Two programs for use of aversive conditioning to manage bold urban coyotes

by

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ABSTRACT

Human-coyote conflicts are increasing in urban areas, where reports of coyotes approaching, pursuing, or attacking pets and people have become more prevalent. Aversive conditioning is increasingly being advocated as a non-lethal method to reduce conflicts with bold coyotes, but it has not been much studied and there are few guidelines for its implementation. In this thesis, I quantified the responses by coyotes and public reporting to aversive conditioning as a management tool for bold, urban coyotes in each of two aversive conditioning programs conducted in Alberta, Canada, between 2018 and 2022.

I first evaluated the use of high intensity aversive conditioning conducted by a team of contracted wildlife professionals and their trained dogs in the City of Calgary, Alberta, between 2018 and 2021. Aversive conditioning treatments consisted of using dogs to attract coyotes from cover and paintball guns to fire chalk balls at coyotes. Most (607/736, 82.47%) coyotes retreated quickly from aversive conditioning. The likelihood of coyote retreat increased with the number of previous aversive conditioning engagements at the site and when high intensity aversive conditioning treatments (i.e., those where dogs were used and shots were fired) had been applied prior to the event being investigated. Retreat likelihood declined with the number of days since the last aversive conditioning engagement.

I then implemented and assessed a community-based hazing program conducted in Edmonton, Alberta, in 2021 and 2022. Trained volunteers patrolled their residential neighborhoods while searching for coyotes and coyote attractants. When coyotes were observed, volunteers determined their boldness and, when appropriate, hazed coyotes by running towards them while shouting and throwing weighted tennis balls in their direction. Throughout 1,598 patrols, volunteers observed coyotes 175 times, and conducted hazing on 23 occasions. Almost

all coyotes (22/23, 95.65%) retreated from hazing. I found little evidence that this treatment affected subsequent coyote boldness or the frequency or timing of subsequent coyote reports, but the low frequency of hazing events limited the power of these tests.

My results suggest that both low and high-intensity hazing cause coyotes to leave the immediate area, but only the higher intensity hazing conducted in Calgary demonstrated measurable changes in subsequent behaviour by coyotes or reporting characteristics by people. High-intensity hazing may be necessary to change the behaviour of bold animals, but low-intensity hazing may deter coyotes during conflict situations while increasing the sense of security in residential areas experienced by people.

PREFACE

This thesis is an original work by Gabrielle Lajeunesse. Chapter 2 has been submitted for publication in *Ecosphere* and is currently in review as Gabrielle Lajeunesse, Eric W. Smith, Howard W. Harshaw and Colleen Cassady St. Clair, "Proactive use of intensive aversive conditioning increases probability of retreat by coyotes". Animal damage control and the City of Calgary were responsible for data collection. G. Lajeunesse and E. W. Smith analyzed the data relating to the coyote management plan review and wrote the associated methods and results. G. Lajeunesse analyzed the remaining of the data and wrote the rest of the manuscript. H. W. Harshaw and C. C. St. Clair assisted with concept formation, data analysis, and manuscript composition. The chapter appears here as submitted.

Chapter 3 received animal ethics approval from the University of Alberta Research Ethics Board, Project Name "Community-based aversive conditioning of urban coyotes", No AUP00003783, December 22, 2020. This chapter is currently being prepared for submission, and is co-authored by Howard W. Harshaw and Colleen Cassady St. Clair. A team of 120 volunteers led by Gabrielle Lajeunesse collected the data. G. Lajeunesse analyzed the data and wrote the manuscript. H. W. Harshaw and C. C. St Clair assisted with concept formation, data analysis, and manuscript edits.

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Chapter 1

Introduction

The number of human-wildlife conflicts in urban areas has increased across North America over the past 30 years (Baker and Timm 1998; Schell et al. 2021; Fidino et al. 2022). Such conflicts occur when the behavior of wild animals negatively impacts people, or when the behavior of people negatively impacts wildlife, although the term usually refers to negative situations for people (Madden 2004). Forms of human-wildlife conflict are diverse and include damage of crops (Yoder 2002; Retamosa et al. 2008; McKee et al. 2021), depredation of livestock (Michalski et al. 2006; Sangay and Vernes 2008; McManus et al. 2015), property loss (Pagany 2020), spread of zoonotic diseases (Daszak et al. 2007; Catalano et al. 2012), and attacks on pets or people (Dunham et al. 2010; Silwal et al. 2017). Because predators have protein-rich diets and large home ranges (Treves and Karanth 2003), these animals can compete with humans for food and space. Growing populations of medium to large predators in and near urban areas (Gompper 2002; Beckman and Lackey 2008; Knopff et al. 2016) creates particular challenges for wildlife managers (Soulsbury and White 2015; Schell et al. 2021).

A prevalent example of an urban-adapting carnivore is the coyote (*Canis latrans*), which historically occurred in arid ecosystems of the North American midwest (Fener et al. 2005). In the past century, coyotes have undergone a dramatic range expansion across North America, facilitated by the conversion of previously forested habitats into agricultural lands and human settlements (i.e., urban expansion; Hody and Kays 2018), and the decline of their main competitors and predators (i.e. gray wolves (*Canis lupus*), cougars (*Puma concolor*) and jaguars

(*Panthera onca*); Berger and Gese 2007; Cove et al. 2012). Coyote populations have also increased due to hybridization with wolves (*C. lupus*, *C. lupus lycaon*, and *C. rufus*) and domestic dogs (*C. lupus familiaris*), which introduced new genotypes that helped coyotes survive in eastern and southern North America (Kayset al. 2010; Hody and Kays 2018). Urban coyote populations can now be found in virtually all North American cities, including Chicago (IL, USA; Gehrt et al. 2011), New York (NY, USA; Henger et al. 2020), Los Angeles (CA, USA; Howell 1982), and Toronto (ON, Canada; Clement and Bunce 2022). Coyotes thrive in urban areas owing to opportunistic and generalist habits and diet (Bateman and Fleming 2012) and tremendous behavioral plasticity (Lombardi et al. 2017). Decades of persecution of coyotes in rural areas across the continent (Flores 2017) may also contribute to population increases in urban areas owing to both immigration (Kierepka et al. 2017; Kilgo et al. 2017) and selection for earlier reproduction and larger litters (Knowlton 1972; Gese 2005; Kilgo et al. 2017).

The relationships between urban coyotes and people range from positive through neutral to highly negative depending on context and perspective (Sponarski et al. 2015; Drake et al. 2019; 2020; Farr et al. 2022). Coyotes may regulate populations of nuisance species like squirrels (*Sciurus* spp.; Jones et al. 2016), and cricetid (Cricetidae) rodents (Quinn 1997; Morey et al. 2007; Liccioli et al. 2015). Coyotes may also help promote avian diversity by controlling domestic cats (*Felis catus*; Crooks and Soulé 1999; Kays et al. 2015). Some people also report aesthetic enjoyment from seeing coyotes in cities (Berchielli 2007; McEwan et al. 2020). However, coyotes are associated with human-wildlife conflict that includes approaching, pursuing, and attacking pets and people (Timm et al. 2004; Lukasik and Alexander 2011). Coyotes sometimes den under porches and decks (Poessel et al. 2013), where they may exert physical risks as well as potential to expose people and pets to zoonotic diseases (Catalano et al.

2012; Santa et al. 2018; 2021). Individuals that pose a risk to human safety are sometimes killed by wildlife managers. The targeted lethal removal of aggressive individuals can be an efficient way to reduce human-coyote conflicts in an area for periods as long as 5 years (Breck et al. 2017), but it tends to be expensive and contentious. Lethal removal is expensive because it requires highly trained individuals and because firearms cannot be used for this purpose in many cities. Trapping is labor-intensive and may require multiple attempts which further increase its costs (Breck et al. 2017; Yashphe and Kubotera 2017). Moreover, there is growing public opposition to lethal control, especially when non-lethal approaches can be used (Yashphe and Kubotera 2017; Sponarski et al. 2018). Non-lethal management is increasingly advocated for urban coyotes (Sampson and Van Patter 2020), and is often viewed as being socially and economically preferable to lethal management (Brady 2016; Yashphe and Kubotera 2017). As an alternative to lethal control, management plans for urban coyotes increasingly recommend the use of hazing to deter coyotes from conflict situations (Lajeunesse et al., *in review*).

Hazing is defined as the reactive application of deterrents to immediately modify the behavior of an animal, and is related to the concept of aversive conditioning, a learning process through which repeated exposure to aversive stimuli is expected to reduce the occurrence of undesirable behaviors over time (Hopkins et al. 2010; White and Delaup 2012; Bonnell and Breck 2017; Breck et al. 2017). As one of the four main forms of associative learning in psychology, aversive conditioning is also known as positive punishment; positive refers to the addition of a stimulus and punishment to the fact that it is undesired by the treated individual (Thorndike 1932; McConnell 1990; Domjan and Burkhard 1993; Poling et al. 2002). Aversive conditioning typically involves the application of a stimulus that is frightening, energetically costly, or painful (Shivik and Martin 2000; Snijders et al. 2021), circumstances that animals naturally avoid and can be taught to associate with a benign stimulus, such as the proximity of people. Aversive conditioning based on these stimuli should not be confused with conditioned taste aversion (which is sometimes also called aversive conditioning), in which animals are exposed to a sickness-inducing substance that they subsequently avoid by detecting its smell or taste (Dragoin et al. 1971; Welzl et al. 2001). Conditioned taste aversion has been used extensively to address human-wildlife conflicts (Snijders et al. 2021), but it is expected to prevent only the consumption of substances with an associated taste, not the avoidance of people or human-inhabited areas where the conditioning took place.

Aversive conditioning has been used extensively to manage wildlife in protected areas, but there are few published studies of its efficacy. It has been used, with mixed success, to manage a variety of wild animals, including wolves (Shivik et al. 2002; Rossler et al. 2012), elk (*Cervus canadensis*; Kloppers et al. 2005; Found et al. 2018), bears (Mazur 2010; Homstol 2011), lions (*Panthera leo*; Petracca et al. 2019), dingoes (*Canis lupus dingo*; Smith et al. 2020), and American alligators (*Alligator mississippiensis*; Kidd-Weaver et al. 2022). However, aversive conditioning applied to urban coyotes has only recently been studied (Bonnell and Breck 2017; Breck et al. 2017; Young et al. 2019; McLellan and Walker 2021) and there are few guidelines for its implementation.

Two studies of wild coyotes occurred in the Denver Metropolitan Area (CO, USA) to determine the effects of community-based hazing programs. The first program sought to increase the wariness of coyotes towards people with a before-after control-impact (BACI) design that compared the overlap in time of activity between coyotes and people (which they used as a proxy for coyote wariness) in two control and two treatment parks (Breck et al. 2017). In all parks, members of the public were asked to report coyote observations to researchers. In treatment parks, besides reporting coyote observations, members of the public were encouraged to haze coyotes by yelling, aggressively approaching, and throwing objects in the direction of the coyotes. These recommendations were posted on signs in the targeted treatment parks and were reinforced by education stations and a social media campaign. The overlap in time of activity between people and coyotes was evaluated via wildlife cameras, with cameras positioned on maintained human trails and game trails in each of the four parks. The authors found a greater overlap in time of activity between humans and coyotes on treatment game trails than on control game trails, and found no significant difference in the overlap in time of activity between humans and coyotes on main trails (Breck et al. 2017). The authors concluded that hazing applied by community members had no long-term effect on coyote behavior, possibly because the treatment was not applied with enough consistency or intensity.

The second program aimed to assess the impact of hazing conducted by citizen scientists on coyote behavior and determine the factors that might influence coyote responses to hazing (Bonnell and Breck 2017). As metrics of success, these authors determined whether people could immediately deter approaching coyotes in the short-term and make coyotes permanently more wary of people in the long-term (Bonnell and Breck 2017). Volunteers were trained to identify appropriate and inappropriate coyote behaviors, based on coyote location and time of day. Volunteers hazed coyotes behaving inappropriately by raising their arms, waving and shouting. Volunteers were also encouraged to take a step towards the animal, use air horns or other noisy objects and, if needed, throw objects in the direction of the animal. Hazing activities, including the hazing tools used and the reaction of the coyote following hazing, was recorded by volunteers in a form. When hazing was conducted, the most common behavioral response expressed by coyotes was to leave the area, but this response was less frequent when dogs were present and in proximity to an active coyote den (Bonnell and Breck 2017). The authors recommend the use of hazing to create a safety buffer during an interaction with a coyote, but found no long-term effects of this treatment on coyote behavior.

Successful aversive conditioning is characterized by the modification or cessation of an unwanted behavior following the application of a negative stimulus. Success is goal-dependent and relative to the specific human-wildlife conflict being addressed. Success can be measured using several behavioral metrics, such as whether an animal immediately leaves an area following an aversive conditioning treatment (Bonnell and Breck 2017), the speed at which the animal retreats from an aversive conditioning treatment (Mazur 2010), and whether an animal changes position or moves away from the person conducting the treatment (Shivik et al. 2002; Appleby et al. 2017). Other examples of success measure the probability of predation (Andelt et al. 1999; Petracca et al. 2019), whether animals become less visible or less active around people following aversive conditioning (Breck et al. 2017), or whether the overt reaction distance (i.e. the distance at which an animal overtly reacts to a person; Smith et al. 2005) or the flight initiation distance (i.e. distance at which an animal retreats from a person; Carrete and Tella 2010) of an individual increases over time following the application of aversive conditioning (Homstol 2011; Found et al. 2018; Kidd-Weaver et al. 2022). More consistent definitions of success are needed to support comparisons of efficacy between programs.

Others have summarized six learning principles that are expected to contribute to the successful modification of behavior (Homstol 2011; Found et al. 2018; Evans Ogden 2021). First, the aversive stimuli should be evolutionarily relevant: the animal should be able to form an association between the conditioned (e.g., people) and the unconditioned (e.g., pain, fear) stimuli (Found et al. 2018; Snijders et al. 2021). Second, the stimuli should be of high initial intensity by causing high discomfort, pain or fear (Azrin 1960; Domjan and Burkhard 1993; Homstol 2011; Found et al. 2018). High intensity actions are needed to prevent animals from habituating to the stimulus and becoming resistant to future treatments as has been found for low intensity punishments (Domjan and Burkhard 1993; Homstol 2011). Third, aversive conditioning treatments should be applied immediately (Camp et al. 1967; Andelt et al. 1999; Homstol 2011) and consistently (Petracca et al. 2019) when the animal is exhibiting the undesirable behavior. The negative stimulus should not be signaled, meaning that there should not be any specific external cue (e.g., trucks, uniforms, locations) leading to the punishment (Kloppers et al. 2005; Gunther et al. 2018). Fourth, unpredictability in time and space allows the animal to generalize the treatment to all contexts and not to only certain situations (Domjan and Burkhard 1993; Found et al. 2018; Sampson and Van Patter 2020). Finally, the aversive conditioning program should reward alternative (i.e., desirable) behaviors (Homstol 2011; Snijders et al. 2019). This can be done by ceasing an aversive conditioning event or adding a positive stimulus when the animal is exhibiting the desired behavior (Homstol 2011; Snijders et al. 2019). These six learning principles might be used as additional metrics for planning and evaluating aversive conditioning programs.

This research tested application of aversive conditioning as a management tool to mitigate conflicts with bold, urban coyotes by comparing two aversive conditioning programs conducted in Alberta, Canada. In Chapter 2, I evaluated the use of high intensity aversive conditioning treatments delivered by a contracted team of wildlife professionals in the City of Calgary, Alberta, between 2018 and 2021. In this program, coyotes were chased by trained dogs and, when appropriate, contractors used paintball guns to shoot chalk balls toward (and occasionally at) coyotes. In Chapter 3, I conducted and reviewed a community-based hazing program conducted in the City of Edmonton, Alberta, in 2021 and 2022. There, volunteer community members patrolled their neighborhoods in search of coyotes. When coyotes were observed, volunteers determined their boldness and, when appropriate, hazed coyotes by running towards them while shouting and throwing weighted tennis balls in the direction of the animal. Finally, in Chapter 4, I contrasted the aversive conditioning programs presented in Chapters 2 and 3 based on their adherence to the principles for aversive conditioning and program success.

Chapter 2

Proactive use of intensive aversive conditioning increases probability of retreat by coyotes

2.1 ABSTRACT

Coyotes (*Canis latrans*) are showing increasingly bold behaviors towards people and their pets throughout North America. Bold behavior by wildlife might be reduced by aversive conditioning, which is recommended in many management plans for coyotes, but few studies have tested this approach. Here, we review recommendations for aversive conditioning in coyote management plans from across North America and report on the implementation of a high-intensity aversive conditioning program delivered by contractors in Calgary, Alberta. We conducted an online search for coyote management plans and reviewed techniques and recommendations related to the implementation of hazing or aversive conditioning. Almost all the management plans reviewed recommended hazing coyotes, most often by using a combination of noises, lights, and movements. Only 20% of 71 plans recommended high intensity techniques like those used by the contractors in Calgary. Contractors there searched for coyotes in 72 public park areas where members of the public had submitted reports to a civic call center of bold coyotes, attended sites on 1917 occasions, observed coyotes on 765 occasions, and reported coyotes treatments and responses on 734 occasions. The probability of coyote retreats increased by 29-37% with each additional previous aversive conditioning events at the site and doubled when use of chalk balls and dogs had been applied prior to the event being investigated, suggesting coyotes learned to avoid contractors. Retreat probability declined by 21-25% with each additional day since the last aversive conditioning engagement, and by 97.2-97.6% with the

presence of dogs and when shots were fired from a paintball gun, presumably because these tools were used only on the boldest coyotes. We found no effect of the presence or past number of aversive conditioning events on the number of coyote reports per week by the public. Although such high intensity aversive conditioning is rarely recommended in management plans, our results suggest that its repeated application can reduce coyote boldness over time, but its efficacy may be lessened by the presence of associated stimuli, such as the visual cues (e.g., high visibility vests, vehicles) associated with contractors.

2.2 INTRODUCTION

Since the late 1990’s, urban-dwelling coyotes (*Canis latrans*) have shown increasingly bold behaviors towards people and their pets (i.e., approaching, stalking, pursuing, or attacking pets or people; Timm et al. 2004; White and Gehrt 2009; Lukasik and Alexander 2011; Poessel et al. 2013; Baker and Timm 2016). More recently, unusual spikes in the frequency of coyote attacks on people have been reported in various cities, including Chicago (Illinois; Andrew and Alonso 2020), Calgary (Alberta; Kaufmann 2021), the San Francisco Bay Area (California; Diaz 2021), Vancouver (British Columbia; Griffin 2022), and Burlington (Ontario; The Canadian Press 2022). Although such incidents remain rare, urban residents have long expressed concerns about the presence of coyotes in their neighborhoods (Webber 1997; White and Gehrt 2009; Siemer et al. 2014) and that concern may be increasing (Drake et al. 2020).

Municipalities across North America have responded to the increased prevalence of urban coyotes and associated conflicts with management plans that address human-coyote coexistence (Appendix 1 Table 1.1). Typical goals of such plans are to increase communication among stakeholders and wildlife professionals (Alexander 2013; Marchini et al. 2019), identify the types of actions that should be used to address human-coyote conflicts, and provide direction for implementing those actions (Schwartz et al. 2018). Many of the plans are based on a template provided by a prominent animal welfare group (The Humane Society of the United States 2019), which recommends targeted lethal management of animals that bite people, opposes the use of translocations, and encourages the use of low intensity hazing (Lesmerises et al. 2018). Targeted lethal removal of individual problem coyotes is effective in reducing conflict with people (Breck et al. 2017), but lethal management of coyotes is logistically difficult, time-consuming, expensive, and increasingly opposed by the public (McCullough et al. 1997; Berger 2006; Worcester and Boelens 2007; Yashphe and Kubotera 2017; Sponarski et al. 2018). Although the translocation of problem animals may be perceived by the public as more humane than targeted lethal management (e.g., Dubois and Harshaw 2013), the survival rates of relocated coyotes is very low (Learn 2021), which is typical of translocated carnivores (Blanchard and Knight 1995; Linnell et al. 1997; Bradley et al. 2005; Boast et al. 2016). The limitations of lethal management and translocations underscore the need for hazing as a more proactive, non-lethal method to address human-coyote conflicts in urban areas.

