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Living with Coyotes: Exploring Human-Wildlife Coexistence in Alberta

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Living with Coyotes: Exploring Human-Wildlife Coexistence in Alberta

by

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Abstract

As human populations grow and utilize more space, interactions between humans, domestic animals and wildlife will become more common. Understanding human-wildlife coexistence, and in particular human-predator coexistence is a key area of research. My research uses a mixed-methods approach that combines interview data with data collected using a Geographic Information System depicting landscape pattern and processes to further our understanding of coyote coexistence and predation by coyotes on pets and livestock in the Foothills Parkland Natural Subregion of Alberta. The interview data represents 48 in-depth, in-person interviews with rural residential and agricultural participants, conducted in situ by Dr. Alexander and Dr. Draper between 2015 – 2017. Data on coexistence values, as well as participant demographics including livestock and pet ownership, predation events, biodiversity checklists, and property size were gathered through interviews. Geospatial data were derived from a geospatial database and were spatially tagged to each property. Three relationships were evaluated: 1) whether coexistence was impacted by demographics, livestock and pet ownership, predation events, or geospatial factors, 2) whether livestock and/or pet predation was impacted by demographics, livestock and pet ownership, biodiversity, or geospatial factors and 3) whether livestock predation specifically was impacted by demographics, livestock and pet ownership, biodiversity, or geospatial factors. Overall, participants were more likely to kill coyotes if they had experienced prior predation, which can be attributed to factors such as the impact of emotional trauma on lethal control methods. Predation by coyotes was more likely to occur on larger properties, which may be attributed to factors such as herd density, as well as if cats were present, who may act as coyote attractants. Since predation is a significant predictor of killing of coyotes, this study recommends three education-oriented strategies to reduce predation. These strategies include developing science communication materials to educate impacted communities about how to reduce predation risk. Reducing predation in the Foothills Parkland Natural Subregion (FPR) will reduce conflict between people and coyotes, setting an example for other communities across North America and improving human, livestock, pet, and coyote wellbeing.

Preface

FCI Database data were used with permission from S. Alexander and D. Draper (2015-2017).

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1 Introduction

Humans and wildlife share this planet. We depend on the same land, we use the same resources, and our actions have repercussions that impact many other forms of life on Earth. However, this is not a one-sided relationship. Animals, as well as the ecosystems they call home, can also have profound impacts on people.

As the human population grows and we utilize more physical space to meet our needs, less natural habitat is available for wildlife (McKinney, 2002; Elliot et al., 2016). This trend has numerous negative impacts on the environment including habitat loss, threatening the survival of animals and plants, and causing the extinction of entire species (McKinney, 2002). But why is this important? Ecosystems have direct impacts on human health (Forget and Lebel, 2001; Nielsen, 2001), happiness, and well-being (Nielson, 2001; Martín-López and Montes, 2015). Collectively, the benefits that the environment provides for humans are called ecosystem services (Daily and Matson, 2008). While they describe important processes that are critical to human survival, ecosystem services often are used as a selling point to justify conservation initiatives (Daily and Matson, 2008). However, ecosystem services are only one part of the conservation puzzle. Arguments recognizing that nature has intrinsic value unrelated to the ecosystem services it provides (König et al., 2020), as well as discussions about morality and the rights of animals (Fox and Bekoff, 2011) have begun to hold more weight within the field of conservation during the last 20 years or so (Elliot et al., 2016; Hunold and Lloro, 2022).

Attempts to generate support for conservation projects can be hindered by human-wildlife conflict (Manfredo and Dayer, 2004). This is an important issue as human expansion into natural habitats creates an increase in human-wildlife interactions of all kinds (Treves and Karanth, 2003; Lukasik and Alexander, 2012; Elliot et al., 2016). Conflict is described as interactions between people and wildlife that have a negative impact on humans, such as when wildlife destroy crops or kill livestock (König et al., 2020). Behaviours that fit this definition are subjective: a behaviour that one person considers to be a conflict could be viewed as acceptable behaviour by another (Manfredo and Dayer, 2004). Concerns about conflict are especially evident when the conflict involves carnivores (Lukasik and Alexander, 2012; Elliot et al., 2016).

Coyotes are medium-sized carnivores who often are highly successful in human-modified landscapes due to their adaptability and tolerance of people (Crooks and Soulé, 1999; Bekoff and Gese, 2003). Due to these traits, coyotes often are considered apex predators in urban environments (Crooks and Soulé, 1999; Hunold and Lloro, 2022). Some people have raised concerns regarding the safety of pets, people (Alexander and Quinn, 2011) and livestock (Mitchell et al., 2004) who live alongside these coyotes. These concerns play a role in the creation of management strategies that often are ineffective and unethical (i.e. lethal methods) (Dubois et al., 2017; Sampson and Van Patter, 2020), or else fail to consider the critical role that coyotes and other apex predators play in the maintenance of ecosystem health (Sandifer et al., 2015) and biodiversity (Crooks & Soulé, 1999; Ritchie and Johnson, 2009).

Research suggests that anthropogenic factors such as human behaviour and values may be the most significant drivers of human-wildlife conflict (Elliot et al., 2016; Dubois et al., 2017). Values towards wildlife are crucial in informing behaviours, such as whether people choose to coexist with or kill coyotes (Alexander and Draper, 2019a; Draheim et al., 2019). These values may be influenced by many factors such as ecological and human dimensions (Alexander and Draper, 2019a), relationships with space and place, personal experiences

(Alexander and Draper, 2019b), as well as safety and economic concerns (Treves and Karanth, 2003).

Peaceful coexistence between humans and wildlife is essential to reducing human-wildlife conflict. Peaceful coexistence has multiple interpretations but here I define it as a state where humans and wildlife share the landscape sustainably, in a way that protects and ensures the survival of wildlife populations while establishing a tolerable risk level of human-wildlife conflict (Carter and Linnell, 2016; König et al., 2020). While this definition strongly discourages the unnecessary killing of wildlife such as coyotes, it does leave room for empathy and discussion around whether killing may sometimes be an ethical choice in certain contexts (Alexander and Draper, 2019a). This definition also relies on a kind of animal ethics where animal wellbeing (Fox and Bekoff, 2011) and rights of nature (Manfredo and Dayer, 2004; Knauß, 2018) are valued, irrespective of their value to people.

Peaceful coexistence with coyotes is hindered in part by human attitudes towards coyotes (Whitley et al., 2023), as well as the need for more data on the factors that influence human-wildlife coexistence behaviors (Lute et al., 2020). Studies that examine the impact of values on coexistence are rare, though researchers have begun to investigate these drivers (Alexander and Draper, 2019a). Mixed-method approaches that use qualitative and quantitative measures to examine ecological factors, human dimensions, and variation over space and time are expected to provide valuable information on human and coyote coexistence, and more broadly on human and wildlife coexistence (Alexander and Draper, 2019a). Furthermore, prior experiences of predation on pets or livestock by coyotes also are expected to impact coexistence values (Naughton-Treves et al., 2003). By understanding the drivers of predation risk, we can develop more effective methods to mitigate predation. Communicating these risk factors and mitigation strategies with at-risk populations may reduce human-coyote conflict and encourage peaceful coexistence.

As a means to contribute to literature and mitigate against human-coyote conflict I explore how people respond to coyotes, in relation to predation patterns by coyotes on pets and livestock, and geospatial influences. Specifically, I am interested in the following three questions: 1) what drives people's coexistence values towards coyotes, 2) what factors influence the likelihood of coyote predation on pets and/or livestock and 3) what factors influence the likelihood of coyote predation on livestock specifically. To explore the relationships presented in these questions, I analysed Foothills Coyote Initiative (FCI) interview data as well as landscape pattern and process data. I examined these data in a mixed-methods framework to better understand how demographics, pet and livestock ownership, predation events, biodiversity, and geospatial variables interacted in the context of coexistence values and predation. I also created several science communication materials based on my research, with the goal of increasing empathy towards coyotes, connecting the public with conservation issues, and spreading awareness about the importance of coyotes to human and ecosystem health. The objective of this research is to deepen our understanding of the factors driving human-coyote conflict and coyote predation on pets and livestock, with the goal of informing the development of more effective coexistence strategies that will allow humans, coyotes, pets, and livestock to peacefully thrive in shared spaces.

2 Literature Review

2.1 Coexistence

2.1.1 Human and Wildlife Coexistence

It is estimated that our planet supports approximately 8.7 million species of animals and plants, with most of these species yet to be discovered (Mora et al., 2011). As human populations grow and we utilize more physical space to meet our needs, less healthy, natural habitat is available for wildlife (McKinney, 2002; Manfredo, 2008; Elliot et al., 2016). The largest cause of habitat destruction is deforestation, followed by other factors such as urbanisation, road construction, energy generation, environmental contaminants, mining, and anthropogenic climate change (Scanes, 2018).

Alongside directly contributing to the destruction and degradation of ecosystems (Scanes, 2018), these human impacts also influence species behaviour (Wilson et al., 2020), population density, morphology, physiology, and life history (Schmitz et al., 2004). These changes have a circular effect, with changes to species traits in turn impacting entire ecosystems (Pirotta et al., 2018). While many species of animals avoid people, habitat destruction often forces animals into more frequent contact with humans (Manfredo, 2008; Goumas et al., 2020). This is particularly true in urban environments, where high human population density increases the likelihood of contact with wildlife (Soulsbury and White, 2015).

Interactions between humans and wildlife usually are assigned as being positive, negative (Nyhus, 2016), or neutral (Soulsbury and White, 2015). Conflicts often are referred to as interactions that negatively impact humans or wildlife (Conover, 2002; Nyhus, 2016; Buijs and Jacobs, 2021). As noted previously, examples of negative human impacts on wildlife include habitat destruction (Scanes, 2018), population decline, and extinction (Nyhus, 2016). Negative impacts on people can manifest as either direct or indirect conflict, such as disease transmission, physical attacks, and property damage (Conover, 2002; Manfredo, 2008; Soulsbury and White, 2015) or perceived threats to humans (Peterson et al., 2010). What counts as conflict towards people is subjective, with factors such as social context, economic interests, personal values, human-human conflict, and even language playing a role in its determination (Peterson et al., 2010). Peterson et al. (2010) found that the term human-wildlife conflict itself may increase the perception of conflict by framing wildlife as an antagonistic force that threatens humans. They suggest that the terms human-wildlife interactions or human-wildlife coexistence better represent the notion that we share our planet with wildlife, and that it is important for both human and animal welfare to find ways to balance the needs of both. In tandem, humans and wildlife also can experience positive interactions or benefits from each other (Nyhus, 2016). One way to determine the benefits of wildlife on humans are ecosystem services (Millenium Ecosystem Assessment, 2005). Ecosystem services are the benefits that healthy ecosystems provide to human well-being, such as food, clean water, climate regulation, and flood mitigation (Millenium Ecosystem Assessment, 2005; Sandifer et al, 2015). They often are measured by their economic value (Krieger, 2001; Ingraham and Foster, 2008; Salles, 2011).

Positive outcomes, such as ecosystem services, are crucial for the survival of all life on earth, including for human survival and quality of life (Daily, 1997). Ecosystem services require functioning ecosystems to provide these benefits (Montoya et al., 2012). An important component of functioning ecosystems is the variety of life, or biodiversity, found within these ecosystems (Díaz et al., 2006). Many ecosystem services are biodiversity-dependent, with higher levels of biodiversity linked to healthier ecosystems that are better able to support people and wildlife (Díaz et al., 2006; Sandifer et al., 2015). In the context of enhancing ecosystem benefits and finding solutions to negative interactions, it is important to better understand how humans can coexist with wildlife.

Negative outcomes, such as habitat destruction and degradation, can occur when humans convert space for human use and leave less habitat available for wildlife (habitat loss) (McKinney, 2002; Manfredo, 2008; Elliot et al., 2016). Habitat loss can impact biodiversity and native species survival (Saunders et al.; Wilcove et al., 1998; Rand et al., 2006), may increase the risk of human-wildlife interactions (Manfredo, 2008), and can alter species behaviour (Wilson et al., 2020), population density, morphology, and life history (Schmitz et al., 2018).

One kind of habitat loss, known as habitat fragmentation, occurs when habitat destruction produces small fragments of remnant vegetation surrounded by a matrix of different vegetation and/or land use types (Saunders et al., 1991; Murcia, 1995), such as forest remnants surrounded by agricultural fields. These remnant fragments are isolated from each other (Saunders et al., 1991; López-Barrera et al., 2007). Habitat fragmentation creates ecological transition zones between fragments and the surrounding matrix, producing what is known as edge effects (Murcia, 1995; López-Barrera et al., 2007). Edge effects are strongest when adjacent habitats are more different from each other structurally, such as when the transition is abrupt (López-Barrera et al., 2007). These edge effects impact the biotic and abiotic conditions found within and around the fragments (Saunders et al., 1991; Murcia, 1995). Edge effects result in different vegetation at the edges of the remnants when compared to the interior (Saunders et al, 1991), which can alter resource availability and reduce foraging opportunities for some species (Saunders et al, 1991). Fragmentation does not always result in a lower number of species, but it does impact species composition (Saunders et a., 1991). This happens because some of the original species die out, while new species who can adapt to the changes in conditions move in (Saunders et al., 1991).

Fragmentation can also impact species distribution, with some species using edges more than interior areas (López-Barrera et al., 2007). For example, Šálek et al. (2010) found that predators exhibit a preference for edge habitats, which may be due to factors such as higher prey density within these edges. This may also have implications for edges that are adjacent to anthropogenic food sources such orchards, crops, and feeders, as access to anthropogenic food can increase species abundance (Janova, 2016; Hansen et al., 2020).

2.1.2 Coexistence Challenges and Solutions

How should we coexist with wild animals? While this question may seem simple, there are many different opinions when it comes to sharing the land with wildlife (Nyhus, 2016; König et al., 2020; Risvoll and Kaarhus, 2020). Firstly, there is the question of what human and wildlife relationships should look like (Elliot et al., 2016). Traditionally this had very little to do with coexistence, with a strong focus on management and control (Sampson and Van Patter, 2020). Today, this view is changing in favour of more ethical paradigms that emphasize coexistence (Elliot et al., 2016).

To develop successful models and programs for coexistence, the values of local stakeholders should be considered (Fox and Bekoff, 2011; Dorresteijn et al., 2016; König et al., 2020). However, stakeholders are not limited to human interests as the most effective solutions will also value the interests of non-human stakeholders (Fox and Bekoff, 2011; Chapron and López-Bao, 2020), such as coyotes, and the ecosystems that they are a part of. This approach pushes against the status quo of assigning lesser value to nature than to humans (Chapron and López-Bao, 2020) and is characteristic of critical animal geographies. This approach ensures that solutions are inclusive of non-human stakeholders and give due weight to each stakeholder’s interest (Fox and Bekoff, 2011).

