We then applied Pearson’s chi square test to determine whether reports occurred more or less frequently than expected in each land cover type. To assess how reporting varied over time, we summarized the number of reports in each of the biological coyote seasons for each year from 2012 to 2021, the percentage of reports during each month, and the number of reports from day and nighttime. For each contextual variable we determined the number of reports assigned to each variable category.

To identify the best spatial and temporal predictors of coyote boldness and human concern, we used ordered logistic regression with the *clm* function in the R package ordinal (Christensen 2019). Time of day and contextual variables were strongly correlated with each other (Table 1 in Appendix 3), so we excluded these variables from our models and examined them separately (see below). To identify the best scale for our spatial variables, we used univariate models with the five buffer areas and information criteria to identify the best-fitting (AIC; Burnham and Anderson 2004; Table 2 in Appendix 3) We used a pseudo-optimized multiple scale approach (Mcgarigal et al. 2016) to select the best-fitting of the five measurement scales for each land cover variable by conducting univariate models and retaining the scale with the lowest Akaike’s information criterion value (AIC; Burnham and Anderson 2004; Table 2 in Appendix 3). The optimal scale for each variable was identified separately for coyote boldness and human concern. If a variable’s best-fit scale did not improve on the AIC of the null model, we excluded that variable from further analyses. We then assessed correlations between the remaining variables using Spearman’s rank correlation coefficient (Table 3 and 4 in Appendix 3), and for any pairs of variables where r > 0.6, we removed the variable that produced a higher AIC value in univariate models. All numerical variables were mean centered and scaled with an SD of 1.

For each of coyote boldness and human concern, we constructed global models (Table 5 in Appendix 3) that included each of the non-correlated spatial variables, year, and coyote biological season (using breeding season as the reference) as additive effects. We included interaction terms between year and each of the spatial variables to test if temporal changes in the response variables were associated with specific spatial factors in the urban environment. In models of coyote boldness, we also included interaction terms between biological season and each of natural and modified open area to test for seasonal changes in coyote behaviour that might be associated with denning in these less-developed areas (Dodge and Kashian 2013). Because we were primarily interested in maximizing the explanatory power of our models (ref), we used AIC-based model selection with the *dredge* function from the package MuMIn (Barton 2020) to identify the variables and interactions that were retained in the top models (ΔAIC < 2). To determine whether reports of coyote behaviour or human perceptions changed over the course of our 10-year dataset, we explored these relationships in more detail using linear regressions predicting the percentage of reports within each of the ordinal scores as a function of year.

We explored the effects of time of day and contextual factors on each of coyote boldness and human perceptions using Pearson’s chi square tests of independence (Weckel et al. 2010), followed by *post hoc* tests (chisq.posthoc.test.package; Ebbert 2019) to determine which levels of each factor were most strongly associated with boldness or concern. For these analyses, we included reports for which each contextual variable could not be determined as a reference category. We also used chi square tests to test whether reports that identified bolder coyote behaviour also expressed more human concern and adjusted alpha values for each residual test with Holm’s correction for multiple comparisons (Macdonald and Gardner 2000). We conducted all statistical analyses in R version 4.1.3 (R Core Team 2022) and considered effects to be significant if 95% confidence intervals did not overlap zero or if p values < 0.05.

**RESULTS**

**Reporting patterns**

From September 2, 2010, to December 31, 2021, *N* = 11,239 reports were submitted on the Edmonton Urban Coyote project website. Of these, we removed *N* = 1,722 spam or duplicate reports, *N* = 256 reports that were outside of Edmonton city limits, and *N* = 127 reports from 2010 and 2011 because of limited reporting in these years. The resulting dataset included *N* = 9,134 unique and spatially explicit coyote reports between January 1, 2012, and December 31, 2021. Of the 100 reports that were re-classified to assess classification repeatability, inter-rater agreement for each variable ranged from 85-96% (Table 1 in Appendix 1).