Hazing and aversive conditioning are recommended by many authors as humane, non-lethal tools to manage bold urban coyotes (White and Delaup 2012; Bonnell and Breck 2017; The Humane Society of the United States 2019; Sampson and Van Patter 2020). Although these terms are often used interchangeably, hazing refers to the reactive application of negative stimuli to immediately change an undesirable behavior (Schirokauer and Boyd 1998), whereas aversive conditioning is a learning process in which negative stimuli are repeatedly and consistently applied to reduce the frequency of an unwanted behavior over longer periods of time (Hopkins et al. 2010). Aversive conditioning has been used to manage a variety of wildlife species, including elk (*Cervus canadensis*; Kloppers et al. 2005; Found et al. 2018), black bears (*Ursus* *americanus*; Beckmann et al. 2004; Mazur 2010; Homstol 2011), wolves (*Canis lupus*; Schultz et al. 2005; Rossler et al. 2012), and African lions (*Panthera leo*; Petracca et al. 2019).

Aversive conditioning or hazing might be used by wildlife professionals and members of the public to address bold behavior by urban coyotes and these approaches are variously described in several online municipal coyote management plans. A review of these online plans (Lesmerises et al. 2018) suggests that they vary in the types, intensity, and implementation sources recommended for aversive conditioning, but there is no authority with which to evaluate these differences. Furthermore, few studies have tested the efficacy of hazing or aversive conditioning, which some authors dispute (Brady 2016; Sampson and Van Patter 2020; Alexander 2022). Low intensity aversive conditioning conducted by volunteer community scientists who were instructed to shout, use noise makers, make themselves appear big, and approach the animal has produced an immediate fleeing response in urban coyotes (Bonnell and Breck 2017). However, this method did not cause coyotes to avoid areas frequented by people, and a companion study suggested that it should be applied proactively on all coyotes, rather than reactively only on problem individuals (Breck et al. 2017). A study conducted on captive coyotes that experienced similar aversive conditioning techniques found that an increasing number of hazing events led to a decrease in the number of approaches by coyotes towards people, providing evidence of a learned response with substantial variation among individuals (Young et al. 2019).

The efficacy of applying aversive conditioning to coyotes and other wildlife species might be increased by employing the principles of effective punishment developed in studies on lab animals and people that are summarized in many introductory textbooks on learning and conditioning (e.g., Domjan 2014) and increasingly apparent in studies of wildlife (e.g., Evans

Ogden 2021). These principles assert that the aversive stimuli should be immediate (e.g., Andelt et al. 1999), consistently applied when the undesired behavior occurs (e.g., Petracca et al. 2019), and not signaled by preliminary cues, such as particular trucks, uniforms, and locations (Kloppers et al. 2005; Homstol 2011). The aversive stimulus should associate sounds with pain or taste with nausea, but not sound with nausea or taste with pain (i.e., evolutionarily relevance; Garcia et al. 1974; Conover 2002; Homstol 2011; Evans Ogden 2021) and have high initial intensity (e.g., Homstol 2011) to prevent the habituation that might result from a gradual increase in the intensity of the stimuli (Domjan 2014) and exacerbate associated human-wildlife conflict.

In response to increasing human-coyote conflicts (Lukasik and Alexander 2011), the City of Calgary (Alberta) produced a coyote management plan that included the development of policy and programming to actively support human-coyote coexistence (The City of Calgary 2018). The city also broadened its civic reporting system to include coyote observations and conflicts and developed a coyote conflict response guide. This guide clarified policy direction to municipal staff and led to the implementation of a high intensity aversive conditioning program delivered by wildlife professionals. Civic employees collated public reports of bold coyote activity and shared them with wildlife professionals who responded to them by patrolling associated parks where they attempted to engage coyotes with trained dogs and, when appropriate, used paintball guns to shoot chalk balls toward (and occasionally at) coyotes. The wildlife professionals measured and reported their own actions as well as the responses of coyotes to the aversive conditioning treatments.

In this study, we review coyote management plans across North America to quantify how often and with which methods hazing is described and report on the implementation of a high-intensity aversive conditioning program conducted in Calgary, Alberta. We (a) identify the most common management techniques recommended to address bold behavior by coyotes in coyote management plans and summarize how hazing or aversive conditioning were to be implemented in those plans, and (b) evaluate the effectiveness of Calgary's program via coyote behavior as assessed by wildlife professionals and changes in public reporting of coyotes. We identify management strategies that maximize the efficacy of aversive conditioning to reduce human-coyote conflicts in urban areas.

2.3 METHODS

2.3.1 Study area

We evaluated the responses of coyotes to an aversive conditioning program conducted in the City of Calgary (5,110.21 km^2), located in southwestern Alberta in the foothills of the Canadian Rocky Mountains (Government of Canada 2017). Calgary has an elevation of 1,060 m above sea level (Liccioli et al. 2012), is characterized by mean temperatures ranging from -7.1°C in the winter to 16.5°C in the summer (Environment and Climate Change Canada 2013), and had a human population of approximately 1.4 million people when the study began (Government of Canada 2017). The municipal area contains over 80 km^2 of parkland and natural areas including Nose Hill Park, one of the largest municipal parks in North America (The City of Calgary and Local Action for Biodiversity Programme 2014). Many city parks border riparian habitats along the Bow and Elbow Rivers. Native habitats in the city include forests, riparian tall shrublands, upland tall and low shrublands, grasslands, streams, and wetlands (The City of Calgary Parks 2015). Semi-natural habitats include manicured green spaces, gardens, agricultural areas, storm ponds, and built habitats. Both native and semi-natural habitats present within the city are widely used by coyotes and other wildlife.

2.3.2 Coyote management plan review

In June 2021, we conducted an exhaustive online search of coyote management plans. We used the following Google search terms in English and French: "urban coyote management plan", "coyote management plan", "coyote coexistence plan", "coyote response strategy", "coyote protocol", "coyote hazing", "coyote aversive conditioning", and "plan de gestion coyote." Many online search engines were used including the Web of Science and Scopus, but Google provided the most comprehensive results for this query. Search terms were developed using Pearl growing, a systematic review strategy whereby documents of interest are used as "pearls" to identify keywords and index names (Schlosser et al. 2006). We then applied the keywords and index names to the search terms to identify other sources until the material searched became less relevant (Appendix 1 Table 1.1; Papaioannou et al. 2009). We did not restrict our search in time.

We first determined the mitigation techniques (i.e., hazing, targeted lethal removal, relocation, attractant removal, public education) recommended or discouraged in each management plan (Table 2.1). When hazing was recommended, we characterized this technique by the types of tools recommended (Table 2.2), and classified these tools based on their intensity level (i.e., low, moderate, high; Mazur 2010, Homstol 2011). We also determined whether the plans indicated who should conduct the treatment and whether use of wildlife professionals or a community-led program was recommended. We recorded whether the plans mentioned when to haze a coyote, how long to haze for, or whether the people implementing the hazing treatment were evident to the coyotes (Table 2.3).

2.3.3 Analysis of aversive conditioning in Calgary

Aversive conditioning was conducted in the City of Calgary by a contracted team of wildlife professionals (hereafter contractors) and their trained dogs between September 25, 2018, and July 17, 2021. The contractors patrolled public areas where aggressive coyote behavior had been reported by the public to the civic 311 call center. These reports were reviewed by city staff and conveyed to the contractors daily.

Contractors surveyed areas with reports of bold coyotes by vehicle and on foot to record whether or not coyotes were found and whether it was possible to safely engage with the coyotes to perform the aversive conditioning actions; all actions were coded on an ordinal scale (Table 2.4). Foot patrols usually included working dogs. Aversive conditioning actions included flushing coyotes from hiding cover with a dog and firing chalk balls from paintball guns at targets that were distant from, near to, or occasionally directly at coyotes (Table 2.4). If aversive conditioning was initiated, it continued until the coyote(s) left the area. Aversive conditioning was only conducted on city-owned land, including municipal parks, and was never conducted on young pups or with a goal to injure coyotes. Public safety was maintained during the aversive conditioning process by avoiding crowded areas and use of conditioning near people. The contractors and their dogs wore high visibility vests so that they could be identified and recognized by members of the public.

Contractors described the responses of coyotes to their actions on a five-point ordinal scale that ranged from leaving the area immediately without looking back (1) to physical attacks by the coyote on a dog or person (5; Table 2.5). Contractors also recorded the location and date of each conditioning event and, when possible, the number and sex of the animals being conditioned. We assigned aversive conditioning events to seasons relevant to coyote ecology: breeding season (January 1 - April 30), pup-rearing season (May 1 - August 31), and dispersal season (September 1 - December 31; Morey et al. 2007).

Public reports of coyote sightings and encounters in the City of Calgary were collected from the City's municipal monitoring database between May 2, 2018 and July 21, 2021. The data were obtained through private communications with the contractors in collaboration with the City of Calgary. When full reports were available, they were coded based on the encounter characteristics as described in the City of Calgary's Coyote Conflict Response Guide on an ordinal scale ranging from observation of coyote sign (e.g., scat) and coyotes to incidents involving conflict between coyotes and people or their pets (Table 2.6; The City of Calgary 2018). Reports also included the location and time of the coyote observation. We included only those reports that described coyote activity; duplicate reports, reports for which no date was provided, and reports originating from parks where no aversive conditioning was conducted were excluded. We assigned coyote reports to seasons relevant to coyote ecology in the same way as described for the aversive conditioning events.

2.3.4 Data analysis

To examine the spatial and temporal distribution of aversive conditioning events, coyote responses to wildlife professionals, and reports to the civic 311 system, we tallied each type of information in each ordinal category by park (or park area within a large park or multiple small parks within a neighborhood) and coyote season (Appendix 1 Table 1.2). We used one-way analysis of variance (ANOVA) to compare the number and types of reports and aversive conditioning events among parks and the three coyote seasons (breeding, denning, and dispersal).

To maximize statistical power in our analyses of the number and type of coyote interactions described by contractors and 311 reports, we converted the ordinal scales for our three main response variables to binary categories. For coyote presence as assessed by contractors, we separated instances where no coyotes were found (category 0) from instances where coyotes were observed and aversive conditioning was conducted (categories 1-6; Table 2.4). Similarly, for coyote responses to contractors, we separated responses indicative of retreat by coyotes (categories 1 and 2) from those associated with resistance (categories 3, 4, and 5; Table 2.5). Finally, for public 311 reports, we separated reports associated with observation (categories 1, 2, and 3) from those associated with conflict (categories 4-7; Table 2.6). As explanatory variables, we coded each event to identify if a dog was used and whether or not the contractors fired a chalk balls in close proximity to or directly at the coyote (coded as 1 = dogs were used, shots were not fired, 2 = dogs were not used, shots were fired, 3 = dogs were used, shots were fired; Table 4). Additional explanatory variables included the number of days since the last aversive conditioning engagement and a count of the number of aversive conditioning events for each park or park area in the one week (7 days, presence model) or eight weeks (56 days, all other models) prior to or during the day of the report. We chose these time periods after testing durations that ranged from 1 to 8 weeks with separate logistic regression models and proceeding with the time period that resulted in Akaike's Information Criterion corrected for small sample size (ΔAIC_c) values < 2 (Burnham and Anderson 2002). We also tallied the number of 311 reports of coyote activity in a park in the four weeks (7 days, presence model) or eight weeks (56 days, all other models) prior to the report, and included as covariates the season relevant to coyote ecology (breeding, pup-rearing, dispersal), and the year of the study (coded as 1-4 beginning in 2018).

We used logistic regressions to model each of the binary response variables associated with coyote responses to wildlife professionals (presence or absence and retreat or resist) and with 311 reports (conflict or observation) with potential fixed explanatory variables that included coyote season, year, the aversive conditioning treatment, the number of days since the last aversive conditioning engagement, and variables related to recent aversive conditioning events and recent coyote reports. We investigated the number of aversive conditioning engagements by contractors and the number of reports of coyote activity made to 311 (tallied separately for each park or park area) in the weeks prior to the event. The continuous explanatory variables were scaled. For the model predicting the type of coyote report (conflict or observation) made to 311, we only considered the coyote reports submitted following the first aversive conditioning event in each park. We included park or park area in these models as a random effect to accommodate repeated use of locations. Models were built using the *glmer* function of the “lme4” package (Bates et al. 2014), with a binomial family link (De Boeck and Partchev 2012; Lee and Grimm 2018). We evaluated models based on their AIC_c score using the *dredge* function in the “MuMIn” package (Bartoń 2022); we identified top models as those with a difference in their Akaike’s Information Criterion corrected for small sample size (ΔAIC_c) < 2 (Stephens et al. 2006; Symonds and Moussalli 2011; Tredennick et al. 2021). We identified uninformative parameters as those whose 85% confidence intervals included zero, increasing the compatibility between the model selection (via ΔAIC_c) and the parameter evaluation processes (via confidence intervals; Arnold 2010). We excluded models that contained at least one of these uninformative parameters if the other parameters were present in another model that we retained (Arnold 2010). Spearman’s correlation coefficients among predictor variables were < 0.5, limiting the effects of multicollinearity (Dormann et al. 2013). We determined the proportion of variance explained by our best models via Nakagawa R^2 by using the *r.squaredGLMM* function of the “MuMIn” package (Bartoń 2022), which provides marginal and conditional r-squared values and is adapted to GLMMs (Nakagawa et al. 2017; Sugden et al. 2020). We assessed model performance via the area under the receiver operating characteristic curve (ROC) using the *auc* function of the "pROC" package (Robin et al. 2011); we considered ROC area under the curve values between 0.7-0.8 to be moderate, and those between 0.8-0.9 to be good (Mandrekar 2010).

We used zero-inflated negative binomial mixed regression (Suraci et al. 2019; Nickel et al. 2020) to model the number of coyote reports (of either conflict or observation) received per park or park area per week between the weeks of September 23, 2018 and July 18, 2021. We only considered the coyote reports submitted following the first aversive conditioning event in each park. This model comprises a zero-inflated submodel to assess the probability that coyotes were reported on a certain park week combination via a logistic regression, and a conditional submodel that assessed the abundance of coyote reports per park (or park area) per week using a negative binomial regression. Potential explanatory fixed effect variables for this response variable included coyote season, year, and the last aversive conditioning treatment type prior to the reporting week if aversive conditioning was conducted in the eight weeks (56 days) prior to the week being evaluated. We also investigated the role of the number of days since the last aversive conditioning engagement, the number of aversive conditioning engagements of coyotes by contractors in the eight weeks prior to a reporting week (tallied separately for each park or park area), and the number of reports of coyote activity made to 311 in the eight weeks prior to the reporting week (also tallied separately) as potential fixed effects, and included park or park area as a random effect in all our models. We built models using the "glmmTMB" function of the *glmmTMB* package (Brooks et al. 2017). We evaluated predictors based on their AICc score, their 85% confidence intervals, and their correlation coefficients as described above. We evaluated model fit using the *r2* function of the "performance" package (Lüdecke et al. 2021), which provides pseudo-R^2 adapted to zero-inflated generalized linear mixed effect models

(Nakagawa and Schielzeth 2013; Johnson 2014). All statistical analyses were carried out using R (R Core Team 2021).

2.4 RESULTS

2.4.1 Coyote management plan review

Among the 72 management plans that we reviewed (Appendix 1 Table 1.1), most were from California (35/72; 49%). All the management plans we reviewed (72/72) recommended public education, which usually focused on differentiating normal vs. unusual coyote behavior, preventing human-coyote conflicts by reducing attractants, keeping pets safe via containment or leashing, using deterrents on private property, and knowing how to respond during a coyote encounter (Table 2.1). All but one plan recommended the use of hazing, usually via the use of human movements (i.e., standing your ground, waving arms, approaching the coyote), motion-activated lights, noises, rocks, balls or sticks thrown by hand, or water sprayed towards or at the coyote. Low intensity hazing was usually recommended as soon as coyotes were observed (category 2), while high intensity hazing involving projectiles launched from an object (e.g., slingshot, paintball gun) were usually only recommended following an incident (category 5) or a pet attack (category 6; Table 2.6). Most of the management plans we reviewed (70/72; 97%) recommended the targeted lethal removal of aggressive coyotes, especially following an incident (n = 23, category 5), a pet attack (n = 24, category 6) or an attack on a person (n = 12, category 7; Table 2.6). Only one management plan (1%) recommended the relocation of aggressive individuals, while 40 management plans (56%) discouraged the use of this technique.

When hazing was recommended, 68/71 (96%) of plans recommended the implementation with lights, noise, and human movements, and 66 (93%) plans also recommended throwing projectiles by hand or spraying water or chemical repellents (i.e., pepper spray, bear spray) towards or at the coyote (Table 2.2). Fourteen of the management plans that recommended hazing (20%) described approaches that used contact with a coyote by shooting a coyote with rubber or clay balls, but only one of those plans (Calgary, Alberta) recommended chasing coyotes with a trained dog. Most of the plans (68/71; 96%) explicitly supported the application of hazing using human movements, motion-activated lights, or noises by community members, but 11 out of 14 plans that described hazing using dogs and rubber or clay balls recommended that these activities be done exclusively by city staff or contractors. Over half (37/71; 52%) of the plans encouraged the engagement of community members to address human-coyote conflict with community-led programs.

We summarized additional details in the plans about how to conduct hazing. Most plans (35/71; 49%) recommended that hazing be conducted so that it was clear to coyotes that the threat came from a person and 42% (30/71) of municipal management plans recommended that hazing should not stop until the coyote left the area (Table 2.3). Half of the plans (34/71) emphasized that hazing was not a one-time tool and must be continued over the long-term. More than half the plans (41/71; 58%) suggested that hazing should be conducted by a number of different people using several different techniques to reduce habituation. Only 7% (5/71) of plans specifically recommended that coyotes be hazed every time that a person sees them. Although half (34/71) of the plans recommended that hazing effort should be exaggerated at the commencement of the hazing program, many of these plans (38/71; 54%) included a decision framework where the intensity of responses to coyotes gradually increased with the frequency and degree of conflict.

2.4.2 Aversive conditioning in Calgary

Between September 25, 2018, and July 17, 2021, a total of 765 aversive conditioning events were conducted by contractors in 72 parks of the City of Calgary. The number of aversive conditioning events conducted per park ranged from 1 to 53 ($\bar{x}$ = 10.6, *SD* = 12.7). The distribution of aversive conditioning events was not significantly different between seasons, with an average per year of 77.7 events in the breeding season (*SD* = 11.6), 97.7 during pup-rearing (*SD* = 50.6) and 79.0 (*SD* = 18.4) during dispersal ($F_{2,6}$ = 0.37, *P* = 0.71). Between May 2, 2018, and July 21, 2021, within the same parks, 911 reports of coyote activity were submitted to the civic call center; the number of reports per park ranged from 0 to 74 ($\bar{x}$ = 12.7, *SD* = 13.4). The distribution of coyote activity reports was not significantly different among coyote seasons, with an annual average of 85.3 reports during the breeding season (*SD* = 75.1), 102.0 reports during the pup-rearing season (*SD* = 92.6), and 82.0 (*SD* = 58.8) reports during dispersal ($F_{2,7}$ = 0.07, *P* = 0.94).

When the immediate reaction of coyotes to an aversive conditioning event was known (*n* = 736, Table 5), coyotes commonly left the area without stopping to look behind them (response = 1, *n* = 353; 48.0%), or delayed leaving for a few moments without letting the contractors get close to them and eventually leaving the area (response = 2, *n* = 254; 34.5%). In approximately 14.8% of events (*n* = 109), coyotes delayed leaving and required multiple treatments, occasionally challenging the handler's dog without leaving and requiring additional aversive conditioning (*n* = 17; 2.3%). On three occasions (0.4%), a coyote attacked or attempted to attack a wildlife professional or their dog during an aversive conditioning event.

Effects of aversive conditioning on the probability of coyote presence and retreat as assessed by contractors

We found that the probability of coyote observation by contractors increased by 11.08-

11.2 times with each additional aversive conditioning event in the week prior to an event (OR = 11.08-11.2, $p < 0.005$) and by 57-58% with each additional day since the last aversive conditioning engagement (OR = 1.57-1.58, $p < 0.005$; Table 2.7, Figure 2.1a). The probability of coyote observation by contractors also increased by 37% during the pup-rearing season (relative to the breeding season OR = 1.37, $p = 0.07$), and by 22% over years (OR = 1.22, $p = 0.05$). We found that the probability of coyote observation as assessed by contractors increased by 26-36% when the last aversive conditioning event conducted involved shots only (relative to when only working dogs were present; OR = 1.26-1.36, p = 0.10-0.21; Figure 2.1a), and by 48-60% when a chalk ball was shot and a working dog was present (relative to when only working dogs were present; OR = 1.48-1.60, p = 0.008-0.02). The fixed and random effects of our top models together explained between 61.9-62.3% of the total variance and resulted in good values for ROC area under the curve (0.898-0.900).