Stakeholders with conflicting interests must work together to build tolerance, respect and collaboration and to value the impact that these opposing viewpoints provide (Fox and Bekoff, 2011). Fox and Bekoff (2011) suggest a guiding sense of ethics they believe should be adhered to in every situation: "do no intentional harm, treat all individuals with respect and compassion, and recognize that all animals have intrinsic value or worth, irrespective of their utility to other animals, including humans" (Fox and Bekoff, 2011, pp. 129). This sense of ethics is especially crucial given emerging research which has demonstrated that all mammals experience emotions (Bekoff, 2013). However, Fox and Bekoff (2011) also acknowledge that the myriads of diverse backgrounds that humans come from necessitate that the universal acceptance of these ethics, or even the understanding of these ethics, vary widely. Regardless, a firm adherence to ethics when considering human coexistence with animals is essential (Fox and Bekoff, 2011).

An individual's worldview is foundational to how a person understands the world, and this has a major impact on their values, attitudes, and behaviours (Alexander and Draper, 2019a, Elliot et al., 2016). People express diverse worldviews, and this leads to the existence of multiple viewpoints (Alexander and Draper, 2019a). The formation of diverse viewpoints towards animals can be influenced by the complex interactions of social factors, such as whether someone has experienced prior wildlife conflicts, as well as the economic and cultural value different individuals attribute to carnivores (Dorresteijn et al., 2016). By examining which factors contribute to an individual's worldview, including which factors drive coexistence with or killing of wildlife such as coyotes, we may influence more inclusive and effective conservation strategies (Alexander and Draper, 2019a).

Emotions also are powerful drivers of the human lived experience with wildlife (Dolan, 2002). They determine how a person will react to an animal (e.g. like or dislike, fear) as well as which interactions with an animal are deemed to be appropriate (e.g. coexistence vs killing) (Sponarski et al., 2015). Sponarski et al. (2015) demonstrated that negative emotions, particularly fear, increased people's acceptance of lethal management methods used on coyotes. Due to the impact of emotions on human behaviour, it is important to understand how certain influential emotions such as fear influence coexistence (Sponarski et al., 2015). Fox and Bekoff (2011) believe that human fears must be addressed, partially by improving communication and education in communities impacted by coexistence concerns.

Fear of an animal may be a cause for dislike or other negative emotions (Elliot et al., 2016). However, fear of an animal often is due to misinformation (Røskaft et al., 2003). Røskaft et al. (2003) found that people who were not exposed to predators had a high level of fear towards them, compared with people who lived with these predators and exhibited a much lower level of fear. This was demonstrated by Hudenko et al. (2008) who showed that fear of coyotes decreased as the length of time that people lived with coyotes increased. Furthermore, people who did not live with predators but participated in outdoor activities or had achieved a higher level of education also exhibited much lower levels of fear (Røskaft et al., 2003). Fear has also been linked to the perceived danger and uncontrollability of an animal, where both metrics often are assumed to be higher in predators (Sponarski et al., 2015). Røskaft et al. (2003) suggest that the communication of knowledge about the biology, behaviour and safety of predators would reduce fear of predators for many individuals.

Coexistence relies on humans and wildlife sharing resources and space, while minimizing conflict (Carter and Linnel, 2016). Alexander and Draper (2019a) discuss two possible avenues through which we can improve coexistence: law (or legislation) and education. The success of each of these avenues is impacted by their audience (Alexander and Draper, 2019a; Veríssimo et al., 2019). Policies or laws specifying how someone is permitted to behave around animals works best for people belonging to worldviews that are strongly influenced by culture and personal environmental beliefs (Alexander and Draper, 2019) or with groups that lack the personal drive to change their behaviour (Veríssimo et al., 2019). Alternatively, educational initiatives are more impactful for people with worldviews which are more central in relation to the role of humans in the environment (Alexander and Draper, 2019a), and who believe that these changes will personally benefit themselves or the community (Alexander and Draper, 2019a; Veríssimo et al., 2019), and/or feel that they have the capacity to change (Veríssimo et al., 2019). Despite these trends, Alexander and Draper (2019a) emphasize that there is no one solution that will work for every problem: it is important to consider factors such as the culture, species, and individuals involved when deciding which methods are best to promote coexistence.

One example of using the law in sharing space peacefully with wildlife is the creation of protected areas, such as national parks (Abrams et al., 2020). In national parks, wildlife may thrive due to laws set in place by governments (Abrams et al., 2020). These protected areas have been shown to be important for carnivore conservation (Carter & Linnel, 2016). Another example of this can be seen in urban areas relating to green spaces. The preservation of green spaces is related to property rights, and therefore their development is impacted by the law (Colding et al., 2020). Green spaces often are the preferred habitat for many species (Aronson et al., 2017; Gallo and Fidino, 2018; Parsons et al., 2018) and provide the opportunity for wildlife to live in habitats that more closely resemble their natural environments.

Education can play a variety of roles in conservation (Bickford et al., 2012; Lamb et al., 2018; Alexander and Draper, 2019a; Veríssimo et al., 2019; Abrams et al., 2020). Public education can be used to help teach people how to interact safely with wildlife while enjoying natural spaces (Abrams et al., 2020). For example, national parks often provide public programming on topics such as preventing wildlife food conditioning, how to maintain safe and respectful distances from wildlife, avoiding disease transmission, and leave no trace policies that protect people, wildlife, and ecosystems (Abrams et al., 2020).

Bickford et al. (2012) suggested that scientists have an important role to play in increasing environmental literacy, and they recommend that researchers utilize better scientific communication methods to engage with the public, policy makers, and key stakeholders. Science communication can include methods such as interactive programming (Abrams et al., 2020), conservation marketing (Veríssimo et al., 2019), citizen science programs (Bickford et al., 2012), researcher involvement in traditional media such as newspapers and magazines (Bickford et al., 2012), non-traditional media such as blogs and social media (Bickford et al., 2012; Lamb et al., 2018), working with policy makers to inform decision-making (Bickford et al., 2012), and applying research within all levels of education to develop programs that emphasize environmental literacy (Cutter-Mackenzie and Smith, 2003). Regardless of the method used, Bickford et al. (2012) suggest that the most effective tactic for researchers is to focus on communicating their passion for the environment with the public.

Additionally, while researchers have an important role to play in improving scientific literacy (Bickford et al., 2012), it is also important to make sure that the public themselves can access scientific materials (Alexander and Draper, 2019a). For example, in their study of how worldviews impact coexistence with coyotes, Alexander and Draper (2019a) demonstrated that some members of the public intentionally seek out new information to inform their relationships with nature. In the context of this study, these individuals were often well established and respected within their communities, suggesting they could have the opportunity to share their knowledge with other members of the community, improving knowledge mobilization and the scientific literacy of their communities overall (Alexander and Draper, 2019a).

2.2 Coyote Ecology and Human-Coyote Conflict

2.2.1 Coyote Ecology

Coyotes (*Canis latrans*) are one of eight species in the genus Canis, the same genus that wolves and domesticated dogs belong to (Bekoff and Gese, 2003). They are classified separately from other Canis species due to morphological differences (Bekoff and Gese, 2003). In 2003 nineteen subspecies of coyote were recognised (Bekoff and Gese, 2003). Coyotes have been widespread across North America for over one million years (Wang et al., 2010; Hinton et al., 2019). They are highly intelligent (Young et al., 2019) and adaptable and are found throughout diverse ecosystems such as grasslands, deserts, and mountains (Bekoff and Gese, 2003; Hinton et al., 2019) between approximately 10ºC N and 70ºN in North America. They show a remarkable ability to adapt to human-modified environments, which has led to their success and proliferation in urban and rural environments (Bekoff and Gese, 2003; Elliot et al., 2016; Hinton et al., 2019). Importantly, even though coyotes can adapt to human-modified environments, urban coyotes commonly suffer from higher parasite loads and poorer health when compared with non-urban coyotes (Sugden et al., 2020). Alexander and Draper (2019b) elaborate on this further, describing the challenges that urban coyotes face. Despite their ability to survive in urbanised environments, coyotes are naturally wary of and prefer to avoid people (Fox, 2006). Living in close proximately to humans introduces the potential for human-coyote conflict (Fox, 2006; Elliot et al., 2016), highlighting the importance of working to decrease this conflict through a better understanding of what causes it.

Coyotes are medium-sized carnivores (Levi and Wilmers, 2012), though some members of the public still view coyotes as dangerous due to their size (Mitchell et al., 2004). The average coyote body length ranges between 1 – 1.5 m with an average tail length of 0.4 m (Bekoff and Gese, 2003), though this size varies geographically and between subspecies (Bekoff and Gese, 2003; Kennedy et al., 1986). Coyotes usually exhibit mild sexual dimorphism, with adult males typically being larger than adult females (Kennedy et al., 1986; Bekoff and Gese, 2003; Mastro, 2011).

Though coyotes exhibit a range of fur colours, they typically display a blended mix of reddish-tinted grey fur with lighter fur on their undersides (Bekoff and Gese, 2003). The texture of their fur differs due to adaptation to the various ecosystems coyotes live in; in northern environments, the hair is longer and coarser, though all coyote fur tends to be coarser, longer, rougher and stiffer than that of other Canis members such as dogs and red foxes (Bekoff and Gese, 2003). Coyotes also exhibit a shorter coat in the summer and a longer coat in the winter, achieved through a yearly molt (Bekoff and Gese, 2003). This process helps coyotes with thermoregulation across changing seasons (Bekoff and Gese, 2003), allowing them to survive and flourish in many different environments. Additionally, the cryptic nature of the colour of coyote fur makes it harder to see them in prairie ecosystems (Hinton et al., 2022), such as the prairie ecosystems studied in the FCI.

Coyotes are most active at sunrise and sunset, though they remain active throughout the day (Bekoff and Gese, 2003; Arias-Del Razo, 2011). In northern climates, such as where the FCI interviews were conducted, coyotes are less active and participate in hunting behaviours less frequently in the winter, which has been attributed to factors such as the lower availability of prey (Bekoff and Gese, 2003), sometimes higher availability of carrion (Shivik, 1997), and lower energy demands outside of the pup-rearing season (Shivik, 1997).

As opportunists, coyotes exhibit high plasticity in their diet, reflecting local food availability (McKinney and Smith, 2007). Coyotes eat prey ranging in size from small insects and rodents to large ungulates (Bekoff and Gese, 2003). Regarding livestock, coyotes are more likely to consume small to medium sized livestock such as sheep (Torres-Romero et al., 2023), or young calves under a month old (Dorrance, 1982). Coyote diet changes in relation to availability, and factors such as drought and temperature impact prey availability (McKinney and Smith, 2007). Research conducted in our study area confirmed that coyotes preferentially eat natural food items such as rodents (Lukasik and Alexander, 2012; Miller et al., 2012), vegetation, rabbits, deer, and birds (Lukasik and Alexander, 2012), and yielded evidence they may forage on human food sources (Lukasik and Alexander, 2011) and livestock (Mitchell et al., 2004).

Female coyotes are seasonally monestrous, which means that they undergo a period of estrus once per year (Carlson, 2008). Coyotes form long-term pair bonds and are socially monogamous (Mastro, 2011). They have a narrow window for reproduction (Alexander, 2020) that typically occurs in January and February (Mastro, 2011). There usually is only one breeding pair in a family, which is typically the dominant pair (Carlson, 2008). The number of breeding females per year is impacted by access to food resources (Bekoff and Gese, 2003), environmental conditions, and age of the coyotes, with older females more likely to be pregnant (Mastro, 2011). As breeding pairs are responsible for the majority of livestock predation (Blejwas et al., 2002), there might be a greater potential for conflict in the FCI area when dominant pairs are provisioning pups.

The average coyote litter size is 3-7 pups (Carlson, 2008). Pups leave the den when they are between 4-5 weeks old (Way et al., 2001; Mastro, 2011) and both parents provide food for the pups (Carlson, 2008). Other members of the family participate in communal pup rearing by defending the den and participating in den sitting, or guarding of the pups (Bekoff and Wells, 1982; Hatier, 1995; Carlson, 2008). Dens continue to be used until the pups are around 8-10 weeks old (Mastro, 2011: Way et al., 2001). Some pups disperse to new territories when they are between 6-9 months old, while others stay with the family to help care for future offspring (Bekoff and Wells, 1982; Bekoff and Gese, 2003; Carlson, 2008). This dispersion can be partially attributed to the carrying capacity of a family's territory or home range (Gese et al., 1996), with home range sizes averaging 12 km^2 (Alberta Agriculture and Rural Development, 1998). The highest level of human-coyote conflict occurs during denning due to resource demands intersecting with high levels of human activity in spring (Lukasik and Alexander, 2012), which may also be a potential cause of conflict in the FCI area.

Most literature refers to coyotes as existing in packs, which may obscure the nuanced relationships that occur within by suggesting that they are just an assemblage of a number of the same individual – these are better described as family groups because individuals have specific roles and purposes. Changing this narrative is important to the perception of the species (Alexander pers. comm, 2024). Hence, for the purpose of this thesis, I refer to these groups as 'families'. Coyotes can either belong to fission fusion family groups, which usually range from 2-10 individuals (Atwood, 2006; Mastro, 2011), or they can be solitary or transient (Mastro, 2011). Coyote families display a dominance hierarchy, with older members of the family holding higher status (Bekoff and Gese, 2003). Dominant pairs have the highest access to food, and therefore the highest survival rates (Gese, 2004). Subordinate coyotes have less access to food and lower survival rates, and solitary and transient coyotes have the least access to food and the lowest survival rates (Gese, 2004). Habitat quality, particularly food distribution and richness, impact family and territory size (Atwood, 2006).

Some participants in the FCI reported using lethal control methods on coyotes. Persecution of coyotes by humans through actions such as culling can influence coyote behaviour (Fox, 2006), social structure (Treves and Naughton-Treves, 2005), and population size (Proulx and Rodtka, 2015). For instance, culled coyotes may be replaced by new coyotes that have not developed a fear of people, contributing to potential human-coyote conflict (Fox, 2006). If the coyotes surviving a cull are young, they may not have learned to successfully hunt wild prey yet and instead may turn to easier prey sources such as livestock and pets (O'Connor, 2024). While culling might result in an initial reduction in carnivore populations, population size usually rebounds in ecosystems that can support higher populations, through processes such as a younger age of reproduction (Bekoff and Gese, 2003) and increased reproductive success, as well as immigration (Bekoff and Gese, 2003; Proulx and Rodtka, 2015).

2.2.2 The Role of Coyotes Within Ecosystems

Coyotes are directly and indirectly outcompeted by larger carnivores such as wolves and cougars, and wolves have been known to kill coyotes (Bekoff and Gese, 2003; Berger and Gese, 2007). Predation by, and food competition with, other carnivores can impact coyote populations (Bekoff and Gese, 2003). Wolves are better at killing large prey such as ungulates, and coyotes are better at killing medium-sized prey such as rabbits, squirrels, and newborn ungulates under four weeks of age (Levi and Wilmers, 2012). Among-predator trophic cascades can impact ecosystems, such as when larger carnivore presence or absence impacts coyote populations; for example, wolf presence in a habitat leads to higher rates of predation on large and small prey, and wolf absence leads to higher rates of predation on medium-size prey (Levi and Wilmers, 2012). Trophic cascades also can occur in prey species, as an increase in ungulate population often leads to an increase in rodent populations, particularly in North American prairie ecosystems (Katona and Coetsee, 2019). Coyotes exhibit behavioural changes in response to threats from larger carnivores, avoiding areas where larger carnivores live, or following and scavenging leftovers from larger carnivore kills (Bekoff and Gese, 2003). A displacement of larger carnivores through activities such as human hunting pressures can therefore impact coyote ranges (Berger and Gese, 2007) and prey populations (Levi and Wilmers, 2012).