Reports were widely distributed across the city and unevenly spread across land cover types (χ24 = 1,564, p < 0.001; Figure 1). Based on the proportion of each land cover type within our study area, we received more reports than expected in residential (59.1%, *N =* 5,396), mowed grass (12.2%, *N =* 1,111), and natural land cover (10.9 %, *N =* 997) areas and fewer than expected in commercial (11.1%, *N*=1,016) and modified open areas (6.7%, *N*=614). Reporting increased over years, and, within years, was consistently higher in the breeding and dispersal seasons (Figures 2A and 2B). Reports were also more common during the day than at night (Figure 2C). Human activity was discernable in 48.1% (*N* = 4,405) of reports and mostly involved walking (19.1%), being in a home or yard (18.4%) or driving (9.1%; Figure 3). Vulnerable individuals (mostly dogs) were present or mentioned in 30.8% (*N* = 2,816) of reports, and a subset of those reports identified dogs as leashed (11.7%) or off-leash (9.4%). Most reports involved a single coyote (59.4%), and a subset of reports identified coyote health as healthy (13.9%) or unhealthy (6.0%).

Coyotes were most commonly reported as avoidant or indifferent, followed by bold and aggressive (Table 1), though measures of human concern indicated that negativity towards coyotes was much more common than neutral or positive responses. Reports that mentioned physical contact between people or pets and coyotes consisted mostly of dog attacks (*N* = 85), followed by cat depredations (*N* = 50); in only one report did a coyote contact a human while the coyote attempted to take a sled from a child. Among the reports for which both boldness and human concern could be classified, the two variables were significantly related (χ26 = 56.3, p < 0.001), with reports of bold or aggressive behaviour being more likely to express negative perceptions of coyotes (Figure 1 in Appendix 2).

**Spatiotemporal predictors of coyote boldness and human concern**

Ordered logistic regression analysis revealed a suite of spatial and temporal variables that predicted each of coyote boldness and human concern (Figure 4). We present results from only the top models for these response variables (Figure 4) because there was little variation among coefficient and confidence estimates within the full set of top-ranked models (ΔAICc < 2; Tables 6 and 7 in Appendix 3) . The top model predicting coyote boldness indicated that the log odds likelihood of bolder behaviour was higher during the pup rearing season and in areas with higher proportions of mowed land cover (within a 100 m radius), but lower closer to roads and in areas with greater building density (within 200 m). The significant interaction term in this model indicated that boldness was higher during the pup rearing season especially in areas with more modified open land cover (400 m buffer size, Figure 1 in Appendix 3). The top model for human concern indicated that a higher likelihood of human concern was associated with increases in the proportion of residential area (within 800 m) and modified open land cover (within 1600 m), as well as during the dispersal season (Figure 4).

Models for both the coyote boldness and human concern indicated a significant increase in the likelihood of human-coyote conflict over years (Figure 4). None of the interaction terms with year were significant when we considered only the single best model for each response variable (Table 6, Table 7 in Appendix 3); however, for models predicting human concern, the negative interaction term between residential area and year was retained in 19 of 20 top models and was significant in 13 of these (Table 7 in Appendix 3). This interaction indicated that concern was generally higher in residential areas in early years, but increasing levels of concern in non-residential areas reduced the magnitude of effect of residential area over time (Figure 2 in Appendix 3). While several other variables and interaction terms appeared in some of the top models (ΔAICc < 2) for boldness and concern, their effects were not significant in any of these (Tables 6 and 7 in Appendix 3).

We examined these temporal changes in greater detail by evaluating the percentage of reports within each of the ordinal scores for each year (Figure 5). Specifically, the percentage of reports describing bold behaviour increased significantly (β = 2.19, p < 0.001) while avoidance behaviour decreased (β = -1.82, p < 0.001), though there were no differences in the percentage of reports describing indifferent (β = -0.71, p = 0.21) and aggressive behaviour (β = 0.24, p = 0.16). Similarly, negative perceptions about coyotes became more common over years (β = 1.07, p = 0.072) and positive perceptions became less common (β = -1.07, p = 0.005), with no change in the proportion of neutral perceptions (β = 0.002, p = 0.997).

Analysis of diel patterns in coyote boldness showed that indifferent behaviour was significantly more common during the day and avoidance behaviour was significantly more common at night (χ22 = 30.1, P < 0.001; Figure 2 in Appendix 2). However, human concern did not differ between day and night (χ22 = 1.09, P = 0.58).