Of the 72 parks where aversive conditioning was conducted, retreats by coyotes (categories 1 and 2; Table 2.4) were recorded in 68 (94.4%) parks. The probability of coyote retreat (categories 3, 4, or 5) decreased by 21-25% with each additional days since the last aversive conditioning event (OR = 0.75-0.79, p = 0.02-0.05; Table 2.7, Figure 2.1b), by 75-77% when a chalk ball was shot in the event being evaluated (relative to when only working dogs were present, OR = 0.23-0.25, p = 0.003-0.005), and by 97.2-97.6% when a chalk ball was shot and a working dog was present in the event being evaluated (relative to when only working dogs were present, OR = 0.024-0.028, $p < 0.005$). The probability of coyote retreat increased by 29-37% with each additional aversive conditioning event in the eight weeks prior to an event (OR = 1.29-1.37, p = 0.04-0.09). The marginal R^2 values suggested that 38.5-39.8% of the variance in the top models was explained by the fixed effects, while the random effect of park alone explained an additional 11.0-12.5% of the variance; this model yielded good ROC area under the curve values (0.908-0.913).

We explored the longer-term reactions of coyotes to aversive conditioning by testing whether aversive conditioning treatments conducted in the eight weeks prior to an event affected the reaction of coyotes to subsequent aversive conditioning. We found that the probability of coyote retreat increased by 34-38% with each additional aversive conditioning event within the eight weeks prior to an event (OR = 1.34-1.38, $p = 0.05$-0.08; Table 2.7, Figure 2.1C). We also found that the probability of coyote increased by 70% when working dogs were present and chalk balls were shot in the most recent prior conditioning event (relative to when only working dogs were present, OR = 1.70, $p = 0.13$). The probability of coyote retreat decreased by 81-83% when a chalk ball was shot during the event being evaluated (relative to when only working dogs were present, OR = 0.17-0.19, $p = 0.003$-0.004), and by 98.0-98.3% when a chalk ball was shot and when a working dog was also present during the event being evaluated (relative to when only working dogs were present, OR = 0.017-0.02, $p < 0.05$). The fixed and random effects of our top models together explained between 52.4-54.6% of the total variance and resulted in good ROC area under the curve values (0.916-0.922).

Effects of aversive conditioning on the type and number of coyote reports

Among reports submitted by the public to the civic 311 service, only observation type reports were made in 13/69 (18.8%) parks where aversive conditioning was conducted, while only conflict type reports were made in 3/69 (4.3%) parks; both coyote observations and conflicts were reported in the remaining 53 parks. We found that the probability of conflict reports increased by 27% with each additional aversive conditioning event in the eight weeks prior to a report (OR = 1.27, $p = 0.02$), and by 51% with each year (OR = 1.51, $p = 0.01$; Table

7; Figure 1d). This was a weak model, with the fixed effects explaining only 3.4% of the variance in the top model, while the random effect of parks explained an additional 9.1% of the variance; the top model yielded a moderate ROC value (0.719).

The two-part zero-inflated negative binomial model that separately examined predictors for the presence and abundance of coyote reports per park and week combination, produced top models for presence (zero-inflated component) and abundance (conditional component) that included the number of prior reports of coyotes, season, and year (Table 2.8; Figure 2.2). The probability of coyote reports increased by 5.99-6.30 times (OR = 5.99-6.30, $p < 0.05$) with each additional report in the eight weeks prior, and by 2.14 times (OR = 2.14, $p = 0.006$) during the pup-rearing season (relative to the breeding season; Table 2.8; Figure 2.2). The number of coyote reports per week increased by 49-50% over years (RR = 1.49-1.50, $p < 0.05$), by 14-15% with every additional coyote reports (RR = 1.14-1.15, $p = 0.003$) and by 49% the pup-rearing season (relative to the breeding season, RR = 1.49, $p = 0.002$; Table 2.8; Figure 2.2). These variables together with the random effect of parks explained between 19.0-19.8% of the variance in the models (Table 2.8).

2.5 DISCUSSION

The generalist habits of coyotes and their tolerance to human activity supports their occurrence in most North American cities (Gehrt 2007; Murray et al. 2015), where urban coyotes have shown increasingly bold behavior towards people and their pets (White and Gehrt 2009; Lukasik and Alexander 2011; Poessel et al. 2013; Breck et al. 2019). Hazing and aversive conditioning are tools that could increase coyote wariness and reduce conflicts with people, but there have been few studies of the efficacy of these approaches. We reviewed management plans for coyotes from across North America and found that all 72 plans explicitly recommended educating the public, and most recommended the use of low intensity hazing to manage coyotes. However, only 14 plans (20%) recommended the use of high intensity hazing that employed projectiles or dogs. We examined the relationships between the responses of coyotes and public reports to the use of high intensity aversive conditioning by contractors in Calgary, Alberta, and found that high intensity aversive conditioning treatments did not predict retreat by coyotes at the time of engagement but predicted a greater probability of retreat during subsequent visits by contractors. We also found that higher numbers of past aversive conditioning events in a park or park area predicted a greater probability of retreat by coyotes during aversive conditioning engagements, but also a greater probability of coyote presence as assessed by contractors and a greater probability of conflict reports. Additionally, we found that a longer period of time since the last aversive conditioning engagement predicted a greater probability of coyote presence as assessed by contractors and a reduced probability of retreat by coyotes during future aversive conditioning engagements. Finally, we found that the pup-rearing season was associated with a greater probability of coyote presence as evaluated by contractors and reported by members of the public, and a higher number of coyote reports per week.

Among the 72 coyote management plans we reviewed, the most consistent recommendation was for public education to manage human-coyote conflicts. Although public education can be used to prevent human-coyote conflicts (Timm et al. 2004; Fox 2006), it does not alter the behavior of problem individuals. That may be the reason that all but one plan also recommended the use of hazing or aversive conditioning to reduce conflicts with bold urban coyotes. Plans more often favored low intensity treatments conducted by community members, which can produce an immediate change in coyote behavior (Bonnell and Breck 2017), but do not appear to change coyote distribution (Bonnell and Breck 2017) and may not produce long-term modification in coyote behavior (Breck et al. 2017). Furthermore, the hazing interventions suggested in management plans typically did not incorporate the principles of effective punishment (Domjan 2014; Found and St. Clair 2019; Evans Ogden 2021). By contrast, 38 of the 71 plans (54%) recommended a step-wise approach beginning with mild treatments that increase in intensity as the frequency or severity of human-coyote conflict increases. Although mild treatments conducted by community members and graduated approaches might be perceived by the public as more humane than high intensity aversive conditioning techniques (Sampson and Van Patter 2020), such gradual escalation of aversive stimuli is expected to produce habituation (Azrin et al. 1963; Banks 1976; Domjan 2014) and could decrease the efficacy of future interventions. High-intensity aversive conditioning that employed projectiles and trained dogs were rarely recommended in coyote management plans, but our work in Calgary suggests that this technique can produce longer-term changes in coyote behavior.

Our finding that most coyotes (83% of 734 events) retreated quickly from an aversive conditioning event was similar to those of Bonnell and Breck (2017), where 71% of coyotes retreated from low intensity aversive conditioning events conducted during a community-based hazing program. Our evidence that the number of previous aversive conditioning events increased the probability of coyotes retreating from subsequent aversive conditioning events suggests a learning process consistent with the purpose of aversive conditioning for wildlife (Kloppers et al. 2005; Mazur 2010; Hopkins et al. 2010). Similar learning was described in hazing studies of captive coyotes (Andelt et al. 1999; Young et al. 2019), as well as wild elk (*Cervus canadensis*, Found et al. 2018, Jones et al. 2021), lions (*Panthera leo*, Petracca et al. 2019), and macaques (*Macaca fuscata*, Honda et al. 2019), in which successive hazing events reduced associated human-wildlife conflicts. We found that longer periods of time since the last aversive conditioning engagement predicted a greater probability of coyote presence as assessed by contractors and a reduced probability of retreat from aversive conditioning, possibly due to interactions with people or pets since aversive conditioning last occurred. These findings differ from a study in which livestock protection dogs were used to address sheep depredation by coyotes; the number of sheep killed significantly declined during the treatment (i.e., dogs) period compared to the pre-treatment period, with no difference in the number of kills during the treatment and post-treatment periods (Linhart et al. 1979). However, our findings are consistent with a study conducted on captive coyotes in which animals that were hand-fed or previously in contact with dogs were more likely to approach people than coyotes that did not have these interactions with pets or humans (Young et al. 2019). Similar findings were also described in an elk hazing program, where the proportion of elk using a conflict zone increased with the number of days since the last hazing event (Jones et al. 2021).

Our finding that longer periods of time since the last aversive conditioning engagement predicted a greater probability of coyote presence and a reduced probability of retreat highlights the need for frequent aversive conditioning interventions. There may be an upper limit to this frequency because intermediate frequencies generated the greatest response to aversive conditioning in elk (Found et al. 2018). Somewhat paradoxically, the most intensive aversive conditioning events in Calgary that involved both chalk balls and a dog were associated with bolder coyote responses. Presumably, this occurred because only the boldest coyotes remained in the area long enough for these treatments to be used. Evidence that these events produced subsequent retreats is provided by prior aversive conditioning treatments (within eight weeks), which was one of the biggest drivers of retreat probability. This result would be predicted by the principles of effective punishment, for which higher initial intensity of aversive conditioning is more likely to initiate a sensitization process while low intensity conditioning could cause habituation (Domjan 2014). Studies of black bears have shown similar responses to high-intensity conditioning that involve projectiles (Mazur 2010; Homstol 2011).

Our results suggest that coyote boldness tends to increase during the pup-rearing season relative to the breeding season. This finding is supported by the work of others where human-coyote conflicts and coyote attacks on people were found to be more frequent during the pup-rearing season (Timm 2006; Lukasik and Alexander 2011; Baker and Timm 2016; Quinn et al. 2016), possibly because coyotes are defending their dens and territories during this period (Gese 2001; Timm 2006; Lukasik and Alexander 2011; Baker and Timm 2016). We also found that the presence and number of reports increased with past numbers of coyote reports, and that both the probability of conflict reports and the number of reports increased between years, as would be expected from the presence of coyotes with increasing boldness. Parks with a high number of coyote reports are likely indicative of the presence of bold individuals. Boldness may arise from consumption of anthropogenic food via multiple mechanisms. Several authors have shown or speculated that food conditioning generally causes conflict in coyotes (Carbyn 1989; Schmidt and Timm 2007; Lukasik and Alexander 2011) and this mechanism is prevalent in other carnivores (e.g., Gunther 1994; Lewis et al. 2015; Herrero 2018; Mohammadi et al. 2019; van Bommel et al. 2020). Our result that bold coyotes were more likely to be associated with human-coyote conflicts highlights the importance of approaches that discourage intentional feeding as well as inadvertent feeding via garbage, compost, fruit trees and bird feeders.

Although we found that aversive conditioning increased the subsequent retreat by coyotes, a greater number of past conditioning treatments increased the probability of coyote presence as assessed by contractors. This result reflects the clustered nature of coyote presence and reports within parks. For the same reason, in a study of captive coyotes, an increase in the cumulative number of hazing events predicted a decrease in the proportion of time a pair of coyotes spent avoiding people (Young et al. 2019). Our result supports evidence by others that this tool does not change the distribution of coyotes in urban areas (Bonnell and Breck 2017; Breck et al. 2017). Managers should address this limitation of aversive conditioning by complementing it with other management techniques. The most important of these is public education programs to reduce food availability to urban coyotes and prevent food conditioned animals, which was recommended by all of the municipal management plans that we reviewed. Similar recommendations can be found in studies of human-wildlife conflict in other species (Espinosa and Jacobson 2012; Purcell et al. 2012; Lackey et al. 2018; Proctor et al. 2018). Aggressive prevention of the anthropogenic attractants that contribute to bold behavior should reduce the need for lethal management. Although targeted lethal removal of problem individuals can rapidly reduce human-coyote conflicts (Breck et al. 2017) and was recommended in all but two of the management plans, it is highly contentious with the public (Martínez-Espiñeira 2006; Jackman and Rutberg 2015; Drake et al. 2020).

Our work has some important limitations that invite further study of aversive conditioning as a tool for managing urban coyotes. First, we treated parks and areas within large parks as independent units in our analyses, but some coyotes undoubtedly traveled among these areas, potentially increasing risk of Type I statistical errors. Because coyotes were not tagged or collared, we cannot be sure that coyotes found at the same location were repeatedly exposed to conditioning treatment even when these occurred in the same park over successive days. A second limitation of this study is the restriction for aversive conditioning to occur only on city-owned property, which prohibited contractors from pursuing coyotes on private property where food and shelter were sometimes available (C. C. St. Clair, personal observations) to limit the consistency of negative stimuli applied to bold animals. Third, our study did not attempt to quantify an impression by several authors that coyotes responded by retreating immediately as contractors approached following an initial aversive conditioning event. Future studies might record a pre-conditioning response to test this impression. Fourth, because our data was collected as part of an active management program, aversive conditioning was conducted in all parks (i.e., we did not have control parks). Without a control, we cannot decisively attribute the changes we recorded in coyote behavior to the aversive conditioning treatment (Snijders et al. 2019). A final potential limitation is that the data were collected by contractors (for contractor actions and coyote responses) and city employees (for 311 reports) who did not anticipate our use of the data; three authors visited the study site to witness the conditioning actions, but did not participate in data collection.

Like other studies of aversive conditioning, logistical constraints prevented us from consistently applying the principles of effective punishment as described by learning theory (Domjan 2014; Found and St. Clair 2019; Evans Ogden 2021), Calgary's high intensity conditioning applied the principles of evolutionary relevance (pursuit and fear), high initial intensity (chalk balls and dogs) and consistency (similar procedures with each engagement), but events could not be performed immediately. It was necessary to violate the principle of contingency (avoiding signals of impending conditioning) to maintain public awareness and safety by implementing the conditioning with a few individuals who wore high-visibility vests. The capacity for coyotes to recognize individual people, behavior that has been described in American crows (*Corvus brachyrhynchos*, Marzluff et al. 2010), sheep (*Ovis aries*; Knolle et al. 2017), domestic dogs (*Canis familiaris*, Huber et al. 2013), and archerfish (*Toxotes chatareus*;

Newport et al. 2016), may have led coyotes to anticipate conditioning events. A final principle of punishment (i.e. the use of rewards for alternative behavior; Domjan 2014) is difficult to achieve in any wildlife setting. Coyotes may perceive the cessation of treatment when exhibiting the desired behavior as a reward (e.g., Homstol 2011, G. Lajeunesse *in preparation*). For example, in some conditioning programs for bears, the aversive conditioning treatment ceased (i.e., a reward is provided) when bears entered hiding cover (i.e., a desirable alternative behavior; Homstol 2011, C. Edwards, personal communication). Future work could aim to employ more of the standard principles for effective aversive conditioning (Domjan 2014, Found and St. Clair 2019, Evans Ogden 2021).

2.6 CONCLUSIONS

Our study demonstrated that high-intensity aversive conditioning, as conducted by contractors and their working dogs, increased the probability of subsequent retreats by coyotes. Similar aversive conditioning techniques used proactively on all coyotes might prevent the occurrence of bold behaviors in other urban areas. Aversive conditioning should be used in combination with management that educates the public to promote coyote reporting to civic databases, discourages wildlife feeding, and improves waste disposal in order to prevent food conditioned coyotes. Although most coyote management plans agreed that highly aggressive animals should be removed, there was less consistency in recommendations for bold animals. More study is urgently needed of non-lethal techniques for managing human-wildlife conflict, particularly for carnivores in urban areas.

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2.8 CONFLICT OF INTEREST

The authors declare no conflict of interest. Data about contractors actions and coyote responses were collected by Animal Damage Control. Data about public reports to 311 were collected by the City of Calgary. Both data sets were provided to the authors to support scientific study without cost or remuneration for any party.

2.9 TABLES

Table 2.1. Management techniques and the number of coyote management plans (n = 72 management plans) that recommend them, do not recommend them, or do not comment on the technique.

Management technique	Number recommending	Number discouraging	Number not commenting
Hazing	71 (98.6%)	0 (0.0%)	1 (1.4%)
Targeted lethal removal of problem individuals	70 (97.2%)	2 (2.8%)	0 (0.0%)
Relocation of problem individuals	1 (1.4%)	40 (55.6%)	31 (43.1%)
Attractant removal	62 (86.1%)	0 (0.0%)	10 (13.9%)
Public education	72 (100.0%)	0 (0.0%)	0 (0.0%)

Table 2.2. Recommended hazing tools and the sources of their implementation among 71 management plans for urban coyotes.

Tools recommended	Community members	City staff and/ or contractors
Low intensity: human movements, motion-activated lights, noises (e.g., shout, air horns or other noisemakers; n = 68)	68 (95.8%)	8 (11.3%)
Moderate intensity: projectiles thrown by hand (e.g., rocks, sticks, cans, tennis balls). Water or water-vinegar mixtures sprayed. Pepper spray, bear repellent or other chemical deterrent used (n = 66)	66 (93.0%)	8 (11.3%)
High intensity: projectiles thrown using an object (e.g., slingshot, paintball gun; n =14)	3 (4.2%)	14 (19.7%)*

*An additional 4 management plans recommended city staff or contractors use high intensity hazing, but did not mention the type of stimuli to be used.

Table 2.3. Number of management plans that made recommendations for the implementation of different coyote hazing approaches among the 71 coyote management plans and the number that promoted this tool.

General recommendation for implementation	Number of plans
Community-led programs encouraged	37 (52.1%)
Hazing threat coming from a person is clear to the coyote	35 (49.3%)
Hazing does not stop until coyote leaves	30 (42.3%)
Hazing should be conducted every time a coyote is seen	5 (7.0%)
Hazing continues over the long-term	34 (47.9%)
Hazing should be conducted by using a variety of tools, techniques, and people	41 (57.7%)
Hazing effort should be exaggerated at the commencement of the hazing program	34 (47.9%)
Respond to coyotes with an initially mild response and increase the severity of the response as the frequency and degree of conflict increases	38 (53.5%)

Table 2.4. Aversive conditioning actions (n = 1917 interventions, 765 aversive conditioning events) performed by private contractors between September 2018 and July 2021 in the City of Calgary, Alberta.

Aversive conditioning actions performed	Ordinal Scale Value	Number of aversive conditioning events	Dogs were used: Yes (1) / No (0)	Shots were fired: Yes (1) / No (0)
No aversive conditioning actions (no coyote seen or aversive conditioning could not be conducted due to the location of the coyote)	0	1152 (60%)	0	0
Dogs were used. No shots were fired.	1	379 (20%)	1	0
Dogs were not used. Distant shots were fired. Balls did not hit close to the coyote.	2	82 (4.3%)	0	1
Dogs were not used. Shots were fired near the coyote. The coyote did not come into contact with a chalk ball.	3	55 (2.9%)	0	1
Dogs were used. Shots were fired. The coyote did not come into contact with a chalk ball.	4	183 (9.5%)	1	1
Dogs were not used. Shots were fired. The coyote came into contact with a chalk ball.	5	11 (0.6%)	0	1
Dogs were used. Shots were fired. The coyote came into contact with a chalk ball.	6	53 (2.8%)	1	1
Misclassified treatments	“4-5”	2 (0.1%)	N/A	N/A

Table 2.5. Response of coyotes to aversive conditioning actions (n = 734 aversive conditioning events) performed and recorded by private contractors between September 2018 and July 2021 in the City of Calgary, Alberta.

Response of coyotes to aversive conditioning	Ordinal Scale Value	Number of aversive conditioning events
Coyotes left immediately and did not stop to look	1	353 (48%)
Coyote delayed leaving for a few moments but did not let the contractors get close. Eventually took off	2	254 (35%)
Coyote delayed leaving, required multiple pushes and did not vacate right away	3	107 (15%)
Coyote challenged the dog and was not leaving, requiring close quarter aversive conditioning	4	17 (2.3%)
Coyote physically attacked the dog or handler resulting in either a close call or an actual bite	5	3 (0.4%)

Table 2.6. Classification code of reports of coyote activity (n = 826 coyote reports) submitted by members of the public to the City of Calgary's 311 reporting database between May 2018 and July 2021 for the 72 parks or park areas subjected to aversive conditioning.