A decline in the population of apex predators can have profound impacts on ecosystems (Prugh et al., 2009). One of these impacts is an increase in the population of smaller predators, called mesopredators (Prugh et al., 2009; Levi and Wilmers, 2012). Some scientists have defined mesopredators by weight (Gehrt and Clark, 2003), while others suggest that different predators can be both apex predators and mesopredators, with the classification depending on what other predators currently are inhabiting an ecosystem (Prugh et al., 2009).

Mesopredators can include species such as skunks, raccoons, and domestic cats (Crooks and Soulé, 1999). Coyotes may also fall within this classification if there are higher trophic-level predators in an ecosystem such as wolves (Berger et al., 2008). Some types of mesopredators, such as domestic cats, are highly adept at hunting and killing small birds and vertebrates (Crooks and Soulé, 1999). It has been suggested that in the role of the mesopredator, coyotes, like other mesopredators, can also have a negative impact on these sometimes-endangered prey species (Ripple et al., 2013). However, in many cases, the coyote is this apex predator in the wild (Bekoff and Gese, 2003). They are also frequently the apex predator in urban environments due to their adaptability and tolerance of humans (Crooks and Soulé, 1999). Prugh et al. (2009) states that the trophic level role that a predator currently occupies within the environment (apex or mesopredator) determines its ecological impacts. Therefore, as they often are apex predators (Crooks and Soulé, 1999; Bekoff and Gese, 2003), coyotes have a beneficial effect on prey species (Crooks and Soulé, 1999).

When acting as an apex predator, coyotes directly impact mesopredator populations (Bekoff and Gese, 2003). In areas with a higher coyote abundance, there is a lower abundance of mesopredators such as free-roaming domestic cats (Levi and Wilmers, 2012). Conversely, areas with lower coyote abundance exhibit higher mesopredator abundance (Crooks and Soulé, 1999). Areas without any coyote presence at all exhibit the highest levels of mesopredator abundance (Crooks and Soulé, 1999). Higher mesopredator abundance directly relates to lower bird and small vertebrate diversity and abundance, a relationship known as the mesopredator release hypothesis (Crooks and Soulé, 1999); this process can also be considered a trophic cascade (Ritchie et al., 2009). Through this mechanism, coyotes play a critical role in the maintenance of ecosystem health and biodiversity (Crooks and Soulé, 1999) and are considered a keystone species (Bekoff and Gese, 2003).

Domestic cats, when allowed to roam outside, are mesopredators that are not constrained by ecosystem limits such as food resources as they rely on human supplementation of diet (Crooks and Soulé, 1999). House cats are indoor cats whose owners allow varying amounts of access to the outdoors (Lepczyk et al., 2004) and barn cats are free-roaming cats that often utilize barns and stables, and whose diet is often supplemented by humans (Bissonnette et al., 2018). Cats can thrive in ecosystems in numbers far above their natural carrying capacity (Crooks and Soulé, 1999). Cats have been responsible for the decline and local extinction of many bird species (Crooks and Soulé, 1999), and they can also impact other species of plants and animals through trophic cascades (Ripple et al., 2016). However, in ecosystems with coyotes, cats can sometimes become a food source for coyotes, reducing the cat population (Crooks and Soulé, 1999). Directly, this leads to the survival of more birds and to higher levels of songbirds (Levi and Wilmers, 2012; Crooks and Soulé, 1999) and rodent diversity (Levi and Wilmers, 2012). Indirectly, coyote predation on cats can impact human behaviour, discouraging owners from allowing their cats to roam outside (Crooks and Soulé, 1999). Therefore, keeping cats indoors has the joint benefit of protecting birds from cats, while also protecting cats from coyotes. Keeping cats indoors is just one example of how people can modify their behaviour to coexist peacefully with coyotes, allowing the urban ecosystem to benefit from the presence of coyotes (Crooks and Soulé, 1999) while protecting the safety of both cat and bird populations.

2.2.3 Human and Coyote Coexistence

Low human tolerance towards predators is one of the challenges facing peaceful coexistence (Fox and Bekoff, 2011). Originally, the coyote was revered and held an important role in First Nations culture (Alexander and Lukasik, 2016). When European settlers arrived in North America, they brought with them a system of predator management that involved killing predators for the purpose of cultivating land, as well as livestock production (Schwartz et al., 2003).

Culls are the process of indiscriminately killing coyotes in large numbers and regularly are used as a solution to human-coyote conflict (Draheim et al., 2021; Whitley et al., 2023). Some stakeholders argue these culls are necessary to protect human and livestock safety and to protect economic losses from coyote predation on livestock (Mitchell et al., 2004; Fox, 2006). In Alberta, it is estimated that economic losses from predation by all predator species cost ranchers approximately $22 million between 2011-2013 (Lee et al., 2017), with coyotes accounting for approximately 75% of livestock predation (Alberta Agriculture and Rural Development, 1998). However, research has shown that culls ultimately are not effective at reducing predation, in addition to being expensive, not widely supported within communities, and being damaging to ecosystems (Mitchell et al., 2004; Draheim et al., 2021). Furthermore, culls are felt by many to be unethical because they ignore the lived experiences of animals (Gillespie and Collard, 2015).

Research has shown that non-lethal alternatives to coyote control such as guardian dogs, exclusion fencing and modified animal husbandry practices are more effective methods of control (McManus et al., 2015; Plotsky et al., 2024). For example, Barnes (2015) recommended livestock management techniques that mimic the anti-predator strategies of wild ungulates. Observations show that smaller groups of prey species are more likely to be attacked by predators (Barnes, 2015). Therefore, predation risk may be reduced by managing grazing livestock so that they form larger groups that are less spread out over the landscape, as opposed to several widely spread, smaller groups (Barnes, 2015). A variety of species of guardian animals, including dogs, llamas, and donkeys, have also been demonstrated to reduce predation of livestock by coyotes (Knowlton et al., 1999). Given the disadvantages of lethal management methods (Draheim et al., 2021), investigating why some people choose to kill coyotes and facilitating more effective (McManus et al., 2015; Plotsky et al., 2024) non-lethal alternatives should be the focus in facilitating coexistence between humans and coyotes.

Research conducted across Canada showed that incidences of conflict that result in injury to humans by a coyote are extremely rare, though conflicts between coyotes and domesticated animals such as cats or dogs are more common (Fox, 2006; Alexander and Quinn, 2011). Regardless of frequency, these conflicts can cause significant emotional trauma for people and impact how a person views coyotes and feels they should be managed (Draheim et al., 2021). In most of these situations, anthropogenic factors contributed to or were the cause of this conflict, which weighed into my analysis of what predicts killing of coyotes.

A major factor influencing conflict with coyotes is coyote consumption of human-sourced food (Fox, 2006; Alexander and Quinn, 2011). Although coyotes preferentially eat natural food items (McKinney and Smith, 2007; Lukasik and Alexander, 2012), in smaller parks there may be a lack of prey resources required to sustain coyote populations (White and Gehrt, 2009). As well, greenspaces and grassland transitionary areas located near residential areas increase coyote access to human resources. This has resulted in reports of coyotes foraging outside natural spaces on human food sources such as garbage, fruiting trees and small household pets, and coyotes have also been observed being intentionally fed by humans (Lukasik and Alexander, 2011). Consumption of anthropogenic foods is closely related to food conditioning, human habituation, and reduced fear of humans (Carbyn, 1989; Lukasik and Alexander, 2012). These factors link strongly with predation towards human food sources and pets (Lukasik and Alexander, 2012).

An improved understanding of livestock predation by coyotes may be an important contribution of my thesis. Livestock predation by coyotes has resulted in concerns about costs from the losses to livestock in the agriculture industry, which are estimated at $40 million per year in the United States (Mitchell et al., 2004). In Canada, agriculture accounted for 1-2% of the GDP in 2009 (Veeman and Gray, 2009). The number of farms in Canada has been declining since 1941, however, farms are increasing in both size and livestock capacity (Veeman and Gray, 2009).

There is evidence that several natural and anthropogenic factors may contribute to predation on pets and livestock. Breeding coyote pairs are responsible for the majority of livestock predation (Blejwas et al., 2002). These pairs are responsible for provisioning pups, and the consumption of livestock has been linked with increased foraging efficiency and reproductive success (Till and Knowlton, 1983). Another contributing factor is that the reduced abundance of smaller prey such as rodents shifts the coyote diet towards larger prey items (McKinney and Smith, 2007). This shift in diet availability can be caused by numerous factors including drought and seasonal changes (McKinney and Smith, 2007). For example, studies examining sheep predation in Texas (Pearson and Caroline, 1981) and California (Sacks and Neale, 2007) found that low rainfall may be associated with reduced prey populations and higher rates of sheep predation by predators, including coyotes. This relationship between rainfall, prey availability, and livestock predation has also been recorded in other predator species (other than coyotes) and ecosystems (Acosta-Jamett et al., 2016). Given the impacts of a shift in coyote diet towards livestock, it is important to understand this shift in greater detail.

Whether a person chooses to coexist with or kill coyotes is thought to be influenced by several factors including variables such as human values, prior predation on pets or livestock by coyotes, and where people live and how long they have resided there (Alexander and Draper, 2019b). The United States Department of Agriculture (USDA) has classified time in situ for ranchers and farmers into two categories: if they have been in operation for less than 10 years, they are beginning farms/ranches, and if they have been in operation for over 10 years, they are experienced farms/ranches (Ahearn, 2011). Factors such as time in situ have been demonstrated to impact feelings towards coyotes, such as the relationship where fear decreases as people spend more time living closely with coyotes (Hudenko et al., 2008).

While coyotes tend to prefer to eat natural food items (Lukasik and Alexander, 2012; McKinney and Smith, 2007), whether they shift their diet to include livestock and/or pets is thought to be influenced by several factors including animal husbandry practices (McManus et al., 2015), natural food availability (McKinney and Smith, 2007), and landscape factors such as proximity to human resources (Fox, 2006; Lukasik and Alexander, 2011). Given the psychological trauma people may experience if they witness the predation or injury of a pet (Alexander and Quinn, 2011) or livestock (Treves and Bruskotter, 2014) and a desire to protect animals under human care from undue harm, understanding the variables that impact predation is expected to have many benefits. Furthermore, in light of the economic concerns regarding coyote predation of livestock (Mitchell et al., 2004), understanding livestock predation more specifically would also be of value.

2.2.4 Theoretical Framing for Coexistence with Coyotes

My research falls within a category known as critical animal geographies, which is an approach to science, decision-making, policy and ethics that places equal value on all shareholders, including non-human shareholders such as animals (Gillespie and Collard, 2015).

Traditionally, the dominant social order has maintained that humans exist in a hierarchy above animals and that only human interests should matter (Gillespie and Collard, 2015). However, multiple, and alternative viewpoints, which stem from numerous worldviews including those provided by stakeholders such as animals, are vital in solving complex problems (Nelson et al., 2011). Nelson (2011) provides an example by discussing the North American model of wildlife management, which suggests that hunting is crucial in conservation, but when multiple viewpoints were considered, it turned out that hunting played a much smaller and possibly detrimental role in conservation efforts. Elden and Crampton (2016) likewise argue for a multi-viewpoint perspective, suggesting that studying opposing viewpoints can illuminate alternative solutions.

A concept that considers multiple viewpoints is the idea of space and place (Gillespie and Collard, 2015). Wildlife relies on adequate space, or habitat, to meet their physical needs (Alexander and Draper, 2019b). Many of the spaces that wildlife use also are shared by humans (Alexander and Draper, 2019b). Space refers to a specific geographical location and can be located on a map (Alexander and Draper, 2019b). Conversely, the meaning that people attribute to specific spaces is known as place (Alexander and Draper, 2019b). Thus, the concept of place is interwoven with space (Alexander and Draper, 2019b). Often unconsciously, humans form ideas about the spaces and places where they feel that wildlife belong or do not belong, and wildlife behaviours they feel are appropriate or inappropriate (Alexander and Lukasik, 2016). These ideas can lead people to feel that animals are out of place in particular spaces, such as when they are around people in rural and urban areas (Alexander and Lukasik, 2016). When people perceive an animal as being out of place, especially a predator such as a coyote, they are often viewed as violating an inherent natural order (Alexander and Lukasik, 2016). Brighenti and Pavoni (2018) discuss the concept of a critical distance, which is the distance away from humans or residences where an animal is viewed as behaving appropriately. If an animal comes within this critical distance, they are viewed as being out of place or as transgressing (Brighenti and Pavoni, 2018). For example, humans typically view built environments such as cities, homes, and yards as being out of place for predators (Ojalammi and Blomley, 2015). Humans can also view more relative locations as being out of place, such as a coyote coming too close to livestock (Alexander and Draper, 2019a). When an animal is viewed to be out of place, people often feel justified in killing them or removing them from a space (Alexander and Draper, 2019a; Alexander and Draper, 2019b). The idea that an animal is out of place (Cresswell, 1996) is a human construct, as these spaces are shared with animals who use the space for their own purposes (Ojalammi and Blomley, 2015). Understanding the alternative viewpoints presented by how animals, such as coyotes, use the land is essential in creating the conditions for peaceful coexistence (Nelson et al., 2011).

Using critical animal geography as a foundation, I believe that we should aim to redefine the spaces and places where humans and animals both live and interact, with the goal of increasing our tolerance for sharing spaces where coyotes traditionally are viewed as being out of place (Alexander and Lukasik, 2016). By exploring multi-viewpoint perspectives (Nightingale, 2003) and giving weight to the perspectives of both humans and coyotes, a broader understanding of the issues and the range possible solutions relating to human-coyote conflict can be investigated.

Space is also important in other contexts. The relationship between objects in space (Kent, 2003) is of primary importance in geographical research. These relationships can be studied using temporal and spatial scales (Kent, 2003). Phillips (1999) suggests that these scales provide a viewpoint through which scientists can quantify the observations that they make. Kent (2003) provides examples where spatial scales, which include units such as plant communities, air masses and drainage basins, are fundamental to the field of biogeography, citing their recent success in the fields of biology and ecology. Alexander and Draper (2017) state that spatial relationships that form the geography of a space can heavily influence settlement patterns, community formation, and the location of various human subcultures on the land. In turn, these communities and subcultures play an important part in influencing how people view their role within the environment (Alexander and Draper, 2017).

3 Research Design and Study

3.1 Study Area

Alberta is currently divided into 6 natural regions and 21 subregions (Willoughby et al., 2020). Vegetation coverage in Alberta is diverse and each region and subregion is classified by its dominant plant communities (Willoughby et al., 2020). These plant communities are influenced by both environmental conditions and human activity (Willoughby et al., 2020).