**Contextual influences on boldness and concern**

All five contextual variables were significantly related to coyote boldness (Figure 6, Table 3 in Appendix 2). described lyAggressive coyote behaviour was reported more frequently than expected when cats or dogs were mentioned, when dogs were off-leash, and when two or more than three coyotes were observed. The least threatening coyote behaviours, avoidance and indifference, occurred mostly in reports when people were driving, cycling, or in their home or yard, when only one coyote was observed, and when coyotes were perceived as healthy.

Most contextual variables were also related to human concern, demonstrating that they were important factors affecting the perceived risk presented by coyotes (Figure 6, Table 3 in Appendix 2). Concern was more frequently reported when dogs, children, or multiple vulnerable individuals were mentioned; conversely, reports that didn’t mention any vulnerable individuals expressed less concern. Perceptions were more likely to be positive when only one coyote was observed and when the coyote(s) were described as healthy.

**DISCUSSION**

Human-coyote conflict is increasing in urban areas throughout North America (White and Gehrt 2009, Baker and Timm 2017), creating a need to better understand the variables that predict conflict so that they can inform future management strategies. We used data from a 10-year database of citizen reports to study whether spatial, temporal, and contextual variables could predict the degree of boldness in descriptions of coyote behaviour and concern in perceptions of coyotes expressed by reporters. We found that descriptions of coyote boldness increased: in residential areas and with building density; over time and in the pup rearing season; and when reporters were walking, mentioned a cat or dog, and when more coyotes were present. Human concern was greater: in areas with higher percentages of residential and modified open land cover; over time and during the dispersal season; and when reporters mentioned vulnerable individuals. Both of boldness and human concern increased significantly from 2012 to 2021.

**Spatiotemporal patterns in coyote boldness**

We found that coyote boldness was higher in less-developed areas that were not naturally vegetated, similar to what was described for open relative to natural areas in Denver, CO, (Poessel et al. 2013) managed clearings in North Carolina (Wine et al. 2015). Collectively, these results suggest that human-coyote conflict in is most prevalent in spaces that are at the interface of natural and developed urban areas. Similar interfaces between peri-urban and rural or rural and wildland areas frequently concentrate human-wildlife conflicts in many other species (König et al. 2020). The pattern we observed may arise because coyotes in open areas are visible at greater distances, and may thus appear to be bolder; alternatively, bolder animals may be more likely to occupy areas with less vegetation cover, as has been reported for brown bears (*Ursus arctos*; Bombieri et al. 2021). This behaviour might be expected of coyotes owing to their evolution in the arid southwest of the North American continent (ref). Our spatial variables were most explanatory of boldness when measured at smaller spatial scales (≤ 400 m radii from reports; Table 2 in Appendix 3), suggesting that boldness is also driven by site-specific factors, like proximity to vegetation cover, territorial boundaries, or dens sites.

Seasonally, boldness was significantly more likely during the summer pup rearing season, which is also consistent with other studies (White and Gehrt 2009, Lukasik and Alexander 2011). The fact that fewer reports were submitted during this period, despite a time of greater outdoor activity by people in our study area, suggests thatthat coyotes avoid humans during pup rearing, but behave more aggressively when interactions occur. Aggression by coyotes during the pup rearing season presumably reflects defence of pups from perceived threats posed by humans or dogs (Bombieri et al. 2018). Many reports described coyotes rushing out of cover to bite large dogs on their hamstrings, suggestive of defensive behaviour. There were also more reports of cat depredations during the pup rearing season (29 of 50 total), probably caused by a combination of coyotes seeking food for their pups and generally greater numbers of free-roaming cats in the summer (Nation and St. Clair 2019).

Boldness during the pup rearing season was particularly associated with modified open areas, which may have been associated with denning by coyotes in these areas. Dens in modified open areas have less vegetative cover than dens in natural areas, which might reduce opportunities for avoidant behaviour and increase defensive aggression. Indeed, reports from natural areas were more likely to describe avoidance (28.9%) than aggression (12.9 %) relative to reports from modified open areas (20.3% avoidance and 20.7% aggression; Table 1 in Appendix 2). An alternative hypothesis is that coyotes denning in more disturbed modified open areas may be more prone to boldness because of repeated exposure to humans and their pets in these areas (Young et al. 2019). In either case, our study shows that coyote behaviour in modified open areas during the pup rearing season may often present a risk to the safety of humans and their pets.