Observation or conflict	Nature of coyote report	Ordinal Scale Value	Definition	Number of reports
Observation	Sign	1	The act of noticing or taking note of tracks, scat, or vocalizations that indicate activity of coyote(s) in an area.	4 (0.5%)
	Sighting	2	A visual observation of a coyote(s)	313 (38%)
	Encounter	3	An interaction between a human and a coyote that is without incident.	186 (23%)
Conflict	Incident - Dog	4	A conflict between a dog and a coyote where a coyote exhibited behavior creating an uncomfortable situation for the human; includes baring teeth, growling, snarling, stalking a dog or crouching as if to attack a dog, or a dog is attacked without injury to the dog.	79 (9.6%)
	Incident - Human	5	A conflict between a human and a coyote where a coyote exhibited behavior creating an uncomfortable situation for the human; includes baring teeth, growling, snarling, stalking a human or crouching as if to attack a human.	173 (21%)
	Pet attack	6	Domestic pet is attacked by a coyote (either injured or killed).	58 (7.0%)
	Human attack	7	A conflict that involves physical contact between a coyote and a human; a human is injured or killed by a coyote.	13 (1.6%)

Table 2.7. Summary of logistic regressions top models output for binary response of coyotes to aversive conditioning (resist = 0, retreat = 1) and the type of reports of coyote activity made to 311 (observation = 0, conflict = 1) in Calgary, Alberta between September 2018 and July 2021. The degrees of freedom (df), difference in Akaike's Information Criterion corrected for small sample sizes (ΔAIC_c), AIC weight (w_i), marginal R^2, conditional R^2, and ROC area under the curve (AUC) are presented for each model. We only presented models within 2.0 AIC_c of the top model. Table excludes the intercept, and the random effect of park or park area included with each model.

Behavioral metric (response variable)	Model terms[a]	df	ΔAIC_c	w_i	Marginal R^2	Conditional R^2	AUC
Coyote presence, as assessed by contractors (n = 1355)	AC + Days + Prior treatment + Year	7	0.00	0.188	0.589	0.620	0.900
	AC + Days + Prior treatment + Season	8	0.38	0.155	0.595	0.623	0.899
	AC + Days + Prior treatment	6	1.97	0.070	0.591	0.619	0.898
Response of coyotes to aversive conditioning (n = 641)	AC + Days + Treatment	6	0.00	0.168	0.397	0.522	0.913
	Days + Treatment	5	0.74	0.116	0.398	0.508	0.908
	AC + Treatment	5	1.46	0.081	0.385	0.508	0.911
Response of coyotes to aversive conditioning, when aversive conditioning had been conducted in the 8 weeks prior to an event (n = 562)	AC + Treatment	5	0.00	0.123	0.420	0.541	0.920
	Treatment	4	0.99	0.075	0.423	0.524	0.916
	AC + Treatment + Prior treatment	7	1.41	0.061	0.427	0.546	0.922

Type of coyote reports (n = 460)	AC + Year	4	0.00	0.242	0.034	0.125	0.719

[a]AC = Number of aversive conditioning events in the 7 days (presence model) or 56 days (all other models) prior to this event, Days = Number of days since the last aversive conditioning engagement, Treatment = The aversive conditioning treatment, Prior treatment = Last aversive conditioning treatment prior to the event, Season = Seasons relevant to coyote ecology (breeding, pup-rearing, dispersal), Year = Year of the event.

Table 2.8. Summary of zero-inflated negative binomial regression top models output for number of coyote reports made to 311 per week and park combination (n = 5,037) in Calgary, Alberta between September 2018 and July 2021. The degrees of freedom (df), difference in Akaike's Information Criterion corrected for small sample sizes (ΔAIC_c), marginal R^2, and conditional R^2 are presented for each model. We only presented models within 2.0 AIC_c of the top model. Table excludes the intercept, and the random effect of park or park area included with each model.

Model terms[a]: Occurrence of reports	Model terms[a]: Abundance of reports	df	ΔAIC_c	Marginal R^2	Conditional R^2
Report + Season	Report + Year	10	1.21	0.073	0.190
Report	Report + Season + Year	10	1.83	0.095	0.198

[a]Report = Number of reports in the 56 days prior to this reporting week, Season = Seasons relevant to coyote ecology (breeding, pup-rearing, dispersal), Year = Reporting year.

2.10 FIGURES

Figure 2.1. Coefficient estimates for the top models from logistic regressions of the predictors of a) the absence (0) or presence (1) of coyotes as assessed by contractors prior to an aversive conditioning event, b) resistance (0) or retreat (1) by coyotes during aversive conditioning (AC) events c) resistance (0) or retreat (1) by coyotes during aversive conditioning events when another aversive conditioning event had been conducted within eight weeks prior to that event and d) observation (0) or conflict (1) coyote reports made by the public to the civic 311 service in the City of Calgary, Alberta, Canada (September 2018 - July 2021). Predictors in the top models included the number of aversive conditioning events in the week (a) or eight weeks (b, c, d) prior to an event (# AC), the number of days since the last aversive conditioning engagement (Days since AC) the aversive conditioning treatment (coded as 1 = dogs were used, shots were not fired, 2 = dogs were not used, shots were fired, 3 = dogs were used, shots were fired), the last aversive conditioning treatment prior to the event (Prior, coded as described above), the seasons relevant to coyote ecology (coded as 1 = breeding, 2 = pup-rearing, 3 = dispersal), and the year of the event (Year). Error bars show 85% confidence intervals of the model fixed effect coefficients. All continuous variables were scaled. The aversive conditioning treatments and the seasons relevant to coyote ecology were modeled as factors, with the treatments "Dogs used, No

shots fired" and the breeding season as the reference categories.

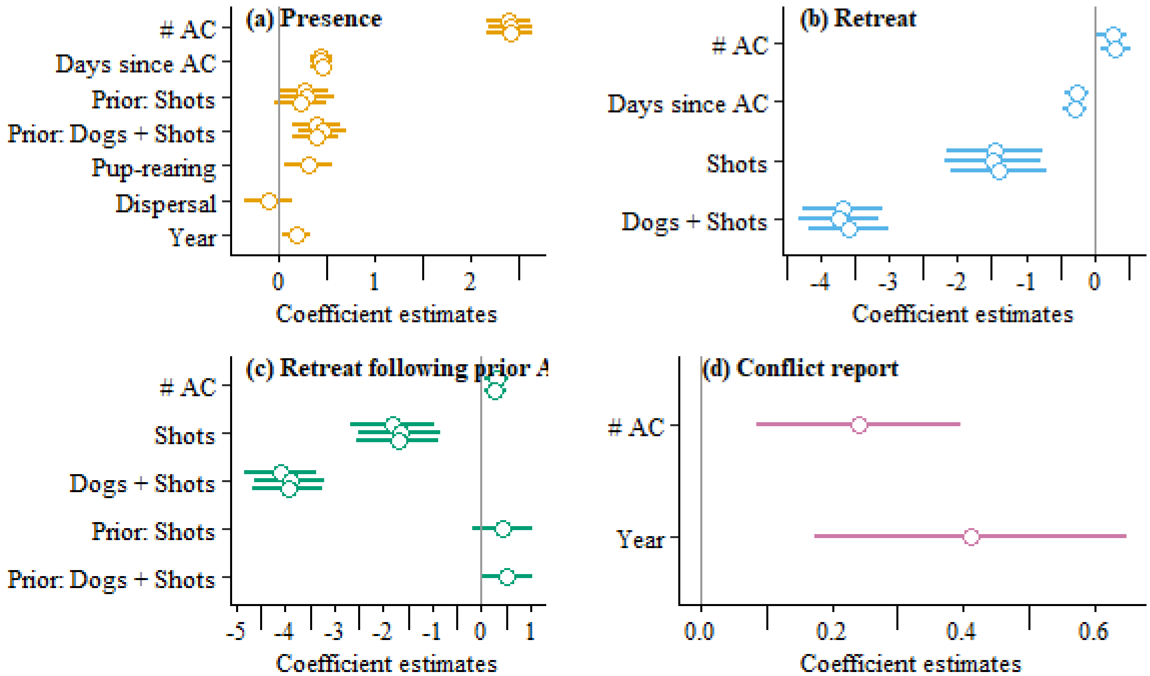
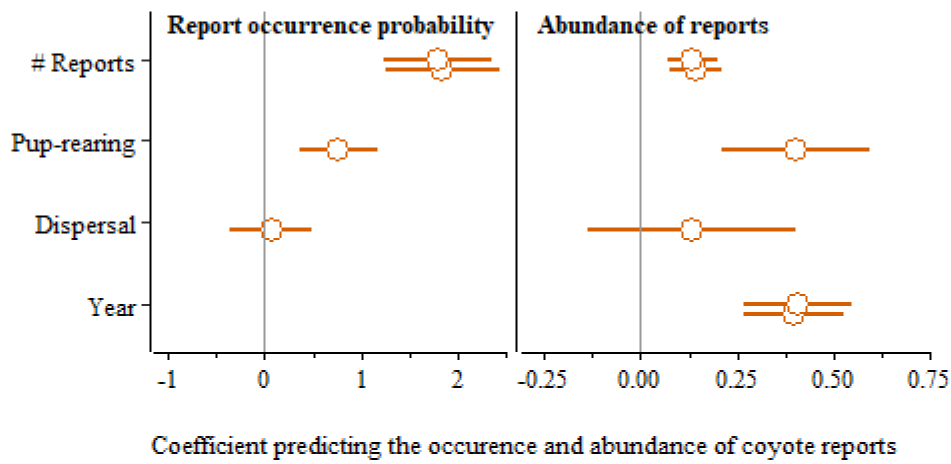


Figure 2.2. Coefficient estimates from the top zero-inflated negative binomial regression models of the predictors of the weekly occurrence (left) and abundance (right) of coyote reports submitted by the public to the City of Calgary's 311 database (September 2018 - July 2021). Predictors included the number of reports in the eight weeks prior to an event (# Reports), the seasons relevant to coyote ecology (coded as 1 = breeding, 2 = pup-rearing, 3 = dispersal), and the year of the event (Year). Error bars show 85% confidence intervals of the model fixed effect coefficients. All continuous variables were scaled. The seasons relevant to coyote ecology were modeled as factors, with breeding season as the reference category.



Chapter 3

An urban coyote intervention program reveals coyotes to be rare and retreat from people in residential neighbourhoods with high previous rates of coyote reports

3.1 ABSTRACT

1. In urban areas, human-coyote conflicts often arise when coyotes follow, pursue or attack pets or people. Although coyote attacks on people are rare, those attacks are often highly publicised, and leave residents concerned about the presence of coyotes in their neighbourhoods. Hazing applied by members of the public is often promoted as a way to mitigate human-coyote conflicts, but this method has only been studied recently and there are few guidelines for its implementation.
2. We developed a community-based hazing program for urban coyotes in Edmonton (Alberta, Canada) implemented by volunteers who patrolled their neighbourhoods in late winter while recording coyotes or coyote attractants, such as prey habitat, fruit trees, unsecured garbage or compost, and birdseed. When coyotes were observed, volunteers walked towards the coyotes and recorded the distance at which coyotes exhibited a reaction (overt reaction distance) and the distance at which they retreated (flight initiation distance). If coyotes did not retreat when volunteers were within 40 m of the animal, volunteers conducted hazing by running towards the coyote while shouting and throwing weighted tennis balls in the direction of the animal.

3. Over the two field seasons of our program, we recruited, trained, and engaged 120 volunteers from 71 neighbourhoods who conducted 1598 patrols, observed coyotes in 175 instances, and conducted hazing 23 times. Coyotes retreated before volunteers were within 40 m during 70.6% of the observations and 22/23 (95.7%) of coyotes retreated from aversive conditioning.
4. Perhaps owing to limitations of sample size and timing mismatch between patrols conducted by volunteers and coyote activity, we found little evidence that hazing changed subsequent measures of overt reaction or flight response distances by coyotes and its effects on the number or timing of subsequent coyote reports by members of the public were inconsistent.
5. *Synthesis and applications*: Our study emphasizes the rarity of close encounters with coyotes and the high frequency with which they retreat from human advances and even directed attention by people. Our study supports continued use of community-based hazing as a means of reassuring members of the public that may also promote wariness in coyotes.

3.2 INTRODUCTION

Urban coyotes are increasingly common across North America (White and Gehrt 2009) and conflicts with them have been described in many communities (Weckel et al. 2010; Lukasik and Alexander 2011; Poessel et al. 2013; Drake et al. 2020). Coyotes approach, pursue and attack pets and people (Timm et al. 2004; Lukasik and Alexander 2011), and den under porches and decks (Poessel et al. 2013), potentially threatening the safety of people and their pets. Although coyote attacks on people remain rare, especially considering the rates of human-coyote interactions within cities (Lukasik and Alexander 2011; Poessel et al. 2013; Quinn et al. 2016), recent attacks on humans have occurred in the Canadian cities of Burlington (ON, Callan 2022), Calgary (AB, Rieger 2021), Edmonton (AB, Panza-Beltrandi 2022) and Vancouver (BC, McSheffrey 2022), leaving many people concerned about the presence of coyotes in their neighbourhoods (Holmes 2021; Taniguchi 2022). Such concerns may be exacerbated by the way these animals are portrayed in print and social media (Alexander and Quinn 2011a; 2011b; Draheim et al. 2011; 2021).

Management plans for urban coyotes frequently recommend the use of aversive conditioning and hazing as humane ways to manage bold, urban coyotes (Lajeunesse et al., *unpublished data*). Aversive conditioning extends the concept of hazing, which is defined as the act of using deterrents to immediately change the behaviour of an animal (Breck et al. 2017). Aversive conditioning refers to the repeated and consistent use of deterrents to reduce the occurrence of similar behaviours in similar contexts over longer time periods by teaching animals greater wariness towards people (Hopkins et al. 2010; White and Delaup 2012). Both dogs and shouting (i.e., deterrents) are occasionally used by indigenous people in Northern Canada to deter bears from conflict situations (Clark and Slocombe 2009). Although aversive conditioning has been applied extensively to elk (*Cervus canadensis*, Kloppers et al. 2005) and black bears (*Ursus americanus*, Mazur et al. 2010) it has been applied to bold urban coyotes only recently (Bonnell and Breck 2017; Breck et al. 2017; Young et al. 2019; McLellan and Walker 2021; Lajeunesse et al., *unpublished data*) and there are few guidelines for implementing this technique.

Repeated applications of aversive stimuli to wildlife that foster learning through aversive conditioning are typically conducted by trained wildlife professionals in high intensity programs that may use projectiles, loud noises and pursuit by humans or trained dogs (Kloppers et al.

2005; Mazur 2010; Homstol 2011; Found et al. 2018). Such a program was applied to coyotes in the City of Calgary (AB) with some evidence that it trained coyotes to retreat from people (Lajeunesse et al., *unpublished data*), but these approaches are often resource intensive (Kloppers et al. 2005; Kidd-Weaver et al. 2022), and the use of high intensity stimuli can be contentious (Sampson and Van Patter 2020; Alexander 2022). Furthermore, these high intensity treatments are often applied reactively to conflict individuals rather than proactively on all coyotes due to limited personnel, possibly limiting the efficacy of these treatments (Breck et al. 2017; Lajeunesse et al., *unpublished data*). One potential solution would be to combine these high intensity treatments with lower intensity hazing programs conducted by community members.

To date, only two studies have addressed the use of community-based hazing to manage bold urban coyotes, both in the Denver Metropolitan Area (Bonnell and Breck 2017; Breck et al. 2017). In one, authors developed a program in which trained volunteers and members of the public were encouraged to haze coyotes when appropriate (determined based on coyote behaviour and location) by standing tall, shouting and sometimes throwing objects in the direction of the animal (Bonnell and Breck 2017). Following a hazing treatment, coyotes most commonly (81/96, 84.4%) retreated, although average responses were diminished by the presence of a dog. A second program encouraged members of the public to haze coyotes in two public parks via posted educational signs (Breck et al. 2017). Hazing was ineffective (i.e., the authors found no difference in the overlap in time of activity between people and coyotes in treatment and control parks) at modifying coyote behaviour when applied reactively on targeted bold individuals. Both studies concluded that coyotes retreated from hazing in the short term

(Bonnell and Breck 2017), but this technique did not seem to have long-lasting effects on coyote behaviour (Bonnell and Breck 2017; Breck et al. 2017).

Community-based hazing offers several advantages for communities that have bold urban coyotes, including an increased general knowledge of the scientific process and the local environment, a higher public support for conservation and wildlife management (Conrad and Hilchey 2011), and cost saving, as community members can often cover larger areas than contracted wildlife professionals and work during non-office hours (Conrad and Hilchey 2011; Van Vliet and Moore 2016). However, more evidence is needed to understand whether, and how, coyotes generalise their hazing experience and to quantify coyote reactions in ways that could translate to management goals or metrics of human safety. In other species, tolerance of and habituation to people have been measured by the distance at which animals react to or flee from people. In grizzly bears (*Ursus arctos*), researchers have recorded overt reaction distance as the distance at which an animal exhibits a visual response to an approaching person (Smith et al. 2005). In elk, researchers have measured flight response distance from animal retreats (Kloppers et al. 2005), which has been generalised as flight initiation distance for dozens of species (Stankowich and Blumstein 2005; Weston et al. 2012; Nunes et al. 2018).

Here we describe a community-based hazing program called the Urban Coyote Intervention Program (UCIP) and implemented in Edmonton, AB. We sought to develop and refine the use of hazing by members of the public in discrete neighbourhoods as a cost-effective tool to reduce conflict by increasing the wariness of coyotes while empowering citizens to address bold behaviour by coyotes in their own neighbourhoods. We targeted residential neighbourhoods because coyotes induce more concern at this scale (Farr et al. 2022; Hunold and Lloro 2022), and conducted the program during the coyote breeding season to reduce their subsequent use of residential areas for denning, which is a season and context with high past rates of human-coyote conflict (Bombieri et al. 2018). Volunteers in treatment neighbourhoods were instructed to treat coyotes during the day and to conduct hazing for individuals that could be approached within 40 m; this is similar to the distance targeted for elk retreat in national parks (Kloppers et al. 2005). We assessed the effects of hazing on coyotes by measuring changes in their overt reaction and flight initiation distances over time and by the frequency and timing of reports made by residents of each neighbourhood to the Edmonton Urban Coyote Project website or the City of Edmonton's 311 report database. If associative learning by coyotes occurred in response to persistent use of hazing by people, we predicted that reaction distances by coyotes would increase and reports of coyotes and associated perceptions of human-coyote conflict would decline.

3.3 METHODS

3.3.1 Study area

We studied the responses of coyotes to a community-based hazing program conducted in the City of Edmonton, central Alberta, Canada (53°34'N, 113°25'W). Edmonton is situated in a transition zone between prairie grasslands and the boreal forest (The City of Edmonton 2008), has an elevation of 671 m, mean temperatures ranging from -12° C in the winter to 16° C in the summer, and annual precipitation of 446 mm (Smith 2019). The human population of Edmonton was approximately 1,010,899 in 2021 over its 685 square kilometres, making it the fifth most populated city in Canada (Smith 2019; Government of Alberta 2022). Half (52%) of the city's total area is occupied by residential lands, with over 242 residential neighbourhoods within the City of Edmonton (The City of Edmonton 2016). Natural areas comprise about 7% of the city's total area (Murray and St. Clair 2017). The city is divided by the North Saskatchewan River which is connected to many ravines that combine to constitute the largest stretch of municipally-owned urban parkland in North America. This area provides natural habitat for many wildlife species, including white-tailed jackrabbits (*Lepus townsendii*), white-tailed deer (*Odocoileus virginianus*), beavers (*Castor canadensis*), porcupines (*Erethizon dorsatum*), and coyotes (*Canis latrans*; The City of Edmonton 2008).

3.3.2 Volunteer training and hazing

Volunteers who lived in or were associated with the participating neighbourhoods conducted the hazing. We used newsletters and social media boards to recruit volunteers living in the 43 communities that had the highest rates of reported coyote observations to the Edmonton Urban Coyote Project (EUCP) website or the civic 311 call centre. We also described the program on the EUCP website, in webinars given for other purposes, in media interviews, and casual conversations, to raise awareness of this program. Volunteers were trained via a website that provided information about coyote behaviour, the goals of the program, features that attract coyotes as food or shelter, aversive conditioning techniques, and volunteer safety. The website also introduced volunteers to the data collection forms to guide their coyote patrols, observations of attractants, and hazing events. Before beginning their patrols, all volunteers had to obtain a perfect score on a quiz that assessed knowledge of program goals, measures of success, key concepts, and the hazing techniques.