The FCI study area is located within the Foothills Parkland Natural Subregion (FPR) (Alexander and Draper, 2019b) (Figure 1). The FPR in southern Alberta is one of Alberta's smallest natural areas (Alexander and Draper, 2019b). The FPR extends east from the Rocky Mountains alongside the foothills (Willoughby et al., 2020) to just west of Calgary, and runs north-south between Sundre and High River (Canid Conservation Science Lab, 2020). The FPR is bordered by the Montane Subregion in the south and the west, the Foothills Fescue Subregion in the east, and the Central Parkland and Lower Foothills Subregions in the north (Willoughby et al., 2020).

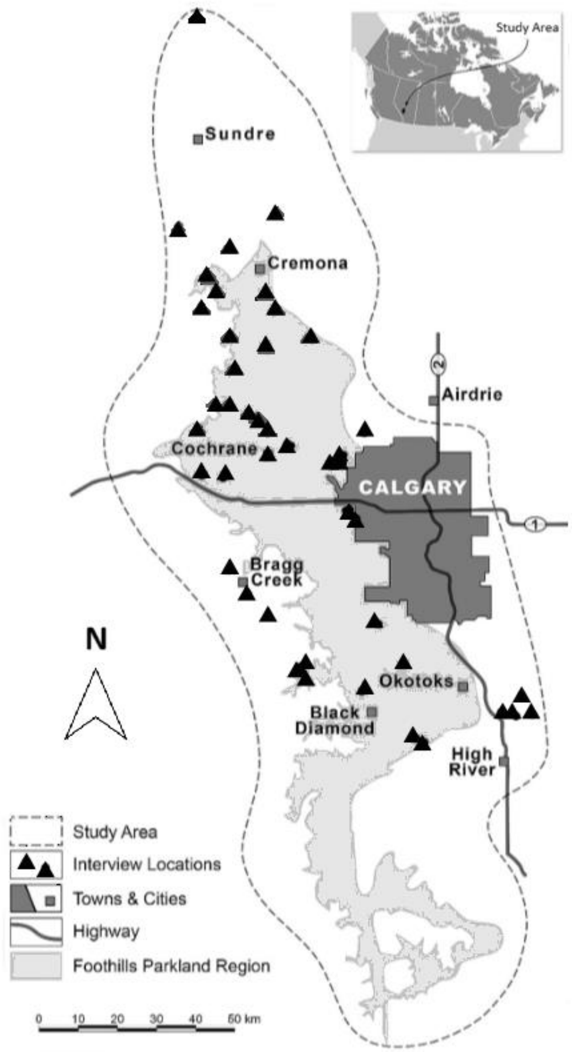

Figure 1: Foothills Coyote Initiative study area, located within the Foothills Parkland Natural Subregion of Alberta (modified from Alexander and Draper, 2019b)

The FPR occurs at relatively high elevations between 1025 m to 1400 m (Willoughby et al., 2020), with an average elevation of 1250 m (Alberta Parks, 2015). The landscape is dominated by rolling hills (Willoughby et al., 2020). The subregion is built on non-marine sandstones, mudstones, shales, calcareous till, and ice-contact glaciolacustrine sediments (Willoughby et al., 2020).

Compared with other subregions in the area, the FPR experiences cooler summers and warmer winters (mean annual temperature is 3°C), experiences more precipitation (391 – 1020 mm of precipitation per year, most occurring in May, June, and July) (Willoughby et al., 2020), and a shorter growing season (Alberta Parks, 2015; Willoughby et al., 2020).

The FPR represents a transitionary area between regions consisting of prairie grasslands, boreal forests, and montane forests (Willoughby et al., 2020). The FPR has more precipitation and cooler temperatures than the Foothills Fescue subregion and less precipitation and warmer temperatures than the Montane subregion, lending the subregion its characteristics as a transition area between the prairie grasslands and forests (Alberta Parks, 2015; Willoughby et al., 2020). The FPR's vegetation is classified into three broad categories, represented by the rough fescue grasslands, willow shrublands, and aspen woodlands (Willoughby et al., 2020). The plant community of the FPR is impacted strongly by climate cycles, fire, and herbivory (Willoughby et al., 2020).

While a comprehensive study detailing wildlife biodiversity in the FPR has not been conducted, it is expected that the subregion would be home to species representing its transitionary nature. This would include species found in Alberta's rough fescue grasslands, willow shrublands, and aspen woodland environments. Faunal species observed in the FPR by participants during this study (Alexander and Draper, 2015 – 2017) included: black bears, grizzly bears, cougars, wolves, lynx, bobcats, foxes, badgers, deer, elk, moose, owls, eagles (golden and bald), hawk(s), magpies, crows, ravens, mice/voles/moles, rabbits (hare), gophers (ground squirrel), weasels, squirrels (red/gray), muskrats, beavers, racoons, porcupines, skunks, marmots, pine martens, woodpeckers, chipmunks, prairie chickens (most likely misidentified as this species is considered to be extirpated in Alberta, (Ross et al., 2006), so this most likely refers to a different species of grouse), pheasants, sage grouse, blue herons, and ringneck pheasants.

The FPR provides important ecosystem services and resources for humans and wildlife, including watersheds, wildlife habitat, biodiversity benefits, rangelands, natural resource deposits, and recreation areas for hunting and camping (Willoughby et al., 2020). The short, cool summers and short growing season of the FPR means that the subregion does not have the right conditions for intensive agriculture, and instead extensive agriculture, hay, and feed crops are more common (Willoughby et al., 2020). Over 60% of the subregion is comprised of native rangelands or tame pasture, which is used for grazing livestock such as cattle (Willoughby et al., 2020).

While agriculture accounts for the largest land use in the subregion, the FPR is one of the fastest-urbanising areas in Canada (Alexander and Draper, 2019b). Over time, the FPR has been in the process of transitioning from a traditionally agricultural population to an increasingly urban population (Alexander and Draper, 2019b). Converting landscapes with native vegetation for agriculture, urbanisation, and other human uses has profound impacts on plant and animal biodiversity (Schieck et al., 2014). The population of species that rely on native vegetation decreases, while the population of species that can survive in human modified environments increases (Schieck et al., 2014). Understanding habitat change is therefore a crucial part of understanding what impacts these changes will have on biodiversity (Schieck et al., 2014). Furthermore, human impacts and shifting settlement patterns can result in an increase in human-animal interactions (Nyhus, 2016), including human-coyote interactions (Fox, 2006). This highlights a growing need to understand the factors that influence coexistence in urbanising areas.

3.2 Research Objectives and Hypotheses

Broadly, this research aims to explore the following questions by analysing interview data and geospatial variables previously collected and compiled by Alexander and Draper (2019b) as part of the Foothills Coyote Initiative (FCI). In reflection on results, I recommend actions to reduce coyote predation on livestock and pets and to mitigate the conditions that contribute to an increased acceptance of lethal coyote management methods. Based on my research, I created science communication materials to share important aspects of my research with the public. The four specific objectives and hypotheses I examined during this thesis are as follows:

Objective 1: Identify causal relationships between coexistence values (kill/no kill) and demographics, livestock and pet ownership, predation events, and geospatial factors.

Null Hypothesis 1 ($H_0$1): How people treat coyotes (kill vs no kill) is not related significantly to demographics (i.e. gender), livestock and pet ownership (i.e. livestock presence), predation events (i.e. livestock predation), or geospatial factors (i.e. road density).

Objective 2: Identify causal relationships between pet and/or livestock predation by coyotes and demographics, livestock and pet ownership, biodiversity, and geospatial factors.

Null Hypothesis 2 ($H_0$2): Pet and/or livestock predation by coyotes is not related significantly to demographics (i.e. gender), livestock and pet ownership (i.e. livestock presence), biodiversity (i.e. predator richness), or geospatial factors (i.e. road density).

Objective 3: Identify causal relationships between livestock predation by coyotes and demographics, livestock and pet ownership, biodiversity, and geospatial factors.

Null Hypothesis 3 (H_03): Livestock predation by coyotes is not related significantly to demographics (i.e. gender), livestock and pet ownership (i.e. livestock presence), biodiversity (i.e. predator richness), or geospatial factors (i.e. road density).

Objective 4: Provide public outreach and education materials, including infographics and videos.

4 Methods

4.1 FCI Interview Data Collection

The FCI Interview data represent 48 in-depth, in-person interviews conducted in situ by Alexander and Draper between 2015 – 2017 (for script, see Appendix). Interview respondents were selected using purposive (non-probability approach where the researcher selects participants, based on the PI's involvement in the communities) and snowball sampling techniques (initial participants recommend further participants, based on who they felt would provide valuable information to the study) (Morgan, 2008) to ensure that sampling occurred across both target groups; rural residential (<20 acres and/or no livestock) and agricultural (>20 acres with livestock) landowners (Alexander and Draper, 2019b). Two participants were selected using the purposive approach and two additional participants approached the PIs after seeing advertising for the project (Alexander and Draper, 2019a). The four participants recommended 41 additional participants via the snowball sampling technique (Alexander and Draper, 2019b). In total, 60 individuals were interviewed across the 48 interviews (some interviews involved two individuals, responding as a couple), comprised of 33 males and 27 females (Alexander and Draper, 2019a). The median age of participants was >25 years (Alexander and Draper, 2019b).

Interviews typically occurred in the participant's homes and followed a pre-prepared questionnaire (Appendix A) (Alexander and Draper, 2019b). The interviews took approximately an hour and a half to complete (Alexander and Draper, 2019b). The questionnaire used closed and open-ended questions (Alexander and Draper, 2019b) and was designed to collect both numeric and descriptive information and displays a range of data on the attitudes, values, and perceptions of the participants toward coyotes as well as basic demographic data, all of which can be spatially tagged on a map (Alexander and Draper, 2019b).

4.2 Dependent Variables

During the FCI Interviews, participants had the opportunity to answer several open-ended questions regarding their experiences with and feelings toward coyotes on their property. If participants indicated that they had ever killed or had someone else kill a coyote on their property, or that they would be willing to kill a coyote on their property, this was recorded in the database. I coded participants who had killed any number of coyotes on their property or would be willing to kill a coyote on their property with a value of 1; participants who had not killed or had anyone kill any coyotes on their property were assigned a value of 0. This coexistence value was the dependent variable used in testing hypothesis 1.

The interviews included questions regarding whether participants had witnessed or suspected predation on livestock and/or pets by coyotes on their property. I coded participants who had experienced pet and/or livestock predation by coyotes on their property with a value of 1; participants who had not experienced any kind of predation by coyotes on their property were assigned a value of 0. This dependent value was used in hypothesis 2.

The interviews also included questions regarding whether participants had witnessed, or suspected, predation specifically on livestock on their property. I coded participants who had experienced livestock predation by coyotes on their property with a value of 1; participants who had not experienced livestock predation by coyotes on their property were assigned a value of 0. This coded dependent data was used to test hypothesis 3.

4.3 Independent Variables Summary

The independent variables used in each hypothesis were selected based on a review of the literature, where I identified factors likely to influence coexistence values and predation, as well as through discussions with my supervisor (Dr. Shelley Alexander), which provided additional insights into the relevant variables for the study. A complete list of the variables selected for analysis and their descriptions are summarized in Table 1.

Table 1: A complete list of the independent variables analysed in this thesis and their definitions.

Variable	**Description**
Gender	What gender participants identified as (male, female, or couple)
Property Size	Property size of participants (measured in acres)
Time In Situ	Number of years participants had lived on their property
Education Class	Level of education achieved by participants (no high school diploma, high school diploma, college degree or diploma, or university degree)
From Study Site	Whether or not participants had grown up within the study area
Livestock Number*	Number of cattle, sheep, and horses owned by participants
Livestock Presence*	Whether or not participants owned one or more cattle, sheep, and horses
Other Livestock Presence*	Whether or not participants owned one or more other livestock species including: bison, pigs, goats, chickens, alpacas, donkeys, llamas, rabbits, partridges, and peacocks
Overall Livestock Presence	Whether or not participants owned one or more kind of livestock
Dogs	Whether or not participants owned dogs
Cat Presence**	Whether or not participants owned one or more house cats and barn cats
Pets on Property	Whether or not participants owned one or more pets (dogs, house cats, and barn cats)
Guard Animals	Whether or not participants owned one or more guard animals (guard dogs and guard donkeys)
Calf or Cow Killed	Whether or not participants had experienced predation on cows or calves by coyotes on their property
Pet Predation*	Whether or not participants had experienced predation on dogs, house cats, or barn cats by coyotes on their property
Livestock Predation	Whether or not participants had experienced predation on any livestock by coyotes on their property
Any Predation	Whether or not participants had experienced predation on any pets and/or livestock by coyotes on their property

Vegetation Change***	Significant change in vegetation over the past 5 years within 100 m, 400 m, and 15,000 m of participant's homes
Tree Cover***	Percent tree cover within 100 m, 400 m, and 15,000 m of participant's homes
Forest Cover***	Percentage forest cover within 100 m and 400 m of participants homes
Distance to Change	Euclidean distance from participant's residence to landscape change
Distance to Water	Euclidean distance from participant's residence to water
Road Density	The density of roads on participant's property, measured as road distance divided by property size (km/km^2)
Terrain Ruggedness Index	Change in elevation on the property (measured by terrain ruggedness index based on 30 by 30 metre plots within properties)
Species Richness*	Number of predator species, prey species, ungulate species, small prey species, and total number of species seen on the property

* These species were analyzed separately.

** House cats, barn cats, and all cats were analyzed.

*** These buffer distances were analyzed separately

4.4 Demographic Variables

The demographic variables (Table 2) was derived from demographic data collected during the FCI interviews and included data on participant gender, how many years participants had lived in the study area, participant education level, and whether participants were originally from the study site or if they had moved to the site from another location.

Table 2: Coding of the Demographic Variables

Variable	Description
Gender	Participants identified as either male or female. There were also instances where a couple (one male and one female) participated in the interview together. I assigned each possible response (male, female, couple) a number from 0-2. I coded the gender classes as follows: male = 0, female = 1, couple = 2.
Time In Situ	Participants were asked how many years they have lived on their property. I used these values for the time in situ variable.
Education Class	Participants were asked about the highest level of education they had received. When a couple participated in the interview, the highest education level received between both participants was recorded. I assigned each education class a number from 0-3 corresponding with the recorded highest level of education received and coded the classes as follows: no high school diploma = 0, high school diploma = 1, college degree or diploma = 2, and university degree = 3).
From Study Site	Participants were asked whether they had grown up within the study area. I coded whether participants had grown up within the study area as a binary variable, where participants who grew up within the study area = 1, and participants who did not grow up within the study area = 0.

4.5 Livestock and Pet Variables

This group of independent variables (Table 3) was derived from the interviews and included: pets (dogs, house cats, and barn cats), livestock (cattle, sheep, horses, bison, pigs, goats, chickens, alpacas, donkeys, llamas, rabbits, partridges, and peacocks), and the presence of guard or herding animals.

The livestock information included data on which species of livestock the participants owned, how many individuals of each species were owned, and presence and absence data for different livestock species. Pet data included information on whether participants owned dogs, house cats, and/or barn cats. I also examined whether participants owned guard animals, including guard dogs or donkeys.