We additionally found that coyote boldness increased over the 10-year reporting period, potentially explaining the mechanism for previous observations of increasing coyote attacks on people in North America (White and Gehrt 2009, Baker and Timm 2017). Both patterns may reflect the greater boldness of urban, relative to rural coyotes that others have reported and attributed to reduced persecution by people, repeated benign interactions with them, and access to anthropogenic food (Breck et al. 2019, Young et al. 2019, Brooks et al. 2020). There is evidence that coyote boldness towards humans is passed from parents to offspring (Schell et al. 2018) and increases with greater exposure to people (Young et al. 2019), both of which could increase coyote boldness over time to accelerate boldness-driven conflict. Separate from these interactions with people, higher coyote population density within cities may lead to intraspecific competition that favours bolder individuals (Bateman and Fleming 2012). A similar mechanism has been described in brown bears, in which tolerance for proximity of conspecifics in dense populations spills over to greater tolerance of people (Herrero et al. 2005) Our top ordinal regression models did not include any interactions between spatial variables and year, suggesting that these changes in boldness were relatively consistent across the urban environment. Despite increases in boldness over time, we did not find a similar increase in aggressive behaviour, possibly because the most aggressive individuals were targeted for removal by city managers.

**Spatiotemporal patterns in human concern**

We coded human perceptions of coyotes described in reports as positive, neutral, and negative to create a metric of human concern that increased with the amount of residential area within 800 m of the report. This observation is similar to previous findings that people are less tolerant of coyotes near their homes despite being generally tolerant of coyotes in cities (Bonnell and Breck 2017, Drake et al. 2020). A similar pattern occurred for cougars (*Puma concolor*) at a rural-wildland interface (Knopff et al. 2016). Such effects show how human concern may not align with the actual risk of a coyote behaving boldly or aggressively: concern was higher in residential areas, but boldness was negatively associated with building density and road proximity, which were correlated with residential area in our study (Table 3 in Appendix 3).

Human concern about coyotes was higher in areas with more modified open land cover, such as x, y, and z, where bold interactions were more likely during the pup rearing season. This land cover may also be disproportionately responsible for the positive correlation we found between reports that described bolder coyotes and greater human concern. Such a correlation may amplified if people gain awareness over time of the bold or aggressive coyote interactions that are more common in those areas, whieh have previously been shown to increase the risk people perceive from coyotes (Sponarski et al. 2018, Draheim et al. 2019). People may respond most to the visibility of coyotes, which is likely highest during the fall dispersal season when our database revealed more reports and higher levels of concern. Interestingly, human concern correlated with land cover variables measured at larger spatial scales (≥ 800 m radii; Table 2 in Appendix 3), than did the measures of boldness derived from descriptions of coyote behaviour. This difference may reveal that coyote behaviour and human perceptions occur on different spatial scales, or, simply, that coyote behaviour is more readily described for animals that are nearby.

Like boldness, human concern about coyotes increased over the 10-year reporting period (Figure 4, 5). This result challenges previous predictions that public acceptance of coyote presence in cities will grow over time (Lawrence and Krausman 2011, Jackman and Rutberg 2015). Such perceptual changes may be quite nuanced. For example, declined inbut mostother Humans are known to habituate to the presence of brown bears (Herrero or Smith et al 2005), x, and y. Public concern about any carnivore may typically increase with increasing carnivore prevalence or boldness if conflict is emphasized by the media (e.g., refs), but it may decline with public education about risk reduction (refs).