Volunteers participated in the hazing program by patrolling their neighbourhoods and responding to reports of coyotes by other people. Volunteers developed their own patrol schedules based on their availability, but were encouraged to conduct one or more patrols per week. While patrolling, volunteers noted the time at which they started and ended their patrols and whether or not they found coyotes or attractants. When one or more coyotes was observed, volunteers recorded the time, date, location, context (e.g. number of coyotes, presence of vulnerable individuals) and behaviour of animals (e.g. travelling). To assess coyote wariness, volunteers measured overt reaction distance and flight initiation distance as they began walking slowly towards the coyote. If the coyote did not retreat when volunteers were within 40 m of the animal, volunteers hazed the coyote. A hazing event consisted of running towards the coyote while shouting and throwing modified tennis balls in the direction of the animal. Tennis balls were modified by adding sand to make them the weight of baseballs, thereby increasing throwing accuracy, and fitting them with three streamers of pink flagging tape to increase their animation and resemble fladry (Young et al. 2019; Windell et al. 2022). Volunteers recorded the direction (i.e., as an angle relative to their own approach) and the behavioural response of coyotes (i.e., run away, trot away, back away, remain in place, or approach). As part of their patrols or hazing events, volunteers recorded potential coyote attractants, such as accessible compost or garbage, spilled bird seed, and piles of wood that might shelter rodents. Volunteers were encouraged to record attractants during patrols even if a coyote was not observed.

The program occurred during two field seasons from January to May 2021 and 2022. In 2021, neighbourhoods were assigned as treatment and control; to the extent possible, neighbourhoods were paired based on spatial proximity to one another and similar proximity to the river valley and ravine parkland. Hazing was only conducted in treatment neighbourhoods. Volunteers in control neighbourhoods recorded coyote presence and responses, but did not haze coyotes. Instead, when volunteers in control neighbourhoods were within 40 m of coyotes, they stopped and retreated. Volunteers in treatment neighbourhoods applied hazing as described above. Because there were few opportunities to conduct hazing in 2021, we eliminated control neighbourhoods in 2022 to increase measures of coyote responses to conditioning.

Public reports of coyote sightings and encounters in the City of Edmonton were collected from the EUCP website between January 1, 2021 and June 1, 2022. Also between January 1, 2021 and June 1, 2022, we collected public reports of coyotes from the City of Edmonton 311 civic database via private communication. We identified the neighbourhood associated with every report, and eliminated reports for which no date was provided.

3.3.3 Data analysis

To assess how the program was implemented by volunteers, we summarised the number of volunteers, duration of coyote patrols, and number of coyotes observed in each neighbourhood. We then used unpaired Mann-Whitney U tests to determine whether there were differences in the average duration of patrols and the number of coyotes volunteers observed between treatment and control neighbourhoods in 2021. We employed Pearson's chi-squared test to determine whether certain behavioural responses occurred more or less frequently than expected depending on the hazing actions conducted by volunteers.

We used logistic regression models to determine the impact of hazing on the overt reaction distances expressed by coyotes. We first grouped overt reaction distances in binary categories based on whether the conditions for hazing to be conducted were met, with overt reaction distances ranging from 0-39 m grouped together and assigned a value of 0, and overt reaction distances of 40 m or more grouped together and assigned a value of 1. As predictors for this binary response variable, we evaluated the number of times (within the past 30 days and within each neighbourhood) the overt reaction distances were evaluated, hazing was conducted, and attractants were reported. We also considered the number of coyotes present while the overt reaction distance was being evaluated by volunteers. Each model included one fixed and one random effect (neighbourhood). We built our models using an inference-based modelling framework (Tredennick et al. 2021) and considered the influence of each potential predictor on the overt reaction distances of coyotes using logistic regressions. For each model, we reported the beta coefficient (β) and confidence intervals (CI) to emphasise effect size (Nakagawa and Cuthill 2007). We evaluated model fit using Nakagawa and Schielzeth's R^2, which is adapted to generalised linear mixed-effects models (Nakagawa and Schielzeth 2013). Finally, we compared our models to a null model using likelihood ratio tests. We used the same approach to determine the effect of hazing and other variables on the flight initiation distances expressed by coyotes, with flight initiation distances classified as less than (0) vs. equal to or more than (1) 40 m.

We investigated the effects of time of day on overt reaction distances using Pearson's chi-squared test. We classified overt reaction distances as less than vs. equal to or more than 40 m. We coded the time of coyote observations as morning (4am - <10am), day (10am - <4pm), evening (4pm-<10pm), or night (10pm - <4am; Shivik et al. 1997).

We assessed the effects of hazing on coyote reports using the frequency and timing of reports made to the EUCP website and 311 civic call centre. To assess frequency, we counted the number of reports made in each neighbourhood for the two weeks before and after the use of hazing. We compared these reports to reports made a) in neighbourhoods that participated in the program and where coyotes were observed by volunteers, but hazing was not conducted (i.e., designated control neighbourhoods in 2021, and neighbourhoods that were not designated as controls, but where hazing was not conducted in 2022) or b) in neighbourhoods that did not participate in the program. Neighbourhoods were paired based on spatial proximity to one another and similar proximity to the river valley and ravine parkland. For neighbourhoods without hazing events, we counted coyote reports before and after the date for hazing in the treated neighbourhoods. We used poisson regression models to determine whether the number of coyote reports made to either the EUCP or the 311 civic call centre significantly differed between the two weeks preceding and the two weeks following each event in neighbourhoods where hazing was conducted compared to neighbourhoods where it was not. As potential predictors, we explored the effects of time period (i.e., before or after the event) and treatment type (i.e., hazing or control) on the number of reports, with neighbourhood pairs as a random effect. All fixed effects were coded as factors, with “before” and “control” as the reference categories. For each model, we reported the β, CIs, and Nakagawa and Schielzeth’s R^2. We compared our models to null models using likelihood ratio tests.

To assess timing, we counted the days to the next report after a hazing event in a neighbourhood and assigned dates for neighbourhoods without hazing events as above. We excluded neighbourhood pairs that were not followed by a coyote report from our analysis. We used poisson regression models to determine whether the number of days to the next report significantly differed between neighbourhoods where hazing was conducted compared to neighbourhoods where it was not. We considered the effect of treatment (i.e., hazing or control) on the number of days to the next report, with neighbourhood pairs as a random effect. The treatment type was coded as a factor, with “control” as the reference category. We reported the beta coefficient (β), confidence intervals (CI), Nakagawa and Schielzeth’s R^2, and compared models to null models using likelihood ratio tests.

We assessed the difference in timing of patrols conducted by volunteers and coyote activity by summarising the number of patrols (n = 1,598), coyote observations (n = 175), and coyote reports (n = 190) for each hour of the day. We collected reports of coyote activity made to the Edmonton Urban Coyote Project website between January and May 2021 and 2022 in neighbourhoods that participated in the program (i.e., where patrols were conducted by volunteers). We eliminated reports for which no time was provided, as well as reports with imprecise time (e.g., morning, afternoon, night). All statistical analyses were performed in R version 4.1.0 (R Core Team 2021).

3.4 RESULTS

In 2021, 59 volunteers in 28 neighbourhoods participated in the program by conducting 657 patrols that summed to 571 hours and 37 minutes. The average duration of patrols was about 13% longer in treatment ($n = 349$ patrols, $\bar{x} = 55.2$ minutes, $SD = 25.7$ minutes) than control neighbourhoods ($n = 308$ patrols, $\bar{x} = 48.9$ minutes, $SD = 25.9$ minutes; $W = 44329$, $p < 0.001$). In 2022, 77 volunteers (16 of them returning from 2021) in 59 neighbourhoods participated in the program by conducting 941 patrols that summed to 737 hours and 19 minutes. Over the two years, the total number of volunteers was 120 in 71 neighbourhoods in which 1,598 patrols summed to 1,308.93 hours.

In 2021, volunteers observed coyotes on 64 occasions in 15 different neighbourhoods with almost half ($n = 28$, or 43.8%) occurring in a single control neighbourhood (Appendix 2 Table 2.1). An additional 20 observations (31.2%) were made in four other neighbourhoods. The mean number of coyote sightings per neighbourhood was over six times higher in control ($n = 6$ neighbourhoods, $\bar{x} = 8.5$ coyotes, $SD = 10.0$ coyotes) than in treatment ($n = 9$ neighbourhoods, $\bar{x} = 1.4$ coyotes, $SD = 0.5$ coyotes) neighbourhoods ($W = 45.5$, $p = 0.025$). In 2022, volunteers recorded a total of 111 coyote observations in 28 different neighbourhoods, again with most concentrated in a few neighbourhoods (Appendix 2 Table 2.1).

Across both field seasons, volunteers were able to measure the overt reaction distance in 132 out of the 175 instances (75.4%) where coyotes were observed. Overt reaction distances were more often assigned to the larger distances ($\bar{x}$ = 42.5 m, SD = 20.4 m), with 22.7% over 60 m (n = 30), 34.8% at 40-60 m (n = 46), 23.5% at 20-39 m (n = 31), 18.2% at 5-19 m (n = 24), and 0.8% less than 5 m (n = 1). When the reaction of coyotes after volunteers measured the overt reaction distance was known (n = 126), over two thirds of coyotes left the area (n = 89 or 70.6%), but many remained in place (n = 35 or 27.8%) and coyotes approached a volunteer or another person on two occasions (1.6%). The flight initiation distance (FID) was measured on 80 occasions. Flight initiation distances were more often assigned to intermediate distances ($\bar{x}$ = 38.4 m, SD = 20.2 m), with 18.8% over 60 m (n = 15), 25.0% at 40-60 m (n = 20), 35.0% at 20-39 m (n = 28), 20.0% at 5-19 m (n = 16), and 1.3% less than 5 m (n = 1).

Hazing was conducted 23 times; 5 in 2021 in 4 neighbourhoods and 18 in 2022 in 11 neighbourhoods. Hazing actions included shouting (n = 18 or 78.3%), running towards the coyote (n = 11 or 47.8%), and throwing weighted tennis balls in the direction of or directly at the coyote (n = 6 or 26.1%). A volunteer conducted hazing with their leashed dog on one occasion by shouting and running towards the coyote. Following hazing, almost all (22/23; 95.7%) coyotes moved away from the volunteer. On almost half of these occasions, coyotes ran away from volunteers (10/23; 43.5%), but some walked away (n = 7; 30.4%), trotted away (n = 4; 17.4%), or backed away (n = 1; 4.3%). One coyote remained in place following hazing. There was no association between the hazing treatment used by volunteers and the response of coyotes to that treatment (X^2 = 12.65, P = 0.24; Table 3.1).

Volunteers recorded attractants on 695 out of the 1,598 patrols (43.5%) that were conducted across both field seasons. Unsecured garbage was recorded in almost half (n = 293 or

42.2%) of the patrols where attractants were observed. Other commonly reported food attractant included prey (i.e., white-tailed jackrabbits, cricetid (Cricetidae) rodents, domestic cats (*Felis cactus*), and American red squirrels (*Tamiascus hudsonicus*), n = 156 or 22.4%), accessible compost (n = 153; 22.0%), fallen fruits (n = 106; 15.3%), and birdseed (n = 96; 13.8%). Volunteers recorded pet food on only 1.6% (n = 11) of the patrols where attractants were reported. Large bushes or low hanging branches were the most commonly recorded shelter attractant (n = 289; 41.6%), followed by accessible sheds, outbuildings or decks (n = 109; 15.7%), piles of trimmed branches or stacked wood (n = 62; 8.9%), and piles of vegetation-based compost, composed of leaves or branches (n = 51; 7.3%).

We found little support that the higher categories of overt reaction distances (i.e., those estimated to be equal to or larger than 40 m) were associated with any of our explanatory variables (Fig. 3.1A). As predictors of overt reaction distances, confidence intervals broadly overlapped zero for each variable: the number of times overt reaction distance was measured in the past, number of coyotes present during the measurement, number of times hazing was conducted and number of times attractants were reported in the neighbourhood (Table 3.2). We found similar non-importance of these four predictors for flight initiation distances (Fig. 3.1B; Table 3.2). None of the 8 models performed significantly better than the null models and the comparison between marginal and conditional R^2 values revealed that most variation occurred among neighbourhoods (Table 3.2). Overt reaction distances also did not differ among times of day ($X^2 = 3.24$, $P = 0.36$; Table 3.3).

Our poisson regressions revealed a repeated effect of treatment on the number of public reports made to both the EUCP and 311 databases, but the direction of this effect differed by the control type (Figure 3.2). In the neighbourhoods with hazing, reports were an average of 56.6%

less frequent in the EUCP database (Fig. 3.2A) and 45.9% less frequent in the 311 database than neighbourhoods where patrols were conducted, but no hazing occurred (Fig. 3.2B; Table 3.4). However, when compared to non-participating neighbourhoods, reports in neighbourhoods with hazing were an average of 243.6% more prevalent in the EUCP database (Fig. 3.2A) and 392.3% more prevalent in the 311 database (Fig. 3.2B). Beta coefficients for treatment rarely overlapped zero (1 out of 4 times), while the coefficients for time (before vs. after) and the interaction between time and treatment overlapped broadly (Table 3.4). All four models performed significantly better than the null models, but each also exhibited much higher values for conditional than marginal R^2 values, indicating that most of the variation in these results resulted from variation among neighbourhood pairs, relative to the effect of hazing (Table 3.4).

The number of days to the next report also produced conflicting results, this time with similarity between the two control types, but differences in direction between the two databases. For the EUCP database, the number of days following a hazing event to the next report was an average of 30.45% higher than in neighbourhoods with no hazing or those that did not participate (Fig. 3.3A and B). For the 311 database, the number of days until the next report was 40.17% lower than the no hazing and non-participating neighbourhoods (Fig. 3.3A and B). Statistically, all but one of these four models performed better than the null model, but again the much higher values for conditional than marginal R^2 indicated that most of the variance was attributable to neighbourhood pairs (Table 3.5).

When comparing the timing of patrols and coyote observations made by volunteers to that of coyote reports made by members of the public, we found that most patrols (n = 1316, 82.4%) were conducted between 7am and 7pm, with a peak in the morning between 7am and 10 am (n = 456, 28.5%), and in the afternoon between 1pm and 5pm (n = 596, 37.3%; Fig. 3.4A).

Coyotes were most commonly observed by volunteers in the morning between 8am and 11am (n = 76, 43.4%; Fig. 3.4B). Although coyotes were reported by members of the public throughout the day, coyote reports were more common between 8am and 10am (n = 35, 18.4%), and between 8pm and 11pm (n = 49, 25.8%; Fig. 3.4C).

3.5 DISCUSSION

Although encounters with bold urban coyotes appear to be increasing across the continent (White and Gehrt 2009; Poessel et al. 2013; Farr et al. 2022), there are few approaches available to alter coyote behaviour and there has been widespread public resistance to culling (Sponarski et al. 2015; Buteau et al. 2022). We designed and implemented a community-based hazing program to determine whether it could increase coyote wariness in the late winters of 2021 and 2022 when coyotes are breeding and potentially establishing territories in residential areas. We recruited, trained, and engaged 120 volunteers from 71 residential neighbourhoods, who spent over 1,308 hours patrolling for coyotes and coyote attractants in their neighbourhoods. Volunteers reported attractants on 695 occasions; unsecured garbage and large bushes or low hanging branches were the most commonly recorded attractants. Although volunteers observed coyotes on 175 occasions, it was possible and appropriate to apply hazing only 23 times by shouting, throwing weighted tennis balls, and chasing coyotes. Most coyotes (70.6%) retreated after volunteers determined the overt reaction distance, which necessarily included a fixed gaze on the coyote, and almost all (95.7%) coyotes retreated from a hazing event. We found little evidence that overt reaction and flight initiation distances changed with the number of previous times in that neighbourhood that overt reaction distances were measured, hazing was conducted, or attractants were reported. We found a repeated, but inconsistent between control types, effect of treatment on the number of coyote reports. Hazing events increased the number of days before the next public report of coyotes in a research database, but reduced those values for a civic call centre, producing an inconsistent effect overall. Our conflicting results might be explained by a mismatch between the time at which volunteers patrolled for coyotes and the time at which coyotes were active.

Perhaps the most important finding from our study is the relative rarity with which people encounter coyotes, even in neighbourhoods with high relative rates of previous reporting and where people were actively patrolling for coyotes. Our protocol required that people patrol only during the day and in residential areas because these are the circumstances that have most alarmed people in the past (Farr et al. 2022; Hunold and Lloro 2022). Our finding that only 7.4% of patrols led to a coyote observation provides useful context for understanding the increasing prevalence of media reports that portray bold coyotes in residential areas (Alexander and Quinn 2011b). When coyotes were observed, more than half (57.6%) presented an overt reaction distance we considered appropriately shy (over 40 m) and most coyotes (70.6%) retreated after being approached at a walk by volunteers. Several authors have reported that urban coyotes typically exhibit avoidance or indifference towards people (Lukasik and Alexander 2011; Poessel et al. 2013; Drake et al. 2020; Farr et al. 2022). Our findings suggest that social media posts and conventional media reporting of rare events may lead people to overestimate the prevalence of bold or aggressive behaviour by coyotes. Other authors have suggested that quantitative information about the low probability of negative encounters could increase public acceptance of coyotes in cities (Alexander and Quinn 2011a; 2011b; Draheim et al. 2021).

The prevalence of coyote observations that supported the use of hazing in our study was remarkably similar, both 13%, to one of the only two studies of community-based hazing in coyotes, which occurred in Denver, CO (Bonnell and Breck 2017). The proportion of coyotes that retreated from hazing is also similar to the Denver study (95.7% in our study, 84.4% for Bonnell and Breck 2017). Although they received the same instructions, our volunteers varied in their use of hazing treatments consisting of running towards coyotes, shouting, throwing weighted tennis balls in the direction of the animals, or by combining these tools. We found no differences in the responses of coyotes to these treatments, but small sample sizes with multiple treatment categories limited the power of our test. Learning theory suggests that more intensive stimuli are more likely to generate a sensitization response to conditioning and prevent habituation (Domjan and Burkhard 1993; Homstol 2011). Our results suggest that community-based hazing is an effective tool for deterring urban coyotes during an encounter, as suggested by others (Bonnell and Breck 2017; Breck et al. 2017).

We found almost no effect of past hazing on two measures of coyote boldness; overt reaction distance and flight initiation distance. We expected both values to increase if coyotes learned to be more wary of people after hazing, consistent with the prediction of a learned association with negative stimuli in association with people. Increases in flight initiation distance following aversive conditioning have been reported in elk (Kloppers et al. 2005; Found et al. 2018) and bears (Homstol 2011). Similarly, we did not find evidence that the number of reports of attractants reduced these distances, as would be expected if attractants produced food conditioning that made animals more tolerant of people (Herrero et al. 2005; Hopkins et al. 2010). Our definition of attractants was broad and may not have had enough spatial and temporal precision to associate them with coyote behaviour. Because food conditioning has been linked to an increased likelihood of attacks on people by coyotes, it remains important to remove or secure attractants in residential areas (Bounds and Shaw 1994; White and Gehrt 2009; Lukasik and Alexander 2011).

In our program, only 1.1% of patrols led to a hazing event and hazing was mostly conducted only once or twice in each neighbourhood, providing coyotes with very few opportunities to learn from those events and generalise their experience to other contexts. Our results for the number and timing of future public reports are consistent with a lack of learning. We found an inconsistent effect of hazing on the number of reports by the public; fewer in comparison to participating neighbourhoods where no hazing was conducted, and more in comparison to non-participating neighbourhoods. It is also possible that the lesser reporting in neighbourhoods with hazing was caused by similar coyote responses to the measurement of overt reaction distances and the very low rates of reporting in non-participating neighbourhoods reflected the overall lack of coyote sightings in these areas. Changes in the timing of reports following hazing were inconsistent between the two reporting databases; later in the EUCP database, but earlier in the 311 database. Taken together, our results about the effect of hazing on public reporting are similar to community-based hazing programs for urban coyotes in Denver, where no longer-term effects of the treatment were observed (Bonnell and Breck 2017; Breck et al. 2017). In other programs employing aversive conditioning, marked animals make it possible to target individuals repeatedly and more consistently (Kloppers et al. 2005; Mazur 2010; Found et al. 2018). Community-based programs will likely be most effective if they are combined with other management tools to produce longer-term changes in coyote behaviour, such as high intensity aversive conditioning conducted by wildlife professionals (Lajeunesse et al., *unpublished data*), and the lethal management of targeted, problem individuals (Breck et al. 2017).