Table 3: Coding of the Livestock and Pet Variables

Variable	**Description**
Livestock Number	Participants were asked how many cattle, sheep, and horses they were currently raising on their property. I used these values for the livestock number variables.
Livestock Presence	Using the livestock number variables, I created binary variables for livestock presence. If participants were not raising cattle, sheep, or horses, I coded these values = 0, and if they were raising them, I coded these values =1
Other Livestock Presence	Participants were asked what other kinds of livestock they were raising on their property besides cattle, sheep, and horses. If participants were not raising other livestock, I coded this value = 0, and if they were raising other livestock, I coded this value =1.
Overall Livestock Presence	If participants were raising at least one of any kind of livestock, I coded this value = 1, and if they were not raising any livestock, I coded this value as = 0.
Dogs	Participants reported whether they owned any dogs that lived on their property. If participants did not own any dogs, I coded this value as = 0, and if they owned dogs, I coded this value =1.
Cat Presence	Participants reported whether they owned any house or barn cats. If participants did not own any cats, I coded this value as = 0, and if they owned cats, I coded this value =1.
Pets on Property	Using the variables for dogs and cat presence, I created a binary variable to describe whether there were any pets on the properties. If participants did not own any pets, I coded this value a= 0, and if they owned any pets, I coded this value =1.
Guard Animals	Participants reported whether they owned any guard animals on their properties. If participants did not own any guard animals, I coded this value as = 0, and if they owned guard animals, I coded this value =1.

Note: For individual variables, see Table 1.

4.6 Predation Event Variables

Predator events (Table 4) were derived from interview responses that confirmed whether calves, cows, livestock, or pets had ever been killed by coyotes on their property. The intent of these variables was to determine whether participants' willingness to kill coyotes is linked to their belief that coyotes have killed animals on their property, so suspected predation events are included in the variable results.

Table 4: Coding of the Predation Event Variables

Variable	Description
Calf or Cow Killed	Participants reported whether they believed that either cows or calves had been killed by coyotes on their property (predation events). If participants did not report any calf or cow predation events, I coded this value as = 0, and if they reported any calf or cow predation events, I coded this value =1.
Pet Predation	Participants reported whether they believed that pets, including dogs, house cats, or barn cats, had been killed by coyotes on their property. If participants did not report any pet predation events, I coded this value as = 0, and if they reported any pet predation events, I coded this value =1.
Livestock Predation	Participants reported whether they believed that any kind of livestock had been killed by coyotes on their property. If participants did not report any livestock predation events, I coded this value as = 0, and if they reported any livestock predation events, I coded this value =1.
Any Predation	Participants reported whether they believed that any pets and/or livestock had been killed by coyotes on their property. If participants did not report any pet and/or livestock predation events, I coded this value as = 0, and if they reported any pet and/or livestock predation events I coded this value =1.

Note: For individual variables, see Table 1.

4.7 Biodiversity Checklist Variables

Biodiversity of other species may impact coyote diet (Bekoff and Gese, 2003; Prugh, 2005; Levi and Wilmers, 2012). For example, prairie dogs and Richardson's ground squirrels are a preferred food source for coyotes in Grasslands National Park from spring to fall (Lingle et al., 2022). These species hibernate in the winter, creating a seasonal shift in coyote diet towards deer (Lingle et al., 2022). Wild prey availability has also been observed to impact livestock predation by coyotes (Sacks and Neale, 2007). For example, in California, Sacks and Neale (2007) found that predation on sheep decreased when there was a higher availability of wild prey. Thus, understanding local biodiversity may also provide insights into predation at the FCI.

Biodiversity checklists were completed by respondents as part of the FCI Interviews (Alexander and Draper, 2019a). In this portion of the interview, participants were provided with a list of mammal and bird species commonly found in the study area and were asked to identify which species of animals they had encountered on their property within the past five years. Participants were also given the chance to include species they had seen that were not included on the list. The species included on the list were: black bear, grizzly bear, cougar, wolf, lynx, bobcat, fox, badger, deer, elk, moose, owls, eagles (golden or bald), hawk(s), magpies, crows, ravens, mice/voles/moles, rabbits (hare), gophers (ground squirrel), weasel, and squirrel (red/gray). Additional species listed by some of the participants included: muskrat, beaver, racoon, porcupine, skunks, marmots, pine martens, woodpeckers, chipmunks, prairie chickens, pheasants, sage grouse, blue heron, and ringneck pheasant.

To determine species richness (total number of species), I created five categories for analysis. These categories included predator species richness, prey species richness, ungulate species richness, small prey species richness, and total species richness. Predator species from the biodiversity checklist included: black bears, grizzly bears, cougars, wolves, lynx, bobcats, foxes, badgers, owls, eagles, hawks, ravens, crows, and weasels. Prey species included: deer, elk, moose, mice/voles, rabbits (hare), gophers (ground squirrels), red/grey squirrels, muskrats, and beavers. Ungulate species included: deer, elk, and moose. Small prey species included: mice/voles, rabbits (hare), gophers (ground squirrels), red/grey squirrels, muskrats, and beavers. The total species richness included all species reported by participants on each property.

4.8 Geospatial Variables

Independent variables that relate to the environment (and space) were called geospatial variables (Table 5). The property size variable was derived from data collected during the FCI interviews. A Geographic Information System (GIS) and various forms of Remotely Sensed data were used to determine the remainder. I used a geospatial database that was created previously for Alexander and Draper (2019b), using ArcGIS Basemap Imagery, Landsat images, hydrology data, and highway data from the Alberta government data (AB_Hydrology and AB_HWY) (Alexander and Draper, unpublished data). Geospatial variables used in the analysis (Table 5) were derived based on their potential to impact either coexistence values or livestock and pet predation, as discussed in the literature review.

Vegetation and land use data were created using a 2015 Landsat 8 OLI Image, obtained from the U.S. Geological Survey Earth Explorer (https://earthexplorer.usgs.gov/) on November 3, 2017. The FCI maps used the NAD83 datum with a 10TM projection.

Relevant variables were estimated in a GIS within 100 m, 400 m, and 15,000 m buffers surrounding each of the participant's homes (for example Tree Cover within 100 m). These data were derived using buffer algorithms in ArcGIS, based on the Euclidean distance from the residences to the specified type of landscape or landscape change. Personal experience was used to establish the different scales of coyote activity. The chosen distances may be associated with the size of den sites (100 m), core use areas (400 m), and home range (15,000 m).

Table 5: Coding of the Geospatial Variables

Variable	**Description**
Property Size	Properties included any homes, buildings, and land belonging to each participant. I used these reported measurements as the property size variables in acres.
Vegetation Change	These variables were derived from Landsat 7 ETM+ and Landsat 8 OLI images. These variables were derived by pixel differencing of NDVI images (2004 and 2015). The output raster was reclassified to reflect changes in vegetation (positive change, no change, negative change). Using buffer sizes of 100 m, 400 m, and 15,000 m, the number of cells that were classified as experiencing change (positive or negative) were calculated, and the percentage of cells that had experienced change was calculated and extracted. In my research, I used the extracted values to determine the percent change of vegetation cover for each residence/buffer.
Tree Cover	These variables were derived from a classified Landsat 8 OLI image (2015). The land cover categories were water, coniferous forest, mixed forest, field-like vegetation, rock or concrete, bare ground, or urban features. The mixed forest and coniferous forest feature classes were aggregated to produce a raster with an aggregated class representing tree canopy cover. These variables describe the percentage of the landscape that is covered by trees within 100 m, 400 m, and 15,000 m from each residence. I used the extracted values to determine the percent of tree coverage for each residence/buffer.
Forest Cover	These variables were derived from a classified Landsat 8 OLI image (2015). These variables describe the percentage of the landscape that is covered by forest within 100 m and 400 m from each residence. The forest cover variable relates to the extent of the tree cover in the raster discussed above. Using the tree cover raster, adjacent cells with tree cover (tree cover cells where at least one of the eight adjacent cells surrounding it were also classified as tree cover) were calculated and compared to a threshold to determine which

	connected cells should be classified as having forest cover. Within each buffer, the number of cells classified as forest were calculated, which allowed for the percentage of forest cover to be calculated and extracted. I used the extracted values to determine the percent of forest coverage for each residence/buffer.
Distance to Change	This variable measures the Euclidean distance from each residence to areas on their land that have undergone high change in vegetation cover (>50% cover change) within the past 5 years. Using the same process outlined in the vegetation change variable above, the change in vegetation between 2010 and 2015 was calculated. This vegetation change raster was fitted over the study site along with the residences, and the Euclidean distance from each residence to the nearest cell with a change in vegetation was calculated.
Distance to Water	This variable describes the distance from each residence to the nearest body of water. Water bodies were classified using the land cover map also used to determine the "Tree Cover" variable above. This water raster was fitted over the study site along with the residences, and the Euclidean distance from each residence to the nearest cell containing water was calculated.
Road Density	This variable measures the density of roads (length of roads (km) per each km^2) on properties. Data about roads, including locations and lengths, was derived using a digital map sourced from Alberta government records (AB_HWY). The vector road layer was fitted over the study site along with the property size polygons associated with each property. Using these layers, a line density tool was used to calculate the length of roads/km^2 within each property.
Terrain Ruggedness Index	This variable measures the amount of elevation difference between adjacent cells, or the ruggedness, on each property. A Digital Elevation Model (DEM) (Aster Global Digital Elevation Model, obtained on February 2, 2017 from http://earthexplorer.usgs.gov) was used to generate a raster Terrain Ruggedness Index (TRI) layer. The TRI layer contained information about the elevation difference between each cell and the eight adjacent cells surrounding it. Each cell in the TRI contained a value between 0-4367, which corresponded to the ruggedness of the adjacent cells as follows (ESRI Analytics Team, 2020): 0-80 m (level surface), 81-116 (nearly level surface), 117-161 (slightly rugged surface), 162-239 (intermediately rugged surface),

	240-497 (moderately rugged surface), 498-958 (highly rugged surface), and 959-4367 (extremely rugged surface). The raster TRI layer was fitted over the study site along with the property size polygons. The average TRI values within each property were calculated.

Note: For individual variables, see Table 1.

4.9 Science Communication Materials

I created three science communication materials to be shared with researchers and the public – one infographic and two short videos. These materials include:

1. **Infographic – Benefits Provided by Coyotes:** I created an infographic (Figure 17 in the Results section to view the infographic) to visualise and communicate some of the benefits that coyotes have on humans and the environment. The infographic uses information collected during the literature review on coyote diet (Bekoff and Gese, 2003; Lukasik and Alexander, 2012), the impacts of coyotes on bird biodiversity (Crooks and Soulé, 1999), and the impacts of biodiversity on ecosystems services (Díaz, 2006; Sandifer et al., 2015). The infographic was created in Canva using stock images (Canva Free Content License, Canva Pro Content License, and Pixabay Free Content Licence via Canva).
2. **Video – *Wild* (Dickson, 2024)**: I created a short video entitled *Wild* to communicate about the research conducted by the FCI and to discuss the importance of coyotes to people and the environment. This video uses information that was collected during the literature review on the FCI, biodiversity information (Crooks and Soulé, 1999; Díaz, 2006; Sandifer et al., 2015), coyote ecology and behaviour (Bekoff and Gese, 2003; Fox, 2006), lethal management (Fox, 2006) and the impact of values on human-wildlife interactions (Alexander and Draper, 2019a). The video was created in OpenShot Video

Editor. For the visuals in *Wild*, I used a combination of footage I captured on my phone's camera, combined with stock images and stock videos. I recorded a voiceover using my phone, which accompanies the visual elements.

3. **Video – *Birdy* (Dickson, 2023):** I created a short video entitled *Birdy* to communicate how introducing the public to birdwatching may promote coexistence with coyotes and foster connections with nature. The video uses information collected during the literature review on biodiversity (Díaz, 2006; Sandifer et al., 2015), human-coyote conflict (Fox, 2006) and the impact of values on human-wildlife interactions (Alexander and Draper, 2019a). The video was created in OpenShot Video Editor. For the visuals in *Birdy*, I used a combination of footage I captured on my phone's camera, combined with stock images and stock videos. I recorded a voiceover using my phone and added royalty free music from Bensound, which accompanied the visual elements.

4.10 Statistical Analysis

4.10.1 Descriptive Statistics

I used descriptive statistics to visualize and communicate relationships within the data (Nick, 2007). These data were derived from the data collected during the FCI Interviews (Table 1). I used Microsoft Excel to create pie charts, a bar graph, and a histogram. Pie charts were used to compare proportions of two or more groups and the bars chart and histogram were used to display frequency distributions of data. All values have been rounded to the nearest whole number. The descriptive statistics I used are described in Table 6.

Table 6: Descriptive Statistics

Descriptive Statistic	Description
Gender of Participants (%): (Figure 2)	Illustrates the proportion of participants who were male, female, or who responded as a couple, using data for all participants. To prevent having more participants than questionnaires, if both a male and female responded together on the same questionnaire, they were categorized as a couple, instead of being counted as one male and one female participant.
Time in Situ (%): (Figure 3)	Illustrates how long participants had lived on site, using data for all participants. The participant data was grouped into two categories, which were defined according to Ahearn (2011) as either beginning (<10 years in situ) or experienced (10+ years in situ).
Property Size (acres): (Figure 4)	Illustrates the property sizes of participants, using data for all participants. The property size was grouped into six categories representing the following ranges: 0-20 acres, 21-100 acres, 101-320 acres, 321-640 acres, 1000-3600 acres, 12,000+ acres.
Livestock Ownership (%): (Figure 5)	Illustrates the proportion of participants who owned livestock compared with the proportion of participants who did not own livestock, using data for all participants.
Coexistence values amongst all participants (%): (Figure 6)	Illustrates the proportion of participants that had killed or would be willing to kill coyotes on their property, compared with the proportion of participants who had not killed or would not be willing to kill coyotes on their property. I used data for all participants.
Experiences of any predation amongst participants who kill coyotes (%): (Figure 7)	Illustrates the proportion of participants that had experienced pet and/or livestock predation compared with the proportion of participants who had not experienced pet and/or livestock predation, from the subset of participants who kill or would be willing to kill coyotes.
Experiences of predation amongst all participants (%): (Figure 8)	Illustrates the proportion of participants that had experienced pet and/or livestock predation compared with the proportion of participants who had not experienced pet and/or livestock predation, using data for all participants.
Experiences of livestock predation amongst participants who have	Illustrates how many participants had experienced livestock predation compared with how many participants had not experienced livestock

experienced any predation (%): (Figure 9)	predation, from the subset of all participants who have experienced some form of predation.
Experiences of pet predation amongst participants who have experienced any predation (%): (Figure 10)	Illustrates how many participants had experienced pet predation compared with how many participants had not experienced pet predation, from the subset of all participants who have experienced some form of predation.
Experiences of cattle predation amongst participants who have experienced any predation (%): (Figure 11)	Illustrates how many participants had experienced cattle predation compared with how many participants had not experienced cattle predation, from the subset of all participants who have experienced some form of predation.
Coexistence Values Amongst Male Participants (%): (Figure 12)	Illustrates how many male participants had killed or would be willing to kill coyotes on their property, compared with how many male participants had not killed or would not be willing to kill coyotes on their property. I used data for all male participants.
Coexistence Values Amongst Female Participants (%): (Figure 13)	Illustrates how many female participants had killed or would be willing to kill coyotes on their property, compared with how many female participants had not killed or would not be willing to kill coyotes on their property. I used data for all female participants.
Experiences of any predation amongst male participants who kill coyotes (%): (Figure 14)	Illustrates how many male participants had experienced pet and/or livestock predation compared with how many male participants had not experienced pet and/or livestock predation, from the subset of male participants who kill or would be willing to kill coyotes.
Experiences of any predation amongst female participants who kill coyotes (%): (Figure 15)	Illustrates how many female participants had experienced pet and/or livestock predation compared with how many female participants had not experienced pet and/or livestock predation, from the subset of female participants who kill or would be willing to kill coyotes.