**Contextual factors affect coyote boldness and human concern**

Coyote boldness and human concern were predicted by several contextual variables had a strong effect on the type of human-coyote interaction that was reported. Reports describing the presence or mention of vulnerable individuals exhibited higher scores for both of coyote boldness and human concern. The mention of dogs and cats were associated with descriptions of bolder and more aggressive coyote behaviour, supporting the findings of others that human-coyote interactions involving pets are more likely to cause conflict (Poessel et al. 2013, Baker and Timm 2017). Coyotes were described as “aggressive” less often when dogs were leashed (14.6%) compared to when they were described as off leash (32.5%; Table 1 in Appendix 2), but bold behaviour by coyotes was more common when dogs were leashed (39.2%) than off leash (22.3%). This result suggests that leashed dogs may still engender coyote behaviour that is associated with conflict even if they are less likely to be attacked than when they are off leash. We did not find a significant relationship between the presence or mention of children and coyote boldness or aggression. . Nonetheless, human concern was significantly higher when reports mentioned dogs, children, or multiple vulnerable individuals, perhaps because occasional coyote attacks on children are well-publicized and can lead to serious injuries (Carbyn 1989, White and Gehrt 2009, Alexander and Quinn 2011). A higher perceived risk of coyote attacks on pet and children likely reduces tolerance for coyotes in cities (Draheim et al. 2019).

Coyotes were described as being bolder when they were observed with other coyotes and when people were walking whereas expressions of human concern were lower when people were driving or when only a single coyote was mentioned. . Although coyotes in poor health may be more conflict-prone (Murray et al. 2015b), we found no evidence that people found unhealthy animals to be bolder or feared them more. However, coyotes that were perceived to be healthy were more likely to described as avoidant or indifferent. It could be that reporters were less likely to notice and characterise a coyote’s health in encounters where coyotes were behaving boldly or aggressively.

**Limitations**

Our study had several limitations. First, reports were collected non-randomly and non-independently, which introduces several potential biases inherent to community reporting databases (Poessel et al. 2013, Sullivan et al. 2014). These biases include greater tendencies for repeat reporting by residents with particular views (ref), uneven advertising of the reporting database across neighborhoods or over years, potentially higher reporting from affluent neighborhoods with higher education levels (Wine et al. 2015, Mowry et al. 2020), and varying visibility of coyotes across seasons, time of day or land cover types due to differences in vegetative cover, human activity and daylight (Quinn 1995, Poessel et al. 2013). We attempted to mitigate these effects by focusing on measures of coyote boldness and human concern, rather than spatiotemporal influences on the number or distribution of reports. Additionally, we attempted to overcome spatial and temporal autocorrelation in the reports that could contribute to Type 1 statistical errors , by restricting analyses to those with large sample sizes and verifying modelling results with chi-square tests (Table 3 in Appendix 2). Despite these precautions, our post-hoc method of quantifying coyote boldness and human concern from a community reporting database cannot compared to empirical behavioural observations of animals (e.g., Breck et al. 2019) or randomized public surveys (e.g., Drake et al. 2020).

**Management implications**

Despite some limitations, our findings identify areas, seasons, and contexts that are associated with higher rates of bold behaviours by coyotes and expressions of concern by people that support several management actions that are already being implemented in our study area and elsewhere. Spatially, coyote boldness was generally higher in less-developed and open areas (Poessel et al. 2013, Wine et al. 2015) where managers might emphasize public education and protection of pets via leashing and fenced areas (Draheim et al. 2019). Managers could also increase their monitoring of urban coyote activity in these higher-risk, human use areas, areas and train community members to haze coyotes that behave boldly (Bonnell and Breck 2017). Both awareness campaigns and community-based hazing programs might target conflict-prone areas in and near residential neighbourhoods during the breeding season prior to den site selection to prevent denning in these areas and proactively prevent negative interactions (Bonnell and Breck 2017).

To Such approaches should include attractant management to reduce coyote attraction to anthropogenic food sources (Murray and St. Clair 2017) and might require targeted removal of particularly aggressive individuals (Breck et al. 2017). Finally, managers might address contextual variables while acknowledging the different scales of our findings to target bold coyote behaviour in localized areas (e.g., where people walk dogs off leash or schoolyards), while using attractant management and public education to address human concern about coyotes at larger scales (e.g., neighborhoods). Greater use of spatiotemporal and contextual predictors of conflict with coyotes could support human-coyote coexistence in cities across North America.

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