Our results should be interpreted with awareness of several limitations. First, our program only operated during daylight hours and was restricted to residential neighbourhoods, excluding natural areas. This approach targeted areas with high past rates of conflict, and maximised the safety of people and coyotes. Other studies suggest that coyotes increase nocturnal behaviour to reduce conflict with people (Murray and St. Clair 2015; Moll et al. 2018), which occurs in many other carnivores (Gaynor et al. 2018; Haswell et al. 2020). Nonetheless, there may be more opportunities to encounter and treat coyotes at times when people are less active (Grinder and Krausman 2001; Riley et al. 2003; Grubbs and Krausman 2009; Weckel et al. 2010), as suggested by the high frequency of coyote reports late at night when no patrols occurred. We also avoided conditioning in natural areas, which provide a refuge for many species and where coyotes provide ecological services and aesthetic enjoyment for people (Brown 2007; Hunold and Lloro 2022). However, several other studies have shown that coyote sightings and encounters are more common in open or natural areas (Atwood et al. 2004; Poessel et al. 2013; Wine et al. 2015; Farr et al. 2022). Finally, all of our data was collected during the breeding season, which is less associated with human-coyote conflicts than the pup-rearing season (Lukasik and Alexander 2011; Quinn et al. 2016; Farr et al. 2022).

3.6 CONCLUSIONS

In summary, our study demonstrated several important results and informs future studies. First, we experienced tremendous enthusiasm by our volunteers with representatives from about one third (29.3%) of the communities in Edmonton and enduring media indicative of public interest throughout the study. Second, our study quantified the rarity (3.5% of patrols) with which people encounter coyotes at distances as close as 40 m in residential Edmonton, even while looking for them in neighbourhoods with relatively high past rates of reporting. Third, we showed that coyotes almost always retreat from people when they are treated aggressively (i.e., when being hazed) and over two thirds of the time when people simply walk towards them while looking directly at them. Our results describing the effects of hazing on coyote behaviour and public reporting were inconclusive, owing to limitations of sample size, as well as spatial and temporal precision, indicating that much more work is needed to determine these effects. Particularly important are assessments of low- vs. high-intensity stimuli that might produce greater evidence of longer-term changes in coyote behaviour. Learning theory predicts that aversive conditioning is more likely to be effective if it is immediate, intensive, consistent, evolutionarily relevant, and easily predicted in advance (Found and St. Clair 2019, Evans Ogden 2021). Techniques that can be used by dog-walkers should be explored because dogs are frequently involved in human-coyote conflict (Alexander and Quinn 2011a; Boydston et al. 2018; Farr et al. 2022) and because the presence of a dog appears to reduce the likelihood that a coyote retreats from an aversive conditioning event (Bonnell and Breck 2017; Young et al. 2019). Complementary tools for managing urban coyotes will likely always be necessary. Education campaigns can reduce conflict and increase public confidence around coyotes (Worcester and Boelens 2007; Sponarski et al. 2016). Most importantly, food attractants that attract animals to conflict situations must be removed or secured (White and Gehrt 2009; Lukasik and Alexander 2011), and lethal removal of targeted problem individuals will sometimes be the best way to maintain public safety (Breck et al. 2017).

3.7 ACKNOWLEDGMENTS

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3.8 CONFLICT OF INTEREST

The authors declare no conflicts of interest.

3.9 TABLES AND FIGURES

Table 3.1. Hazing actions (n = 23) performed by community scientists between January and May 2021 and 2022 in Edmonton, Alberta and resulting response of coyotes.

Hazing actions performed	Response of coyotes to hazing		
	Remained in place	Backed or walked away	Trotted or ran away
Shouted	1	0	2
Ran towards the coyote	0	0	1
Threw weighted tennis ball in the direction of the coyote	0	0	1
Other	0	2	0
Two actions performed	0	4	7
Three or more actions performed	0	2	3

Table 3.2. Summary metrics of logistic regression models predicting the overt reaction distances (n = 140) and flight initiation distances (n = 90) of coyotes observed in Edmonton, Alberta, between January and May 2021 and 2022, with distances were classified as less than (0) vs equal or greater than (1) 40 m. Predictors included the past number of times (each measured within the previous 30 days and within a neighbourhood) the overt reaction distance (overt reaction distance) was measured, hazing was conducted (hazing), or attractants were recorded (attractants), as well as the number of coyotes present during the event being evaluated (number of coyotes). The beta coefficients (β), odds ratios (OR), 95% confidence intervals (CI), Nakagawa and Schielzeth's marginal and conditional R^2 are presented for each model. Model performance was compared to a null model using likelihood ratio tests with $P < 0.05$ as a significance level, and we reported whether there was a difference from the null (Y) or not (N). The table excludes the random effect of neighbourhood.

Predictor	β	CI (β)	*P*	Marginal R^2	Conditional R^2	OR	CI (OR)	Vs. null
Overt reaction distance								
Overt reaction distance	0.02	-0.11, 0.16	0.74	0.001	0.049	1.02	0.90, 1.17	N
Hazing	-0.25	-0.81, 0.30	0.38	0.007	0.072	0.78	0.45, 1.36	N
Attractants	-0.04	-0.12, 0.03	0.20	0.016	0.086	0.95	0.89, 1.02	N
Number of coyotes	0.18	-0.21, 0.56	0.37	0.008	0.058	1.19	0.81, 1.75	N
Flight initiation distance								
Overt reaction distance	0.08	-0.05, 0.21	0.24	0.019	NA	1.08	0.95, 1.24	N
Hazing	-0.02	-0.70, 0.65	0.95	0.000	NA	0.98	0.50, 1.91	N
Attractants	-0.01	-0.10, 0.07	0.75	0.001	NA	0.99	0.91, 1.07	N
Number of coyotes	0.06	-0.40, 0.52	0.81	0.001	NA	1.06	0.67, 1.68	N

Table 3.3. Distribution of overt reaction distances (*n* = 140) presented by coyotes as evaluated by volunteers in Edmonton, Alberta, between January and May 2021 and 2022 by time of day. Time of day was classified as morning (4am - <10am), day (10am - <4pm), evening (4pm- <10pm), or night (10pm - <4am).

Time of day	> 40 m	40 m
Morning	19	35
Day	23	26
Evening	17	19
Night	1	0

Table 3.4. Summary metrics of poisson regression models predicting the number of coyote reports made in each neighbourhood to the Edmonton Urban Coyote Project website (EUCP reports) or to the 311 civic call centre (311 report) for the two weeks before and after the use of hazing. We compared these reports to reports made for the same dates in participating neighbourhoods where coyotes were observed but hazing was not conducted (control: no hazing conducted) and in non-participating neighbourhoods (control: non-participating neighbourhoods). Potential predictors included the time period considered (i.e., before or after) and the event type (i.e., control or hazing), classified as factors with "before" and "control" as the reference categories. The beta coefficients (β), rate ratios (RR), 95% confidence intervals (CI), Nakagawa and Schielzeth's marginal and conditional R^2 are presented for each model. Model performance was compared to a null model using likelihood ratio tests with $P < 0.05$ as a significance level, and we reported whether models were significantly different from the null (Y) or not (N). The table excludes the random effect of neighbourhood pairs.

Predictor	β	CI (β)	*P*	Marginal R^2	Conditional R^2	RR	CI (RR)	Vs. null
EUCP reports, control: no hazing conducted								
After	-0.25	-0.72, 0.21	0.29	0.082	0.618	0.78	0.48, 1.24	Y
Treatment	-0.69	-1.23, -0.16	0.01			0.50	0.29, 0.86	
After * Treatment	-0.34	-1.21, 0.53	0.44			0.71	0.30, 1.70	
EUCP reports, control: non-participating neighbourhoods								
After	-0.22	-1.54, 1.09	0.74	0.121	0.456	0.80	0.21-2.98	Y
Treatment	1.39	0.40, 2.37	0.006			4.00	1.50-10.66	
After * Treatment	-0.37	-1.88, 1.13	0.63			0.69	0.15-3.10	
311 reports, control: no hazing conducted								
After	0.05	-0.32, 0.43	0.77	0.011	0.996	1.06	0.73-1.54	Y
Treatment	-0.41	-0.84, 0.01	0.057			0.66	0.44, 1.01	

After * Treatment	-0.43	-1.07, 0.21	0.19			0.65	0.34, 1.23	
311 reports, control: non-participating neighbourhoods								
After	0.34	-0.81, 1.48	0.57	0.132	0.869	1.40	0.44-4.41	Y
Treatment	1.94	1.01, 2.88	<0.001			7.00	2.74, 17.87	
After * Treatment	-0.71	-1.97, 0.55	0.27			0.49	0.14, 1.73	

Table 3.5. Summary metrics of poisson regression models predicting the number of days to the next report made to the Edmonton Urban Coyote Project website (Days until the next EUCP reports) or to the 311 civic call centre (Days until the next 311 report) following a hazing event conducted in Edmonton, Alberta, between January and May 2021 and 2022. We compared these days to the number of days to the next report made at the same dates in participating neighbourhoods where coyotes were observed but hazing was not conducted (control: no hazing conducted) and in non-participating neighbourhoods (control: non-participating neighbourhoods). Potential predictors included the event type (i.e., control or hazing) classified as a factor with "control" as the reference category. The beta coefficients (β), rate ratios (RR), 95% confidence intervals (CI), Nakagawa and Schielzeth's marginal and conditional R^2 are presented for each model. Model performance was compared to a null model using likelihood ratio tests with $P < 0.05$ as a significance level, and we reported whether models were significantly different from the null (Y) or not (N). The table excludes the random effect of neighbourhood pairs.

Predictor	β	CI (β)	P	Marginal R^2	Conditional R^2	RR	CI (RR)	Vs. null
Days until the next EUCP report, control: no hazing conducted								
Hazing	0.40	0.27, 0.52	< 0.001	0.028	0.984	1.49	1.31, 1.69	Y
Days until the next EUCP report, control: non-participating neighbourhoods								
Hazing	0.13	-0.01, 0.26	0.07	0.003	0.985	1.13	0.99, 1.30	N
Days until next 311 report, control: no hazing conducted								
Hazing	-0.73	-0.82, -0.64	< 0.001	0.073	0.992	0.48	0.44, 0.53	Y
Days until next 311 report, control: non-participating neighbourhoods								
Hazing	-0.35	-0.45, -0.24	< 0.001	0.018	0.991	0.71	0.63, 0.78	Y

Figure 3.1. Average counts of the number of times the overt reaction distance was measured (ORD), hazing was conducted (hazing), or attractants were recorded (attractants) in the two weeks preceding a coyote observation reported by volunteers of a community-based hazing program conducted in Edmonton (Alberta) between January and May 2021 and 2022. We also presented average counts for the number of coyotes observed during the event. The panels represent the overt reaction distances (A) and flight initiation distances (B) exhibited by coyotes, classified as less than or equal or greater to 40 m. Error bars represent standard deviation.

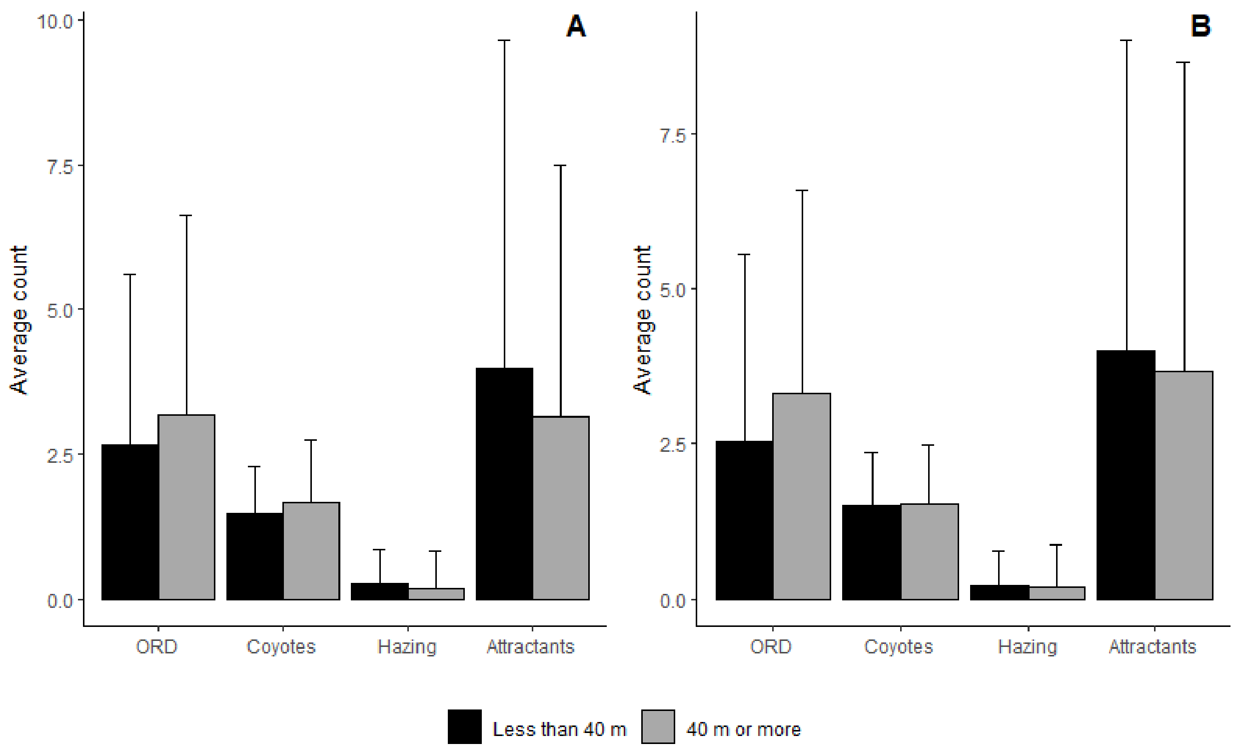


Figure 3.2. Average number of coyote reports made to the Edmonton Urban Coyote Project (EUCP) website (A) or 311 civic call centre (B) in periods before and after dates for hazing. We compared the average number of reports to reports made for the same dates in neighbourhoods where hazing was conducted (hazing), in non-participating neighbourhoods (non-participating), and in participating neighbourhoods where coyotes were observed by volunteers but hazing was not conducted (no hazing). Error bars represent standard deviation.

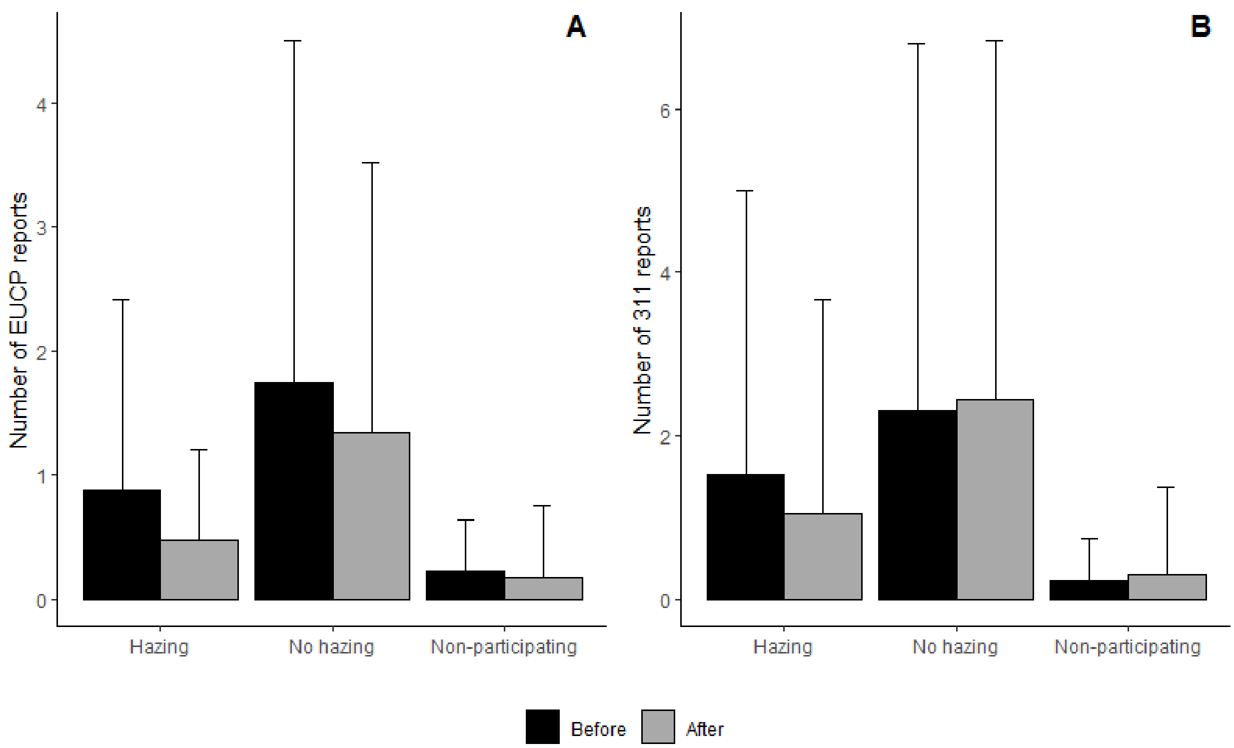


Figure 3.3. Average number of days to the next coyote report made to the Edmonton Urban Coyote Project (EUCP) website (A, B) or 311 civic call centre (A, B). We compared the average number of days to the next report for the same dates between neighbourhoods where hazing was conducted (hazing; A, B), participating neighbourhoods where coyotes were observed by volunteers but hazing was not conducted (no hazing; A), and non-participating neighbourhoods (non-participating; B). Error bars represent standard deviation. We excluded neighbourhood pairs where no coyotes were reported following the date for hazing.