Tree cover within 100 m of residences (% range): (Figure 16)	Illustrates the frequency of different amounts of tree cover within 100 m of each residence, using data for all participants. The amount of tree cover, measured as a percentage (%), was grouped into four intervals representing the following ranges: 0-23%, 23-46%, 46-69%, and 69-92%. I chose to use four intervals using a manual breaks method.

4.10.2 Inferential Statistics

A statistical model approach was used to describe patterns in the data according to each of my three null hypotheses:

1. How people treat coyotes (kill vs no kill) is not related significantly to demographic factors (i.e. gender), livestock and pet ownership factors (i.e. livestock presence), predation events (i.e. livestock predation) or geospatial factors (i.e. road density).
2. Pet and/or livestock predation by coyotes is not related significantly to demographic factors (i.e. gender), livestock and pet ownership factors (i.e. livestock presence), biodiversity factors (i.e. predator richness), or geospatial factors (i.e. road density).
3. Livestock predation by coyotes is not related significantly to demographic factors (i.e. gender), livestock and pet ownership factors (i.e. livestock presence), biodiversity factors (i.e. predator richness), or geospatial factors (i.e. road density).

Before analysing the data, I derived and coded data from the FCI Database and stored these data in a spreadsheet (using Microsoft Excel). The data were coded as discussed earlier in the methods section. I standardized the data by checking for missing values, formatting each variable in a consistent way, and making sure that each variable had the same data type. Once the data were prepared for analysis, I followed a similar workflow to analyse the data for each of the three hypotheses.

A common approach to describing whether there are significant relationships between a response variable and multiple explanatory variables is to use multivariate regression methods, such as logistic regression (Hosmer et al., 2013). Logistic regression fits well with hypotheses that evaluate the impact of multiple independent variables on binary dependent variables, and logistic regression is often used for ecological data (Salas-Eljatib et al., 2018). Given that my dependent variable for each hypothesis is binary, and each hypothesis has multiple independent variables, I selected a logistic regression to evaluate my hypotheses.

Logistic regression relies on the assumption that multicollinearity is not present between the independent variables (Stoltzfus, 2011). This multicollinearity occurs when two or more independent variables experience a high correlation with each other (Bayman and Dexter, 2021; Kim, 2019). Furthermore, having multicollinearity within a dataset makes it difficult to interpret the relationships between the independent variables and the dependent variable (Ranganathan et al., 2017; Bayman and Dexter, 2021), can mask significant variables by causing them to appear insignificant (Shrestha, 2020), and can result in incorrect interpretation of the p-values used to determine statistical significance (Vatcheva et al., 2016). A simple way to remove multicollinearity from a dataset consists of identifying instances of multicollinearity and removing some of these variables, so that the variables that remain are not affected (Bayman and Dexter, 2021).

To identify multicollinearity, it is standard practice to use statistical tests to check data for correlation (Ranganathan et al., 2017; Shrestha, 2020). A Pearson’s correlation test is commonly used to measure a linear correlation, which is the correlation between two variables (Akoglu, 2018; Ly et al., 2018; Kent State University Libraries, 2023). Pearson’s correlation was also a good fit for this dataset, which was composed of interval and ratio data, was not missing any values, and was normally distributed (Kent State University Libraries, 2023). It should be noted that despite testing this data for normal distribution, there is debate in the field regarding whether this is necessary for Pearson's correlation tests (Nefzger and Drasgow, 1957).

Using Pearson's correlation, I created correlation matrices containing all the dependent and independent variables I was evaluating for each hypothesis. The independent and dependent variables that were analysed in hypothesis 1 are shown in Table 7.

I conducted all analyses in R Studio Statistical Environment using R version 4.1.1 "Kick Things" (R Core Team, 2021). SPSS (Statistical Package for the Social Sciences) and R are two statistical analysis tools used in academia and industry. Both tools are reliable for performing statistical analyses (International Business Machines Corporation, 2025a). SPSS is often viewed as being less intimidating to learn, especially by learners who do not have a coding background (Rode and Ringel, 2019). However, SPSS requires a subscription to use (International Business Machines Corporation, 2025b) and may be cost prohibitive for many users (Larson-Hall and Mizumoto, 2019). R is open-source and free to use (R Foundation, 2025). It can also handle more complex statistical analysis than SPSS (Larson-Hall and Mizumoto, 2019; International Business Machines Corporation, 2025a). R has been demonstrated to have the same accuracy as SPSS and has been recommended for classroom use to help students better understand statistics basics (Larson-Hall and Mizumoto, 2019). As someone who did not have much exposure to inferential statistics and wanted to gain a stronger understanding of the basics, and who also had prior experience with other coding software (C++ and Python), I chose to use R. The book *Getting Started with R: An Introduction for Biologists* (Beckerman et al., 2017) was particularly helpful while teaching myself to use R, as well as the many valuable conversations I had with professionals in the field of statistics. While learning R was time consuming at the beginning of my project, I feel that the statistics knowledge and programming skills I learned during this process will be worthwhile during my future research endeavours.

Table 7: Hypothesis 1 – Dependent and independent variables used to test whether people kill or coexist with coyotes.

Dependent Variable	Independent Variables
Kill/ No Kill	Property Size; Gender; Time in Situ; Education Class; From Study Site; Livestock Number; Livestock Presence; Other Livestock Presence; Overall Livestock Presence; Dogs; Cat Presence; Pets on Property; Guard Animals; Calf or Cow Killed; Pet Predation; Livestock Predation; Any Predation

The independent and dependent variables that were analysed in hypothesis 2 and hypothesis 3 are shown in Table 8.

Table 8: Hypothesis 2 and 3 – Dependent and independent variables used to test whether pets and/or livestock experience predation by coyotes.

Dependent Variables	Independent Variables
Any Predation Livestock Predation	Property Size; Vegetation Change; Tree Cover; Forest Cover; Distance to Change; Distance to Water; Road Density; Terrain Ruggedness Index; Species Richness; Livestock Number (cattle); Livestock Presence; Other Livestock Presence; Overall Livestock Presence; Dogs; Cat Presence (house or barn); Guard Animals; Time in Situ; From Study Site

My correlation matrices outputted p-values, which represent the likelihood that a correlation of the strength of Pearson's *r* would occur if the variables were unrelated. The p-values in a Pearson's correlation represent whether each of the correlations between variables are statistically significant (Kent State University Libraries, 2023) and are often used to interpret correlations in data (Woolley, 2003). To determine significant correlations within my dataset, I relied on the most commonly use standard value of $p < 0.05$, suggesting that the correlation did not occur by random chance, with a $p < 0.06$ category suggesting that the variables might still be marginally correlated (Thiese et al., 2016).

For each hypothesis, I created a list containing the pairs of correlated variables from the correlation matrices. To determine which of the correlated variables should be removed from my analyses, I used a univariate logistic regression test to determine which of the variables was the strongest predictor of each of my dependent variables (Stoltzfus, 2011; Ranganathan et al., 2017). The univariate logistic regression tests outputted p-values. I compared the p-values for each variable in the pairs of correlated variables and removed one from each pair by keeping the lowest (most significant) p-values. As many of the variables within my dataset demonstrated correlations, I started with pairs with the lowest p-values (strongest predictors) and moved up the pairs with higher p-values (weaker predictors) to ensure that the stronger predictors were not prematurely removed, and that the data was processed consistently (Stoltzfus, 2011). After removing the correlated variables, I was left with a list of non-correlated variables for each hypothesis. As discussed previously, this step was important as removing highly correlated variables is important to correctly interpreting statistical significance.

I used the lists of non-correlated variables and their associated p-values, determined previously using univariate logistic regression, for model selection (Ranganathan et al., 2017).

For each hypothesis, I created models based on the industry standard for significance ($p < 0.05$) as well as expanded p-value thresholds ($p < 0.07$ and $p < 0.2$) to account for other potentially significant variables (McShane et al., 2019). Although larger p-values generally suggest less statistical significance, smaller sample sizes (Gómez-de-Mariscal et al., 2021) and data with more variables (Thiese et al., 2016) can have larger p-values. Previous research has also found that increasing the p-value threshold is helpful in cases where there may be an information bias, such as asking participants to recall information, and/or a selection bias, where certain individuals are more likely to volunteer to participate in a study (Thiese et al., 2016). I used the p-values from the univariate logistic regression tests to assign variables to each model: if their p-value fit into one of the three categories ($p<0.05$, $p<0.07$, $p<0.2$), that variable was assigned to that model (Ranganathan et al., 2017). Once the models were built, I checked each model for multicollinearity using the Variance Inflation Factor (Akinwande et al., 2015). After determining that there was no multicollinearity, I used a logistic regression to determine the final model statistics: these included the p-values, as well as the unstandardized beta coefficients (which illustrates the strength and direction of the relationship between the predictor variable and the dependent variable (Stoltzfus, 2011), for each variable in the models. The results from the logistic regression analyses are discussed in the next section.

5 Results

5.1 Study Group

Of the 48 interviews conducted for the study, the largest group of respondents was males (44%), followed by females (31%) (Figure 2). One quarter (25%) of the respondents answered together as a couple (male and female) (Figure 2). Most of the respondents (73%) had lived within the study area for over 10 years (Figure 3), with the shortest time of residence being 1 year, and the longest time of residence being 63 years. Property sizes ranged from 2 acres to 12,000 acres, with property sizes between 0-20 acres and 101-320 acres occurring most frequently (Figure 4). Property sizes were classified into six categories determined according to the expert knowledge of the FCI researchers (Alexander and Draper, FCI): 0-20 acres, 21-100 acres, 101-320 acres, 321-640 acres, 1000-3600 acres, and 12,000+ acres. The first category, 0-20 acres, represented the rural residential participants, while the five other categories represented the agricultural participants. None of the participants had property sizes between 3600-12,000 acres, so this category was not included in Figure 4. Three-quarters (75%) of participants owned at least one kind of livestock, which could include cattle, sheep, horses, and/or other livestock species (Figure 5).

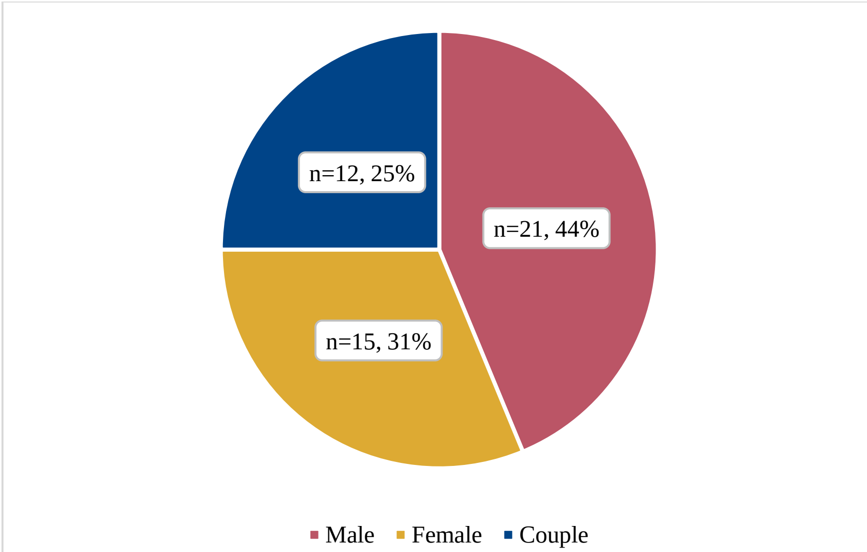

Figure 2: Percentage of participants that identified as male, female, or interviewed together as a couple.

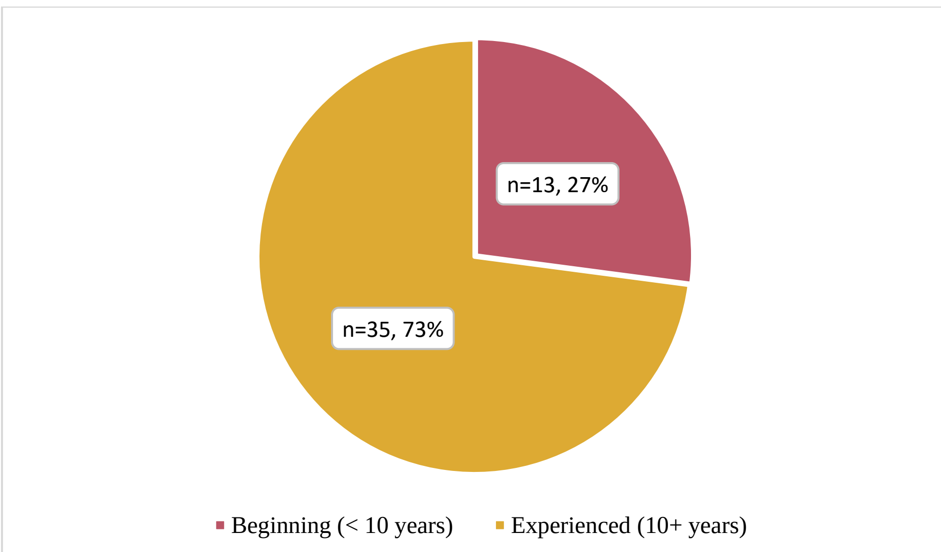

Figure 3: Length of time participants had lived in the study area in years.

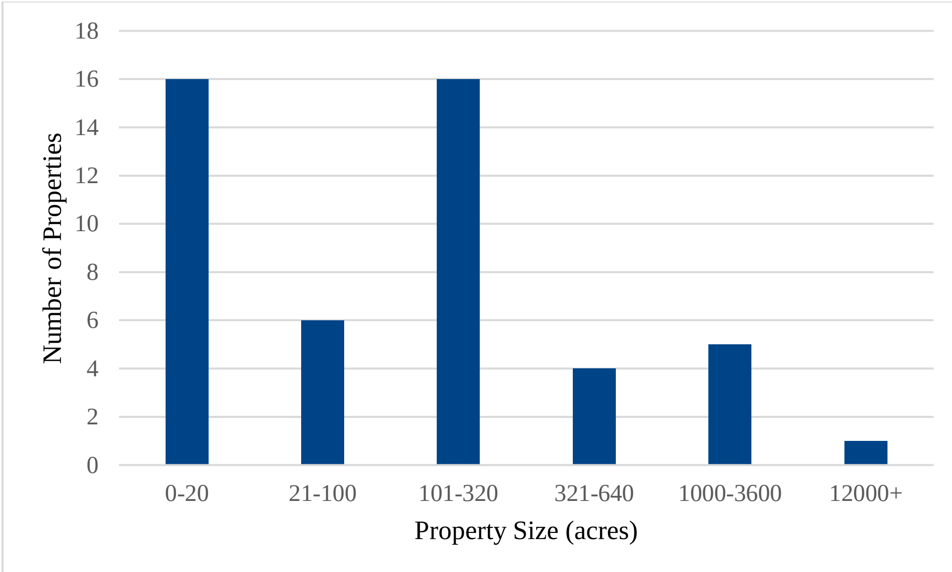

Figure 4: Size of properties owned by study participants.