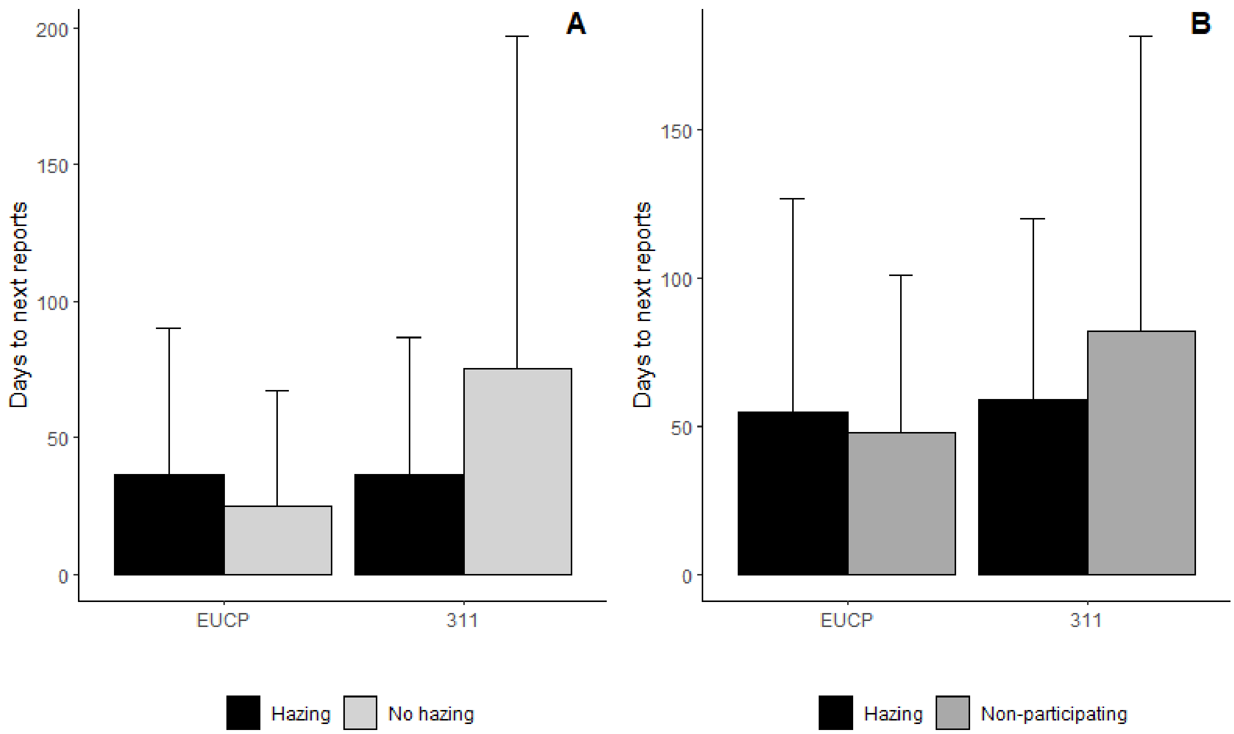
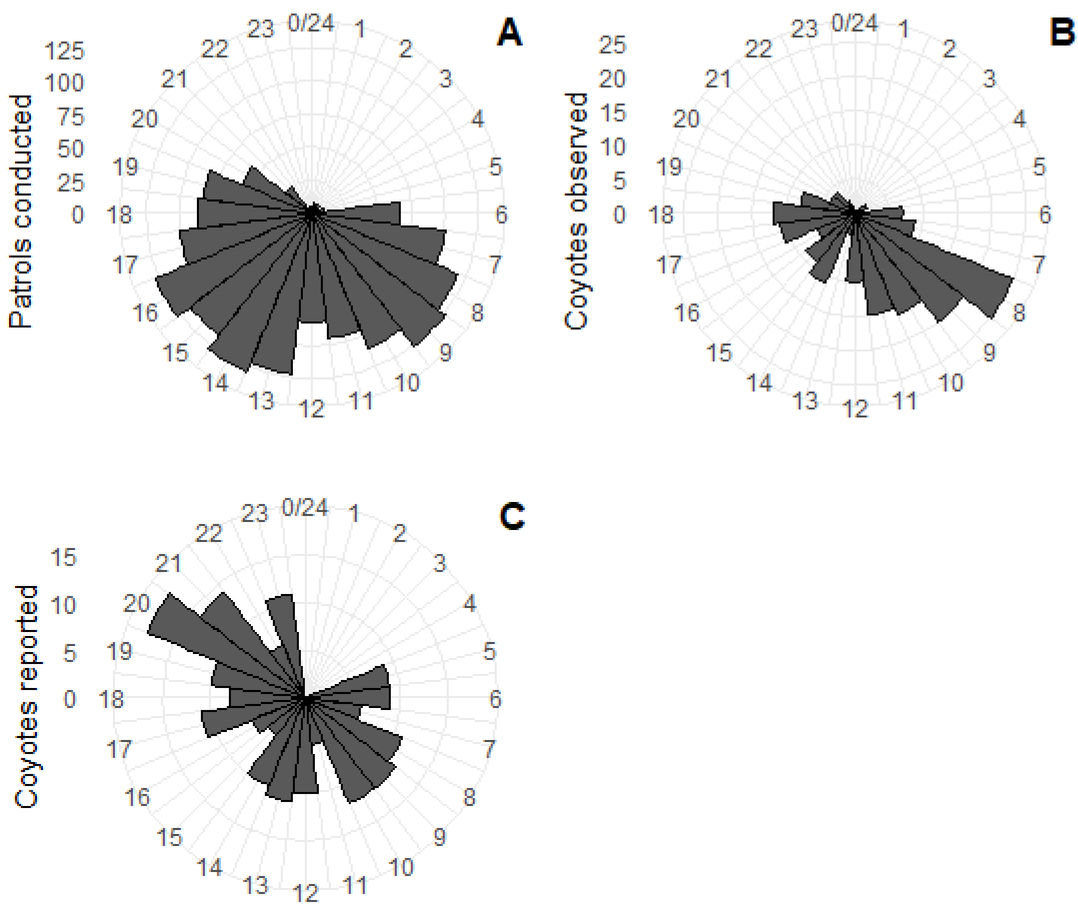


Figure 3.4. Timing of patrols, coyote observations, and coyote reports between January and May 2021 and 2022 in participating neighbourhoods. We compared the time at which patrols were conducted by volunteers (n = 1598; A), coyotes were observed by volunteers (n =175; B), and coyotes were reported by members of the public to the Edmonton Urban Coyote Project website (n = 190; C). We excluded reports for which no time was provided, as well as reports with imprecise time (e.g., morning, afternoon).



Chapter 4

General discussion

Human-wildlife conflicts appear to be increasing in cities where the habitat of humans and wildlife overlaps (Schell et al. 2021; Fidino et al. 2022). Conflicts involving large predators, like bold urban coyotes, are particularly concerning to the public because of the threat to public safety (Peterson et al. 2010; Poessel et al. 2013). In urban areas, human-coyote conflicts occur when coyotes approach, pursue, and attack pets and people (Timm et al. 2004; Lukasik and Alexander 2011) as well as when they den under porches and decks (Poessel et al. 2013). Targeted lethal control can reduce conflicts with aggressive coyotes (Breck et al. 2017), but this method is increasingly opposed by members of the public, especially when non-lethal approaches can be used (Yashphe and Kubotera 2017; Sponarski et al. 2018).

Aversive conditioning has been identified as a humane, cost effective non-lethal technique with potential to mitigate human-coyote conflicts (Bonnell and Breck 2017; Breck et al. 2017; Sampson and Van Patter 2020). Successful behavioral modifications are contingent on the application of six main learning principles (Homstol 2011; Found et al. 2018; Evans Ogden 2021): evolutionary relevance between the conditioned and unconditioned stimuli (Garcia and Koelling 1966; Snijders et al. 2021), high initial intensity (Azrin 1960; Domjan and Burkhard 1993), immediacy (Camp et al. 1967) and consistency of application (Petracca et al. 2019), contingency of implementation (Kloppers et al. 2005), and reward for alternative behaviors (Homstol 2011). Although aversive conditioning has been used extensively to manage a variety of wild animals (Snijders et al. 2019), its application to urban coyotes has only recently been studied (Bonnell and Breck 2017; Breck et al. 2017; Young et al. 2019; McLellan and Walker

2021) and there are few guidelines for its implementation. This thesis aimed to determine whether aversive conditioning could be used to mitigate conflicts with bold, urban coyotes. I addressed this purpose by evaluating two aversive conditioning programs implemented in Alberta (Canada), which differed in the aversive stimuli used, adherence to the learning principles, and apparent program success.

In Chapter 2, I investigated the application of aversive conditioning in a high intensity program delivered by wildlife professionals in Calgary. In this program, contractors pursued coyotes with trained dogs and shot them with chalk balls fired from paintball guns. I found that most coyotes retreated quickly from aversive conditioning. Aversive conditioning had long-term effects on coyote behavior, with high intensity treatments (i.e., those where dogs were used and shots were fired) predicting a greater likelihood of retreat during subsequent treatments. I also found that higher numbers of past aversive conditioning events predicted a greater likelihood of retreat by coyotes. The effects of aversive conditioning on coyote behavior decreased over time.

In Chapter 3, I implemented and reviewed a hazing program conducted by volunteer community members in Edmonton. When appropriate, volunteers hazed coyotes by running towards them while shouting and throwing weighted tennis balls in their direction. Despite considerable volunteer effort, coyotes were rarely observed in residential neighborhoods. When observed, most coyotes retreated after being approached at a walk by volunteers, and almost all coyotes retreated from hazing. I found little evidence that hazing had an effect on two measures of coyote boldness (the overt reaction distance and flight initiation distance) or on the frequency or timing of coyote reports made to public reporting databases.

Inconsistent application of several learning principles might have contributed to the outcomes in each program. In Calgary, bold coyotes observed in public parks were pursued with dogs and shot with chalk balls, applying the principles of evolutionary relevance and high initial intensity. Treatments were also applied consistently, with 765 aversive conditioning events conducted with similar procedures during each engagement. Contractors also rewarded alternative coyote behaviors by ceasing the aversive conditioning treatment when coyotes left the public park. However, because of delays between the initial coyote report by a member of the public and the contractors' intervention, treatments could not usually be performed immediately. Treatments were also signaled by high-visibility vests worn by contractors and their dogs to maintain public awareness and safety.

Similarly, the community-based hazing program conducted in Edmonton applied the principle of evolutionary relevance by hazing bold coyotes (pursuing coyotes on foot while throwing weighted tennis balls in their direction) that were observed in residential neighborhoods during the day. This program also met the principles of unpredictability (120 volunteers were involved in the program, and no uniforms were provided), and rewarded alternative behaviours (hazing was not conducted in natural areas or at night, and ceased when the coyote left the area). However, the hazing program was of low intensity (shouting, approaching and throwing weighted tennis balls) and the treatments were not applied consistently (hazing was conducted 23 times over a two year period) and probably did not occur immediately after coyotes entered a residential area.

Both programs illustrated the short-term change in coyote behavior that would be expected of any aversive stimulus or deterrent. However, only the program in Calgary with high-intensity aversive conditioning provided evidence of changes over time in the behaviour of coyotes or reporting by people. Even though the use of trained dogs and chalk balls can be contentious (Sampson and Van Patter 2020), the results I obtained in Chapter 2 demonstrated that high intensity aversive conditioning treatments may increase the likelihood of coyote retreat over time, providing evidence of long-term behavioral modifications. However, because employing a contracted team of wildlife professionals can be expensive (Kloppers et al. 2005), I recommend future programs to combine greater stimulus intensity with the use of community members. On top of being cost-effective, community-based hazing programs offer the additional benefit of contingency, which is often lacking in high-intensity programs conducted by small contracted teams. By integrating more of the principles for effective aversive conditioning, future work might be more successful at creating long-term modifications in wildlife behavior, contributing to human-wildlife coexistence.

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APPENDIX 1

Supplemental material for Chapter 2

Appendix 1 Table 1.1. Location, publication year, and URL for 66 coyote management plans yielded by an online search conducted in June 2021. Accession dates for the URLs also date from that month.

State/ Province	Place	Year	URL
Alberta	Calgary	2019	http://www.fonhs.org/docs/coyote-conflict-response-guide.pdf
California	Anaheim	2019	https://www.anaheim.net/DocumentCenter/View/16816/Coyote-Management-Plan?bidId=#:~:text=Coyote%20Management%20Plan-,Coyote%20Management%20Plan%20Goals,response%20to%20aggressive%20coyote%20behavior.
California	Arcadia	2017	https://cms9files.revize.com/arcadia/Discover%20Arcadia/living/AdoptedCoyoteManagementPla.pdf
California	Brea	None given	https://www.ci.brea.ca.us/DocumentCenter/View/8830/Brea-Coyote-Mgmt-Plan_FINAL
California	Buena Park	None given	https://cms7files1.revize.com/buenaparkca/Document_center/City%20Departments/Community%20development/Code%20enforcement/BuenaPark_Coyote_Managemen.pdf
California	Calabasas	None given	https://www.cityofcalabasas.com/Home/ShowDocument?id=1803
California	Carson	None given	https://ci.carson.ca.us/content/files/pdfs/publicsafety/coyoteactivities/CoCCoyoteMgmtPlan2017.pdf
California	Costa Mesa	None given	https://www.costamesaca.gov/home/showpublisheddocument/25777/636490563866670000
California	Culver City	None given	https://www.culvercity.org/files/assets/police/documents/coyote/coyotemanagementplan.pdf
California	Cypress	2019	https://www.cypressca.org/home/showpublisheddocument/8698/636869560183500000
California	Davis	None given	https://www.cityofdavis.org/home/showpublisheddocument/2896/635705837350170000
California	Downey	None given	https://www.downeyca.org/home/showpublisheddocument/2938/636990964551230000
California	Fountain Valley	2017	https://www.fountainvalley.org/DocumentCenter/View/5540/FVPD-Coyote-Management-Plan
California	Garden Grove	None given	https://ggcity.org/sites/default/files/coyote-management-plan.pdf
California	Glendora	2020	https://www.cityofglendora.org/home/showpublisheddocument/27441/637377737117900000
California	Huntington Beach	None given	https://www.huntingtonbeachca.gov/files/users/admin_pio/Coyote_Management_Plan.pdf

California	Inglewood	None given	https://www.cityofinglewood.org/DocumentCenter/View/10550/Coyote-Management-Plan-09-17?bidId=
California	La Habra	None given	https://www.lahabraca.gov/DocumentCenter/View/4088/La-Habra-Coyote-Management-Plan-PDF
California	La Verne	None given	https://www.cityoflaverne.org/index.php/documents/community-services/1287-coyote-management-plan/file
California	Long Beach	2015	https://www.longbeach.gov/globalassets/acs/media-library/documents/wildlife/living-with-urban-coyote/long-beach-coyote-management_final-11-3-15/#:~:text=This%20strategy%20is%20comprised%20of,tiered%20responses%20to%20coyote%20behavior.
California	Newport Beach	None given	https://www.newportbeachca.gov/home/showpublisheddocument/21605/635834591807930000
California	Norwalk	None given	https://www.norwalk.org/home/showpublisheddocument/23047/637068141152570000
California	Palos Verdes Estates	2017	https://www.pvestates.org/home/showdocument?id=6929
California	Pasadena	2019	https://www.cityofpasadena.net/wp-content/uploads/DRAFT-Urban-Wildlife-Management-Plan.pdf
California	Rancho Palos Verde	2018	https://www.rpvca.gov/DocumentCenter/View/12546/Revised-coyote-management-plan-AM-9-25-18-edits_2
California	Rolling Hills Estates	2017	https://www.ci.rolling-hills-estates.ca.us/home/showpublisheddocument/16830/636469615443370000
California	Rosemead	2019	http://p1cdn4static.civiclive.com/UserFiles/Servers/Server_10034989/File/Gov/City%20Departments/Public%20Safety/Animal%20Control/Coyote%20Information/Adopted%20CC%20100819%20%20Coyote%20Plan%20-%20Attachment%20A%202019.pdf
California	San Dimas	None given	https://cms8.revize.com/revize/sandimasca/Document_Center/Residents/Public%20Safety/Coyote%20Information/Attachment-City-of-San-Dimas-Coyote-Management-Plan2-Proposed.pdf
California	San Gabriel	2018	https://www.sangabrielcity.com/DocumentCenter/View/7844/Coyote-Management-Plan
California	Seal Beach	None given	https://www.sealbeachca.gov/Portals/0/Documents/Seal%20Beach%20Coyote%20Management%20Plan%20-%20Final.pdf
California	Tega Cay	None given	https://www.tegacaysc.org/DocumentCenter/View/10300/TC-Coyote-Management-Plan?bidId=
California	Ventura	2020	https://www.vcas.us/wp-content/uploads/2020/08/Ventura_County_Coyote_Management_Plan_July2019.pdf
California	West Covina	None given	https://www.westcovina.org/home/showpublisheddocument/14552/636516315362200000
California	West Hollywood	None given	https://www.weho.org/home/showpublisheddocument/38806/636772644730000000
California	Whittier	None given	https://www.cityofwhittier.org/home/showpublisheddocument/2018/636652045970930000
California	Yorba Linda	2010	https://www.yorbalindaca.gov/DocumentCenter/View/1877/Coyote-Manangement-Plan-PDF?bidId=
Colorado	Boulder	2012	https://bouldercolorado.gov/sites/default/files/2021-02/coyotemanagementplan2013.pdf
Colorado	Broomfield	2010	https://www.broomfield.org/DocumentCenter/View/1392/CoexistencePolicyFinal?bidId=
Colorado	Castle Pines North	2010	https://www.castlepinesco.gov/wp-content/uploads/2021/03/resolution_10-26.pdf

Colorado	Cherry Hills	2013	http://www.cherryhillsvillage.com/DocumentCenter/View/1573/Coyote-Management-Plan-Revised-2013-PDF?bidId=
Colorado	Denver	2009	https://www.mspca.org/wp-content/uploads/2015/08/denver-coyote-management-plan.pdf
Colorado	Louisville	2014	https://www.louisvilleco.gov/home/showpublisheddocument/25344/637110651571570000
Colorado	Parker	None given	http://www.parkerpolice.org/DocumentCenter/View/22687/Parker-Coyote-Management-Plan---October-2010?bidId=
Colorado	Superior	None given	https://projectcoyote.org/wp-content/uploads/2016/02/Coyote-Coexistence-Plan.Superior.12-June-2014.pdf
Colorado	Wheat Ridge	2013	https://ci.wheatridge.co.us/DocumentCenter/View/20110/Coyote-Management-Plan?bidId=
Colorado	Woodmoor	None given	https://woodmoor.org/wp-content/uploads/2017/01/WIA-Coyote-Wildlife-Plan.pdf
Florida	Atlantic Beach	2019	https://www.coab.us/DocumentCenter/View/10893/COAB-Coyote-Management-and-Education-Plan-Master#:~:text=This%20Coyote%20Management%20and%20Education,coyotes%2C%20people%20and%20companion%20animals.
Illinois	Machesney Park	2019	https://3358nc4e1je93h11tu493nryr3i-wpengine.netdna-ssl.com/wp-content/uploads/2019/12/2019-VMP-Coyote-Management-Plan.pdf
Illinois	Chicago	2020	https://www.chicago.gov/content/dam/city/depts/cacc/PDFiles/CoyotePlan_ChicagoAPR-10-2020.pdf
Illinois	Geneva	None given	https://www.geneva.il.us/DocumentCenter/View/2004/The-COG-Coyote-Management-Plan?bidId=
Illinois	Riverside	None given	https://www.riverside.il.us/DocumentCenter/View/3105/Coyote-Policy?bidId=
Illinois	St. Charles	None given	https://www.stcharlesil.gov/sites/default/files/page-attachments/Coyote%20Management%20Plan%202017.pdf
Illinois	Wheaton	None given	https://www.wheaton.il.us/DocumentCenter/View/667/Coyote-Policy-PDF
Michigan	Grosse Ile	2019	https://www.grosseile.com/Coyote%20Management%20Plan.pdf
Minnesota	North Oaks	2020	https://www.northoaksmn.gov/sites/g/files/vyhlif5416/f/pages/north_oaks_coyote_management_plan_2020.pdf
New York	New Castle	2015	https://www.village.mamaroneck.ny.us/sites/g/files/vyhlif826/f/uploads/coyote-proposal.final-for-printing.pdf
Ontario	Burlington	2015	https://www.burlington.ca/en/services-for-you/resources/Animals/Report_PB-90-15.pdf https://www.burlington.ca/en/services-for-you/resources/Animals/Strategy_PB-90-15-Appendix-A.pdf
Ontario	Collingwood	None given	https://www.collingwood.ca/sites/default/files/uploads/documents/coyote_management_plan.pdf
Quebec	Montreal	None given	http://ville.montreal.qc.ca/pls/portal/docs/PAGE/GRANDS_PARCS_FR/MEDIA/DOCUMENTS/plan_gestion_coyote.pdf
Rhode Island	Rhode Island	2021	http://www.dem.ri.gov/programs/bnatres/fishwild/pdf/coyote-mgnt-response-guide.pdf
South Carolina	Isle of Palms	2018	https://www.iop.net/sites/default/files/uploads/coyotes/iop-coyote-management-plan-adopted-5.22.2018.pdf
South Carolina	Mount Pleasant	None given	http://www.tompsc.com/DocumentCenter/View/7767/Mount-Pleasant-Coyote-Management-Plan?bidId=
South Carolina	Sullivan's Island	2013	https://sullivansisland.sc.gov/sites/sullivansisland/files/Documents/Coyote%20Management%20Plan%202013%20-%202014.pdf

Texas	Austin	2014	https://www.austintexas.gov/edims/document.cfm?id=214608#:~:text=In%202013%20the%20City%20adopted,%2C%20non%2Dlethal%20conflict%20management.
Texas	Galveston	None given	https://www.galvestontx.gov/1157/Coyote-Managment
Texas	Sunset Valley	None given	https://www.sunsetvalley.org/home/showpublisheddocument/462/637737297679470000
Washington	Lake Forest Park	None given	https://www.cityoflfp.com/DocumentCenter/View/487/Wildlife-Management-Plan---4-6-12-3?bidId=
Wisconsin	Glendale	None given	https://www.glendale-wi.org/DocumentCenter/View/752/Coyote-Management-Plan?bidId=#:~:text=The%20City%20of%20Glendale%20Coyote,human%20safety%20as%20a%20priority.
Wisconsin	Milwaukee	2016	https://county.milwaukee.gov/ImageLibrary/Public/MilwaukeeCounty/Parks/Coyotes/MilwaukeeCountyUrbanCoyoteManagementPlan.pdf
Wisconsin	Wauwatosa	None given	https://elmgrovewi.org/AgendaCenter/ViewFile/Item/11635?fileID=18305
Wisconsin	Mequon	None given	https://www.ci.mequon.wi.us/sites/default/files/fileattachments/community/page/3471/mequon_coyote_policy_final.pdf
Wisconsin	River Hills	None given	https://riverhillswi.com/wp-content/uploads/2017/02/CMP-Final-Draft.pdf

Appendix 1 Table 1.2. Number and types of coyote reports, aversive conditioning (AC) events and reaction to aversive conditioning per parks or park areas reported in the City of Calgary, Alberta, Canada (2018-2021). Conflict-type reports were those coded as 4, 5, 6, or 7 (Table 3). Aversive conditioning actions were considered to be of high intensity when coded as 4, 5, or 6 by the contractors (Table 4). The response of coyotes to aversive conditioning were considered as "resist" when coded as 3, 4, or 5 (Table 5).