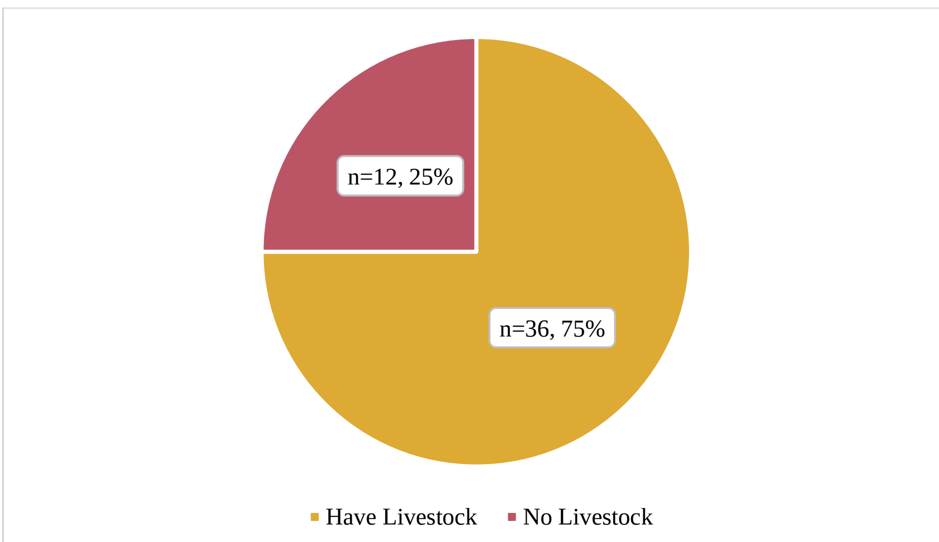

Figure 5: Percent of participants who owned livestock vs those who do not own livestock.

5.2 Hypothesis 1 – Coexistence Values

More than half (65%) of all the participants in the study group have either killed coyotes on their property before or would be willing to kill coyotes on their property (Figure 6). Of the participants who kill/are willing to kill coyotes, 74% have witnessed livestock and/or pet predation (Figure 7). When looking at the data for all participants, which includes people both people who kill coyotes and people who don't kill coyotes, 60% have experienced predation (Figure 8).

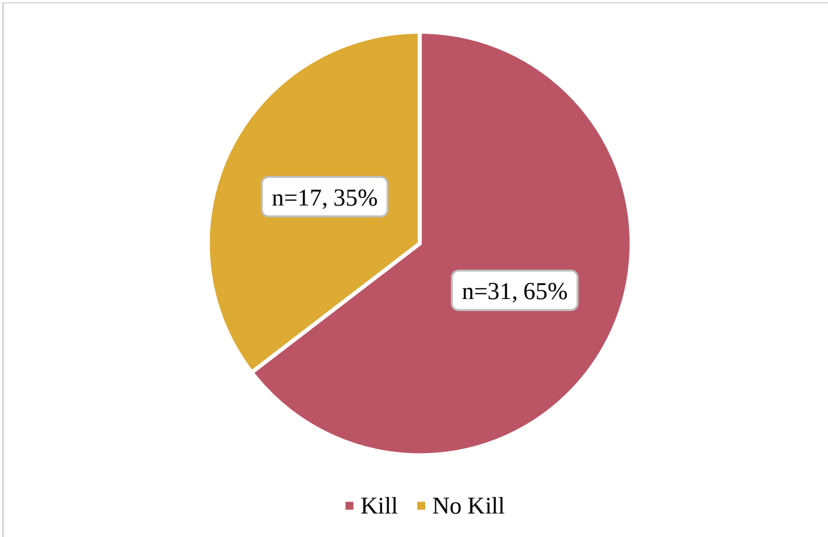

Figure 6: Percent of participants who had killed coyotes and/or were willing to kill coyotes on their property vs. those who had not killed coyotes and were not willing to kill coyotes on their property.

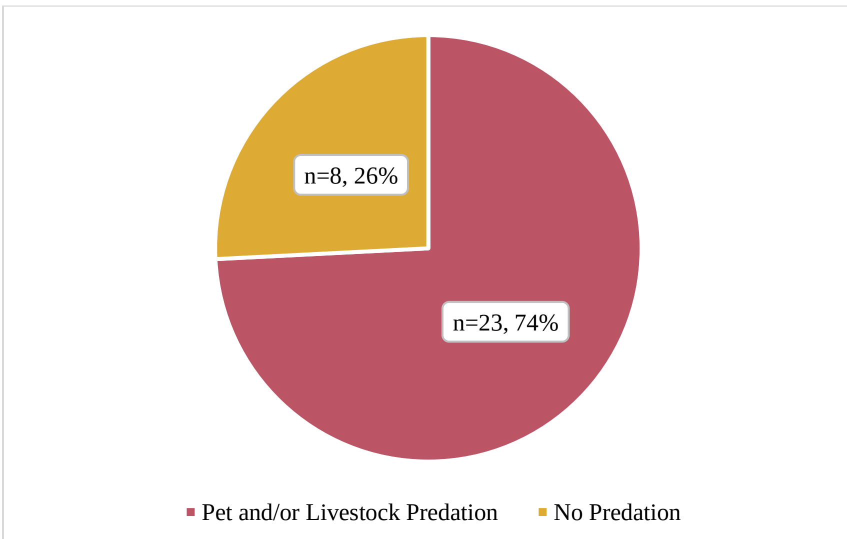

Figure 7: Of the participants who had killed coyotes and/or were willing to kill coyotes (n=31), percent of participants who had experienced pet and/or livestock predation vs those who had not experienced pet and/or livestock predation.

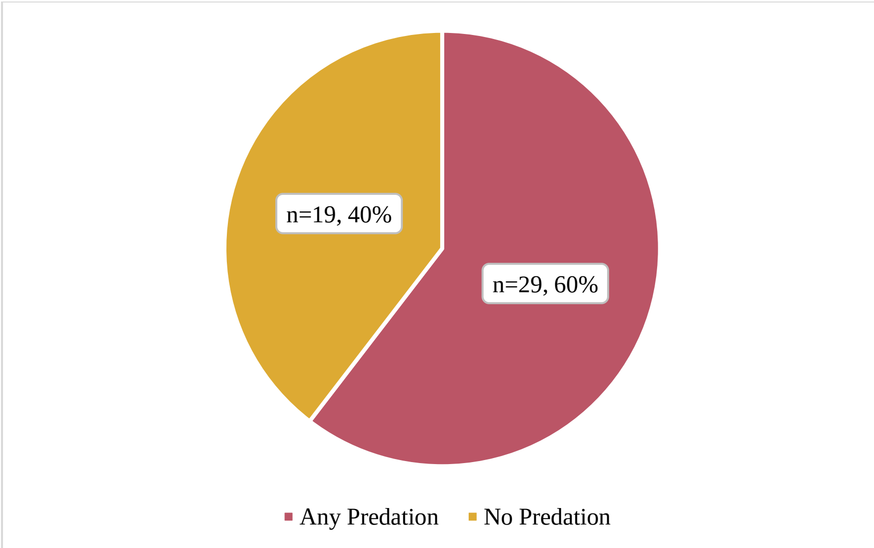

Figure 8: Percent of participants who had experienced pet and/or livestock predation vs those who had not experienced pet and/or livestock predation.

Of the participants who have experienced any kind of predation, livestock predation is the most common predation event (66%) (Figure 9), followed closely by pet predation (62%) (Figure 10). Cattle predation was least common, with only 38% of participants witnessing this kind of predation (Figure 11). Other species of livestock owned by participants can be found in Table 1 (Other Livestock Presence). Witnessing any kind of predation was shown to be a statistically significant ($p < 0.05$) factor that increased the likelihood of a person having previously killed a coyote or being willing to kill a coyote (Table 9).

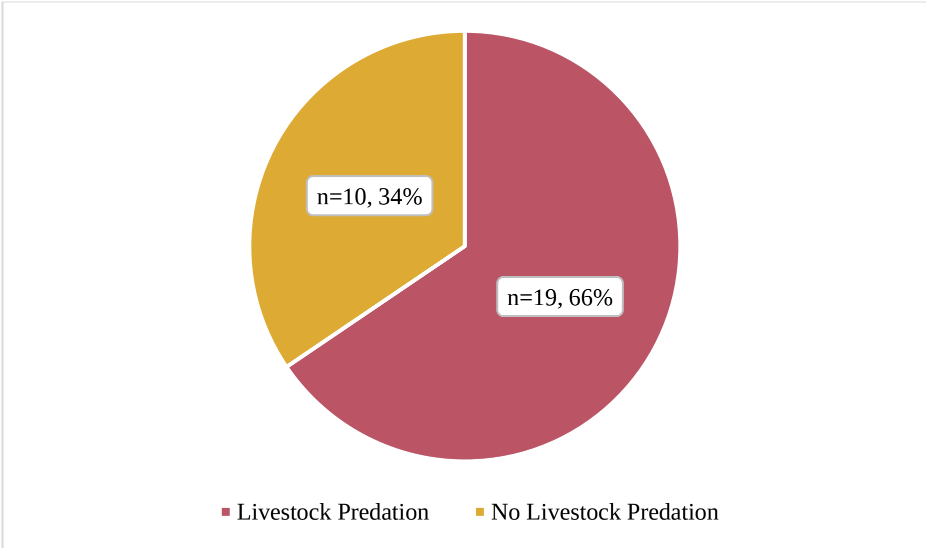

Figure 9: Of the participants who had experienced predation (n=29); the percent of participants who had experienced livestock predation vs those who had not experience livestock predation.

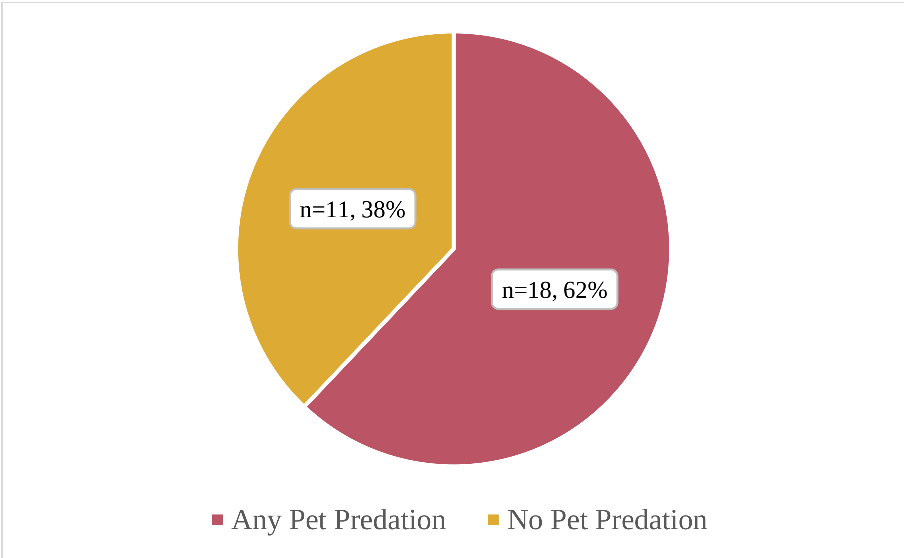

Figure 10: Of the participants who had experienced predation (n=29); the percent of participants who had experienced pet predation vs those who had not experience pet predation.

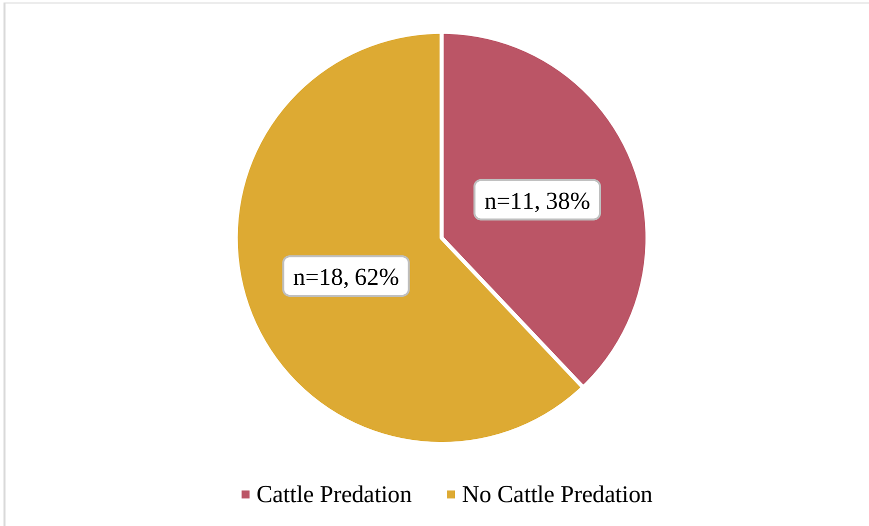

Figure 11: Of the participants who had experienced predation (n=29); the percent of participants who had experienced cattle predation vs those who had not experience cattle predation.

Male participants were more likely to kill coyotes (71%) (Figure 12) than female participants (67%) (Figure 13), though these percentages are similar. Male and female participants who had witnessed pet and/or livestock predation were both more likely to report that they had killed or would kill coyotes on their property than male and female participants who had not witnessed predation (Figure 14, Figure 15). Of the male respondents who killed coyotes, 67% had experienced predation (Figure 14), while slightly more (70%) of the female respondents who killed coyotes had experienced predation (Figure 15).

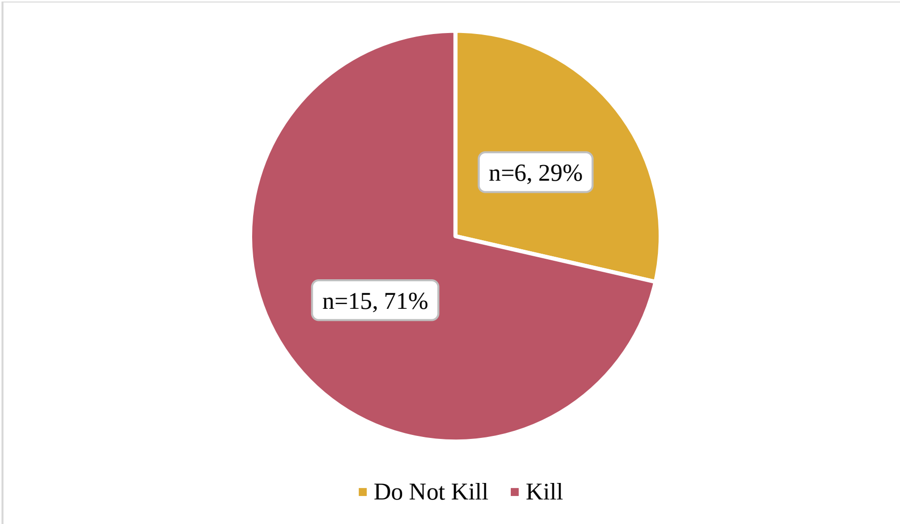

Figure 12: Of the male participants in the study (who did not respond as part of a couple) (n=21), percent of male participants who had killed coyotes and/or were willing to kill coyotes vs those who had not/were not willing to kill coyotes.