Park or park area names used by contractors	Identification code[a]	Area (square meters)	Number of 311 reports	Proportion of conflict reports	Number of AC events	Proportion of high intensity AC	Proportion of resist responses
14st NE - Coventry	ST1009	270,280	4	0.50	10	0.50	0.00
Airways Park	VIS250	300,007	3	0.50	3	1.00	0.33
Arbour Lake East	ARB130, ARB211, ARB346, ARB352	246,052	55	0.47	38	0.43	0.27
Arbour Lake West	ARB012, ARB212, ARB305, ARB582, ARB934	406,523	18	0.21	36	0.31	0.08
Aspen Heights	ASP001, ASP011, ASP101, ASP505, ASP514, ASP995	386,316	13	0.09	13	0.15	0.15
Auburn Bay	AUB009, AUB011, AUB012, AUB013, AUB201, AUB209	424,478	9	0.00	4	0.00	0.25
Baker Park	SCE410	408,688	7	0.43	1	0.00	0.00
Bayview	BYV056, GPK056	2,494,833	26	0.20	29	0.28	0.14
Bears paw	HSN001	1,451,605	1	1.00	2	0.50	0.00
Beaverdam Flats	OGD792, 09H862	750,001	10	0.50	9	0.33	0.00
Brentwood -Brenner Park	BRE452	64,399	74	0.17	40	0.18	0.10
Briar Hill	HOU481, HOU484,	162,188	7	0.67	1	0.00	0.00

	HOU542, HOU543, HOU562, WHL563						
Brittannia	BRT346	211,218	5	0.20	2	0.00	0.00
Carburn Park	RIV840	444,840	4	0.50	30	0.30	1.17
Cityscape	CSC001, CSC003, CSC005	573,782	3	0.00	1	1.00	0.00
Confederation Park	CAP670, MOP671, MOP771	429,742	15	0.20	3	0.00	0.00
Country Hills Golf Course - Nose Creek	HID241	504,260	5	0.40	25	0.24	0.16
Coventry Hills	COV045, COV106, COV108, COV111, COV873, COV945, COV971	499,670	2	0.50	3	0.00	0.00
Cranston	CRA999	480,978	11	0.36	22	0.52	0.38
Crestmont	CRM301, CRM305, CRM306, CRM319	158,660	20	0.13	15	0.20	0.00
Currie Barracks	CUR005, CUR552	182,943	3	0.00	4	0.25	0.25
Douglasbank Park	DDG718	558,812	5	0.20	8	0.75	0.13
Dover	DOV010, DOV030, DOV091, DOV753, DOV758, DOV769, DOV771, DOV777, DOV784, DOV899	1,143,387	14	0.23	17	0.35	0.24
East Landfill Elliston	East Calgary Waste Management Facility. No identification code	3,221,523	5	0.33	4	0.50	0.00
East Landfill Stoney	East Calgary Waste Management Facility.	2,455,029	1	1.00	1	0.00	0.00

	No identification code						
Edgemont North	EDG055	601,190	7	0.57	20	0.30	0.15
Edgemont South	EDG053	816,197	13	0.46	3	0.33	0.33
Evanston	EVN007, EVN011, ENV017, EVN027, EVN028, EVN260, EVN267, EVN271, EVN273, EVN275	649,944	28	0.22	16	0.60	0.27
Fairview	FAI207, FAI209	79,658	2	0.50	2	0.00	0.00
Flint Park	FAI203	30,050	0	N/A	5	0.25	0.25
Hamptons	HAM187	136,947	5	0.00	3	0.33	0.00
Hidden Valley	HID239,HID241	603,208	18	0.00	6	0.17	0.17
Inglewood - Pearce Estates	ING037	243,305	6	0.50	5	0.80	0.40
Mackenzie Lake	MCT779	100,621	9	0.33	3	0.00	0.00
Mahogany	MAH001, MAH002, MAH003, MAH020, MAH440	468,292	8	0.00	7	0.00	0.14
Malloy-Huntington	HUN586, HUN588, HUN675, HUN676, HUN715, HUN716, HUN717, HUN718, HUN719, HUN722, HUN728, HUN838, HUN842	852,278	5	0.20	2	0.50	0.00
Marlborough	MRL513, MRL516, MRL517, MRL522, MRL526, MRL555	280,187	5	0.25	1	1.00	0.00
Montgomery	MON004, MON216, MON291, MON503	589,817	6	0.20	1	1.00	0.00

Mount Royal	UMR289	26,026	12	0.33	1	0.00	0.00
New Brighton	NEB842, NEB844	528,047	13	0.50	13	0.46	0.00
Nickle School - Bonavista	LKB482	52,302	0	N/A	1	0.00	0.00
Nolan Hill	NOL002, NOL003, NOL005, NOL017, NOL018	487,005	27	0.35	2	0.00	0.00
Nose Creek Park	ST1938	149,951	2	0.50	5	0.66	0.66
Nosehill Dalhousie	NPK454	2,116,501	18	0.24	10	0.50	0.40
Nosehill 64 ave	NPK454	1,064,766	4	0050	27	0.39	0.00
Nosehill gravel pit	NPK454	3,009,859	19	0.88	49	0.24	0.17
Nosehill Hunter Valley	NPK454	1,784,370	1	0.00	24	0.36	0.05
Nosehill Macewin	NPK454	1,400,323	11	0.60	53	0.13	0.04
Nosehill Sandstone	NPK454	2,155,611	4	0.50	15	0.47	0.33
Panetella Boulevard - Carrington	CAR002, PAN060, PAN096	252,789	5	0.00	48	0.55	0.36
Pump Hill	PUM032	20,469	23	0.24	21	0.38	0.43
Quarry Park	DDG049	225,845	22	0.33	13	0.08	0.00
Queens Park - Highland	QPK065,BOW177	569,977	12	0.30	10	0.20	0.20
Rocky Ridge	ROC004, ROC010, ROC190, ROC192, ROC202, ROC290, ROC400, ROC402, ROC403, ROC405, ROC670, ROC671, ROC672	545,542	25	0.39	1	0.00	0.00
Royal Oak	ROY356	44,107	10	0.11	4	1.00	0.75
Sage Hill	SGH005,SGH008	724,288	8	0.00	3	0.00	0.00
Scenic Acres	SCE352	257,682	16	0.31	9	0.22	0.11
Silversprings	SIL245	1,378,567	18	0.47	10	0.30	0.20

Springbank	SPH021	203,016	2	0.00	3	0.00	0.00
Spruce Cliff	SPR050	198,522	2	0.00	1	1.00	1.00
St. Andrew Park	STA544	81,365	23	0.39	1	0.00	0.00
St. Georges Hts - Bridgeland	BRD890,REN890	318,377	29	0.46	10	0.40	0.40
St. Mary's Cemetery	ERL064,ERL066	103,302	6	0.00	1	1.00	0.00
Strathcona	STR815,CHR813	285,736	5	0.40	1	1.00	1.00
Sunnyside	SSD495, RDL560, SSD560	348,689	11	0.20	1	0.00	0.00
Tuscany East	TUS603	994,990	10	0.22	3	0.33	0.33
Tuscany West	TUS601	381,727	26	0.45	3	0.50	0.00
Union - Burnsland Cemetery	MNI061,MNI063	303,677	2	0.00	9	1.00	0.00
University District	MON217, MON218, MON240, STA506, STA544, STA667, UNI546, VAR431	625,863	58	0.48	3	0.00	0.00
Valleyridge	VAL934	254,613	2	0.50	2	0.50	0.00
Varsity	VAR456	540,145	26	0.23	1	0.00	0.00
Winston-Victoria Park	WIN800	1,072,371	27	0.29	12	0.17	0.08

[a]In reference to the "Asset CD" field on the City of Calgary website (The City of Calgary 2022)

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APPENDIX 2

Supplemental material for Chapter 3

Appendix 2 Table 2.1. Summary of all coyote observations made by volunteers of a community-based hazing program in Edmonton, Alberta, between January and May 2021 and 2022.

Neighbourhood Name	Date	Treatment type	ORD if applicable	AC conducted
Anthony Henday	2022-01-29	Treatment	40-60 m	No
Aspen Gardens	2022-02-06	Treatment	Not applicable	No
Aspen Gardens	2022-03-01	Treatment	40-60 m	No
Athlone	2021-04-27	Treatment	Over 60 m	Yes
Athlone	2022-01-18	Treatment	Over 60 m	No
Belmead	2022-02-06	Treatment	40-60 m	No
Belmead	2022-02-11	Treatment	20-39 m	No
Belmead	2022-02-26	Treatment	40-60 m	No
Belmead	2022-03-19	Treatment	20-39 m	No
Belmead	2022-04-02	Treatment	Over 60 m	No
Callingwood South	2022-03-09	Treatment	20-39 m	Yes
Crestwood	2022-02-04	Treatment	Not applicable	No
Cromdale	2022-02-07	Treatment	Not applicable	No
Cromdale	2022-02-20	Treatment	Not applicable	No
Cromdale	2022-02-22	Treatment	Not applicable	No
Cromdale	2022-03-06	Treatment	Not applicable	No
Cromdale	2022-03-25	Treatment	Not applicable	No
Cromdale	2022-04-27	Treatment	Not applicable	No
Cromdale	2022-04-28	Treatment	Not applicable	No
Desrochers Area	2021-04-08	Treatment	Over 60 m	No
Dovercourt	2022-02-15	Treatment	Over 60 m	No
Dovercourt	2022-03-11	Treatment	Over 60 m	Yes
Duggan	2022-04-17	Treatment	5-19 m	Yes
Duggan	2022-05-01	Treatment	20-39 m	Yes
Edgemont	2022-04-20	Treatment	5-19 m	Yes
Grandview Heights	2022-01-29	Treatment	40-60 m	No

Grandview Heights	2022-03-26	Treatment	40-60 m	Yes
Grandview Heights	2022-04-24	Treatment	5-19 m	Yes
Grandview Heights	2022-04-26	Treatment	40-60 m	No
Grandview Heights	2022-05-01	Treatment	40-60 m	No
Griesbach	2021-02-04	Control	40-60 m	No
Griesbach	2021-02-19	Control	20-39 m	No
Griesbach	2021-02-20	Control	20-39 m	No
Griesbach	2021-02-26	Control	Not applicable	No
Griesbach	2021-02-27	Control	20-39 m	No
Griesbach	2021-04-06	Control	Over 60 m	No
Griesbach	2021-04-09	Control	Not applicable	No
Hazeldean	2022-02-16	Treatment	20-39 m	No
Hazeldean	2022-03-27	Treatment	Not applicable	No
Idylwylde	2022-02-23	Treatment	Not applicable	No
Idylwylde	2022-02-25	Treatment	Not applicable	No
Inglewood	2021-02-03	Treatment	Not applicable	No
Inglewood	2021-02-15	Treatment	Not applicable	No
Inglewood	2022-03-27	Treatment	Not applicable	No
Lansdowne	2022-01-15	Treatment	20-39 m	Yes
Lansdowne	2022-01-15	Treatment	5-19 m	No
Lansdowne	2022-01-17	Treatment	Not applicable	No
Lansdowne	2022-01-19	Treatment	Not applicable	No
Lansdowne	2022-02-02	Treatment	40-60 m	No
Lansdowne	2022-03-13	Treatment	40-60 m	No
Lansdowne	2022-04-22	Treatment	40-60 m	No
Lansdowne	2022-04-29	Treatment	20-39 m	No
Larkspur	2021-02-19	Treatment	Not applicable	No
Larkspur	2021-03-11	Treatment	Not applicable	No
Laurier Heights	2021-03-16	Treatment	40-60 m	No
Laurier Heights	2021-04-02	Treatment	Over 60 m	No
Lynnwood	2021-03-01	Control	5-19 m	No
Lynnwood	2021-03-03	Control	5-19 m	No
Lynnwood	2021-03-05	Control	5-19 m	No
Lynnwood	2021-03-21	Control	20-39 m	No
Lynnwood	2021-04-13	Control	5-19 m	No
Lynnwood	2021-04-17	Control	5-19 m	No
Lynnwood	2021-04-17	Control	Over 60 m	No
Lynnwood	2021-05-01	Control	40-60 m	No
Lynnwood	2021-05-02	Control	40-60 m	No

Lynnwood	2022-02-06	Treatment	5-19 m	No
Lynnwood	2022-03-01	Treatment	5-19 m	Yes
Lynnwood	2022-03-06	Treatment	5-19 m	No
Lynnwood	2022-03-24	Treatment	Not applicable	No
Lynnwood	2022-03-31	Treatment	Not applicable	No
Lynnwood	2022-04-01	Treatment	5-19 m	No
Lynnwood	2022-04-22	Treatment	5-19 m	No
Lynnwood	2022-04-22	Treatment	5-19 m	No
Lynnwood	2022-05-01	Treatment	40-60 m	No
Mckernan	2022-02-12	Treatment	40-60 m	No
Ogilvie Ridge	2022-04-02	Treatment	Not applicable	No
Ottewell	2021-03-11	Treatment	40-60 m	No
Ottewell	2022-01-18	Treatment	Not applicable	No
Parkallen	2021-02-02	Control	Over 60 m	No
Parkallen	2021-02-15	Control	40-60 m	No
Parkallen	2021-02-16	Control	5-19 m	No
Parkallen	2021-03-02	Control	20-39 m	No
Rio Terrace	2022-02-07	Treatment	40-60 m	No
Rio Terrace	2022-02-14	Treatment	Not applicable	No
Rio Terrace	2022-03-15	Treatment	Not applicable	No
Rio Terrace	2022-03-17	Treatment	40-60 m	No
Rio Terrace	2022-03-28	Treatment	Not applicable	No
Rio Terrace	2022-04-02	Treatment	Not applicable	No
Rossdale	2021-03-03	Treatment	20-39 m	Yes
Rossdale	2021-03-08	Treatment	Less than 5 m	Yes
Royal Gardens	2022-01-19	Treatment	Over 60 m	No
Royal Gardens	2022-03-08	Treatment	40-60 m	Yes
Royal Gardens	2022-03-26	Treatment	Not applicable	No
South Terwillegar	2022-02-15	Treatment	Over 60 m	No
South Terwillegar	2022-04-12	Treatment	Over 60 m	No
South Terwillegar	2022-04-17	Treatment	5-19 m	No
South Terwillegar	2022-04-17	Treatment	40-60 m	No
South Terwillegar	2022-04-20	Treatment	20-39 m	No
South Terwillegar	2022-04-20	Treatment	40-60 m	No
South Terwillegar	2022-04-22	Treatment	Over 60 m	No
Steinhauer	2021-03-03	Control	Over 60 m	No
Steinhauer	2021-03-04	Control	40-60 m	No
Steinhauer	2022-02-17	Treatment	Not applicable	No
Strathcona	2021-02-05	Treatment	40-60 m	Yes

Strathcona	2022-02-03	Treatment	20-39 m	No
Strathcona	2022-02-16	Treatment	20-39 m	No
Strathcona	2022-03-11	Treatment	40-60 m	No
Sweet Grass	2021-04-14	Treatment	5-19 m	Yes
Terrace Heights	2022-03-05	Treatment	5-19 m	Yes
Terwillegar Towne	2021-02-15	Control	40-60 m	No
Terwillegar Towne	2021-02-17	Control	20-39 m	No
Terwillegar Towne	2021-02-18	Control	40-60 m	No
Terwillegar Towne	2021-02-22	Control	20-39 m	No
Terwillegar Towne	2021-02-23	Control	20-39 m	No
Terwillegar Towne	2021-03-03	Control	40-60 m	No
Terwillegar Towne	2021-03-04	Control	5-19 m	No
Terwillegar Towne	2021-03-09	Control	Over 60 m	No
Terwillegar Towne	2021-03-10	Control	40-60 m	No
Terwillegar Towne	2021-03-12	Control	Over 60 m	No
Terwillegar Towne	2021-03-15	Control	Over 60 m	No
Terwillegar Towne	2021-03-16	Control	Not applicable	No
Terwillegar Towne	2021-03-16	Control	20-39 m	No
Terwillegar Towne	2021-03-18	Control	Over 60 m	No
Terwillegar Towne	2021-03-22	Control	40-60 m	No
Terwillegar Towne	2021-03-26	Control	40-60 m	No
Terwillegar Towne	2021-03-30	Control	Over 60 m	No
Terwillegar Towne	2021-03-31	Control	20-39 m	No
Terwillegar Towne	2021-04-04	Control	Not applicable	No
Terwillegar Towne	2021-04-08	Control	Over 60 m	No
Terwillegar Towne	2021-04-11	Control	5-19 m	No
Terwillegar Towne	2021-04-11	Control	40-60 m	No
Terwillegar Towne	2021-04-13	Control	Over 60 m	No
Terwillegar Towne	2021-04-22	Control	20-39 m	No
Terwillegar Towne	2021-04-26	Control	40-60 m	No
Terwillegar Towne	2021-04-29	Control	Not applicable	No
Terwillegar Towne	2021-05-01	Control	20-39 m	No
Terwillegar Towne	2021-05-06	Control	40-60 m	No
Terwillegar Towne	2022-01-15	Treatment	Over 60 m	No
Terwillegar Towne	2022-01-18	Treatment	Over 60 m	No
Terwillegar Towne	2022-01-21	Treatment	40-60 m	No
Terwillegar Towne	2022-01-22	Treatment	Not applicable	No
Terwillegar Towne	2022-01-25	Treatment	40-60 m	No
Terwillegar Towne	2022-01-29	Treatment	Over 60 m	No

Terwillegar Towne	2022-02-01	Treatment	Over 60 m	No
Terwillegar Towne	2022-02-10	Treatment	Over 60 m	No
Terwillegar Towne	2022-02-13	Treatment	20-39 m	No
Terwillegar Towne	2022-02-17	Treatment	40-60 m	No
Terwillegar Towne	2022-02-21	Treatment	40-60 m	No
Terwillegar Towne	2022-02-23	Treatment	Not applicable	No
Terwillegar Towne	2022-02-26	Treatment	Not applicable	No
Terwillegar Towne	2022-02-27	Treatment	40-60 m	No
Terwillegar Towne	2022-03-06	Treatment	Over 60 m	No
Terwillegar Towne	2022-03-09	Treatment	40-60 m	No
Terwillegar Towne	2022-03-11	Treatment	20-39 m	Yes
Terwillegar Towne	2022-03-13	Treatment	20-39 m	Yes
Terwillegar Towne	2022-03-19	Treatment	40-60 m	Yes
Terwillegar Towne	2022-03-22	Treatment	20-39 m	No
Terwillegar Towne	2022-03-26	Treatment	40-60 m	Yes
Terwillegar Towne	2022-03-31	Treatment	Not applicable	No
Terwillegar Towne	2022-04-01	Treatment	Over 60 m	No
Terwillegar Towne	2022-04-04	Treatment	Not applicable	No
Terwillegar Towne	2022-04-13	Treatment	20-39 m	No
Terwillegar Towne	2022-04-15	Treatment	20-39 m	No
Terwillegar Towne	2022-04-22	Treatment	Over 60 m	No
Terwillegar Towne	2022-04-24	Treatment	5-19 m	Yes
Terwillegar Towne	2022-04-28	Treatment	40-60 m	No
Terwillegar Towne	2022-04-30	Treatment	5-19 m	Yes
Virginia Park	2022-02-11	Treatment	Not applicable	No
Virginia Park	2022-02-17	Treatment	20-39 m	Yes
Virginia Park	2022-02-18	Treatment	Not applicable	No
Virginia Park	2022-02-25	Treatment	40-60 m	No
Virginia Park	2022-02-26	Treatment	20-39 m	No
Virginia Park	2022-03-23	Treatment	Not applicable	No
Wedgewood Heights	2022-02-23	Treatment	Not applicable	No
Windsor Park	2021-04-26	Control	5-19 m	No