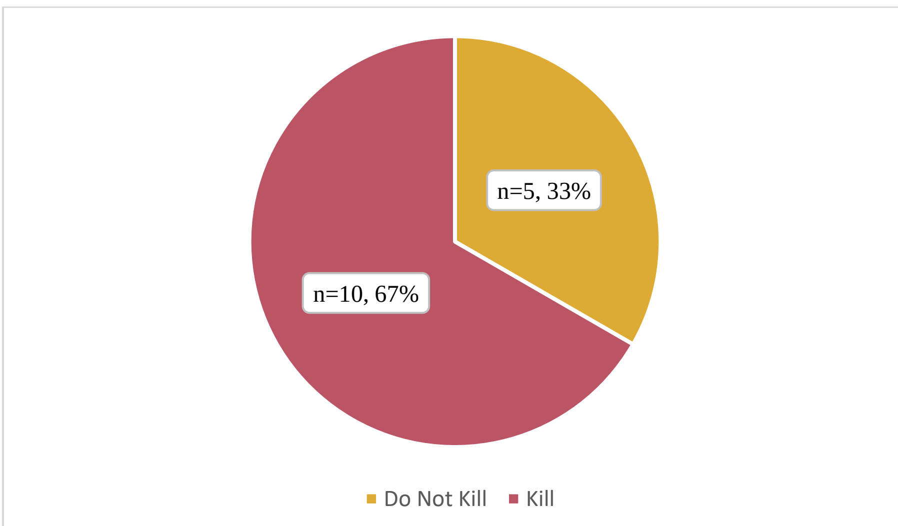

Figure 13: Of the female participants in the study (who did not respond as part of a couple) (n=15), percent of female participants who had killed coyotes and/or were willing to kill coyotes vs those who had not/were not willing to kill coyotes.

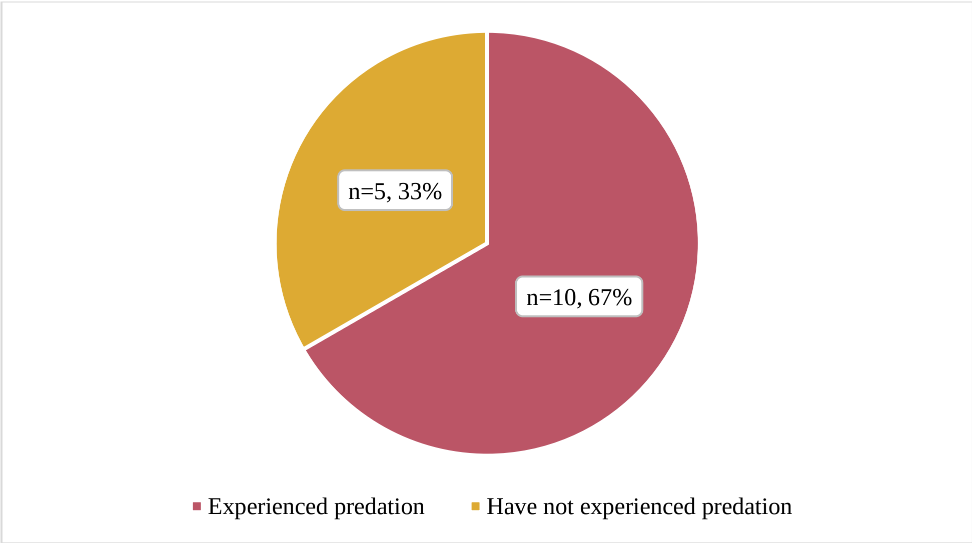

Figure 14: Of the male participants (who did not respond as part of a couple) who had killed coyotes and/or were willing to kill coyotes (n=15), the percent who had experienced predation of pets and/or livestock vs those who had not experienced predation of pets and/or livestock.

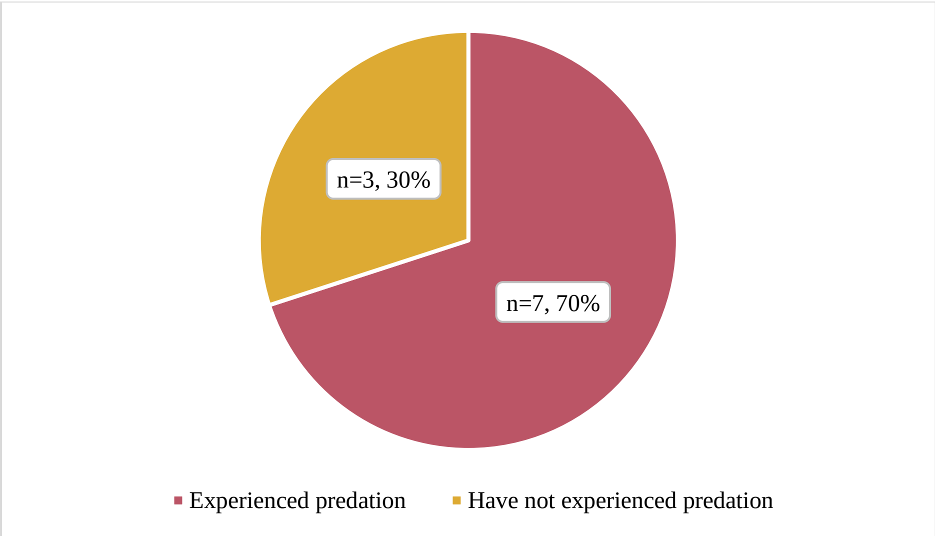

Figure 15: Of the female participants (who did not respond as part of a couple) who had killed coyotes and/or were willing to kill coyotes (n=10), the percent who had experienced predation of pets and/or livestock vs those who had not experienced predation of pets and/or livestock.

5.2.1 Generalised Linear Models for Kill/No Kill (Coexistence)

Hypothesis 1 examines the factors that had an impact on whether participants chose to kill or coexist with coyotes. Three significance models were used ($p < 0.05$, $p < 0.07$, and $p < 0.2$), while p values < 0.2 were considered statistically significant. When tested individually using univariate logistic regression, a statistically significant association was observed between participants who had killed coyotes, any predation, and the presence of barn cats on properties, and these variables were used for the binomial logistical regression.

Any predation was a significant predictor variable for the $p < 0.05$ model and the $p < 0.07$ model (p=0.011 and p=0.026, respectively) in the binomial logistical regression (Table 9). Both barn cat presence and any predation were significant predictors for the $p < 0.2$ model (p=0.026 and p=0.14). Any predation was a major predictor of participants' willingness to kill coyotes, as evidenced by the fact that it was a significant predictor in all three models. The coefficient values for both predictor variables were positive indicating that both any predation and the presence of barn cats contributed to a higher likelihood of killing coyotes (Table 9). Although less of a strong predictor, having barns cats (p=0.14) on a property was also a statistically significant (p <0.2) predictor of whether a person had killed coyotes or would be willing to kill coyotes (Table 9).

Table 9: Summary of best-fitting models utilized for H1: Kill/No Kill analysis using GLM – Logistic Regression. The table shows the p-value, regression coefficient and the three p-value cut-offs.

Model	Predictor Variables and Direction	P-Value	B
<0.05	Any Predation (+)	0.011	1.66
<0.07	Any Predation (+)	0.026	1.49
	Barn Cats Present (+)	0.14	1.29
<0.2	Any Predation (+)	0.026	1.49
	Barn Cats Present (+)	0.14	1.29

5.3 Hypothesis 2 – Pets and/or Livestock Predation

Tree coverage within 100 m of residences ranged from 0% covered by trees at the low end, to ~88% covered by trees at the high end (Figure 16). Of the 48 residences sampled, the majority (33 residences) had a low percentage of tree coverage within 100 m (0-23%) (Figure 16). Only a small number of residences (n=3) exhibited the highest tree coverage range within 100 m (69-92% percent covered). These results indicate that most of the area within 100 m of the residences in the study area is open and not covered by trees.

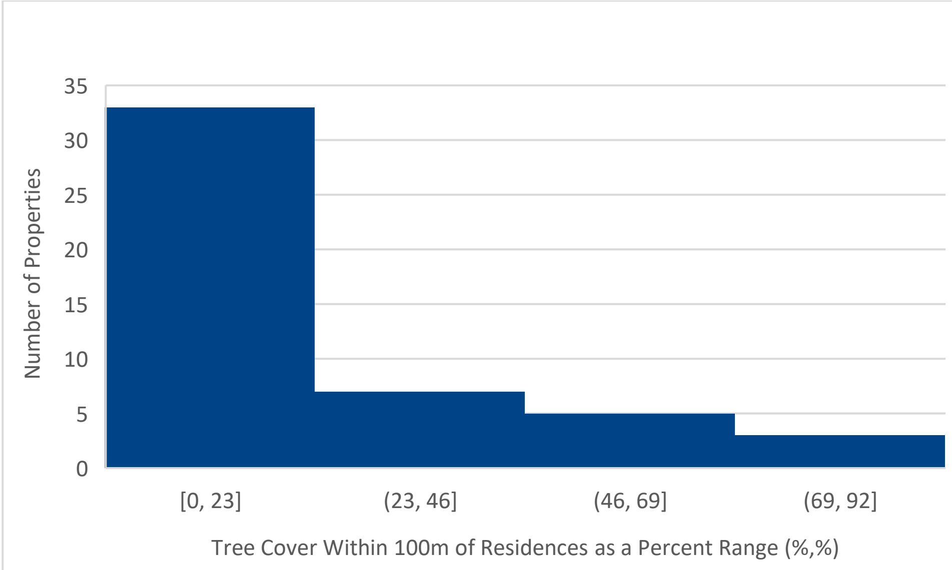

Figure 16: The number of properties with four ranges of tree cover within 100 m of the main residence.

5.3.1 Generalised Linear Models for Predation

Table 10 presents the factors that had an impact on whether participants experienced predation of pets and/or livestock. Three significance models were used ($p < 0.05$, $p < 0.07$, and $p < 0.2$), while p values < 0.2 were considered statistically significant. When tested individually using univariate logistic regression, a statistically significant association was observed between participants who had experienced predation, property size, time in situ, ungulate richness, the presence of guard animals, and the percent of landscape covered by trees within 100 m of a residence, and these variables were used for the binomial regression.

The property size was the only significant predictor for the binomial regression under the $p > 0.05$ model (p=0.0028). The $p > 0.07$ model also produced the same results with only property size as a significant predictor (p=0.012). The percentage of tree cover within 100 m of the residence and the size of the property were both significant predictors for the $p > 0.2$ model (p=0.014 and p=0.19 respectively), indicating that the higher significance cutoff value of $p < 0.2$ is required to include some significant variables. The coefficient for property size was positive, and the coefficient for the percentage of tree cover within 100 m of residences was negative. This indicates that larger property size and a lower percentage of tree cover within 100 m of the residence both contributed to a higher likelihood of pet and or livestock predation. Although the time in situ variable had a negative coefficient in the combined binomial regression, it had a positive coefficient (0.049) when analysed alone as the only predictor variable.

Table 10: Summary of best-fitting models utilized for H2: Pet and/or Livestock Predation analysis using GLM – Logistic Regression. The table shows the p-value, regression coefficient and the three p-value cut-offs.

Model	Predictor Variables and Direction	P-Value	B
<0.05	Property Size (+)	0.0028	0.017
	Time in Situ (-)	0.73	-0.010
<0.07	Property Size (+)	0.012	0.015
	Time in Situ (-)	0.75	-0.0099
	Ungulate Richness (+)	0.45	0.59
	Guard Animal (+)	0.41	1.16
<0.2	Property Size (+)	0.014	0.015
	Time in Situ (-)	0.71	-0.012
	Ungulate Richness (+)	0.33	0.77
	Guard Animal (+)	0.58	0.79
	Tree Cover 100m (-)	0.19	-0.022

5.4 Hypothesis 3 – Livestock Predation

5.4.1 Generalised Linear Models for Livestock Predation

Table 11 presents that factors that had an impact on whether participants experienced livestock predation. Three significance models were used ($p < 0.05$, $p < 0.07$, and $p < 0.2$), while p values < 0.2 were considered statistically significant. When tested individually using univariate logistic regression, a statistically significant association was observed between participants who had experienced livestock predation, time in situ, cats, the presence of guard animals, the percent of landscape covered by trees within 100 m of a residence, property size, and ungulate richness, and these variables were used for the binomial regression.

The presence of house and/or barn cats on the property was a significant predictor (p=0.032) for the logistical binomial regression under the $p > 0.05$ model, while time in situ (0.025) was correlated but not a predictor. This contrasted with the results of the $p < 0.07$ model, which showed no significant predictor variables ($p > 0.07$). For the $p < 0.2$ model, presence of cats ($p > 0.20$) and the percent of landscape covered by trees within 100 m of a residence (p=0.14) were significant variable predictors. While presence of guard animals (p=0.075) and time in situ (p=0.094) were correlated with livestock predation, they were not considered predictors because the data was not collected with this in mind. The percent of landscape covered by trees within 100 m of a residence had a negative regression coefficient and the presence of cats had a positive regression coefficient. This indicated that the presence of cats contributed to a higher likelihood of livestock predation. The percentage of landscape covered by trees had a negative regression coefficient, which indicated that less tree coverage contributed to a higher likelihood of livestock predation.

Table 11: Summary of best-fitting models utilized for H3: Livestock Predation analysis using GLM – Logistic Regression. The table shows the p-value, regression coefficient and the three p-value cut-offs.

Model	Predictor Variables and Direction	P-Value	B
<0.05	Time in Situ (+)	0.025	0.039
	Cats (+)	0.032	1.46
<0.07	Time in Situ (+)	0.087	0.034
	Cats (+)	0.18	1.01
	Guard Animal (+)	0.080	1.62
	Tree Cover 100m (-)	0.14	-0.036
	Property Size (+)	0.44	0.00038
<0.2	Time in Situ (+)	0.094	0.033
	Cats (+)	0.20	1.00
	Guard Animal (+)	0.075	1.62
	Tree Cover 100m (-)	0.13	-0.037
	Property Size (+)	0.49	0.00030
	Ungulate Richness (+)	0.24	0.89

5.5 Objective 4 – Science Communication Materials

I used the following science communication tools to visualise and communicate my research with researchers and the public:

1. **Infographic – Benefits Provided by Coyotes**: Figure 17 presents four of the benefits that coyotes have on humans and the environment. These benefits include improving ecosystem health, increasing biodiversity and survival of endangered bird species, and controlling rodent populations.

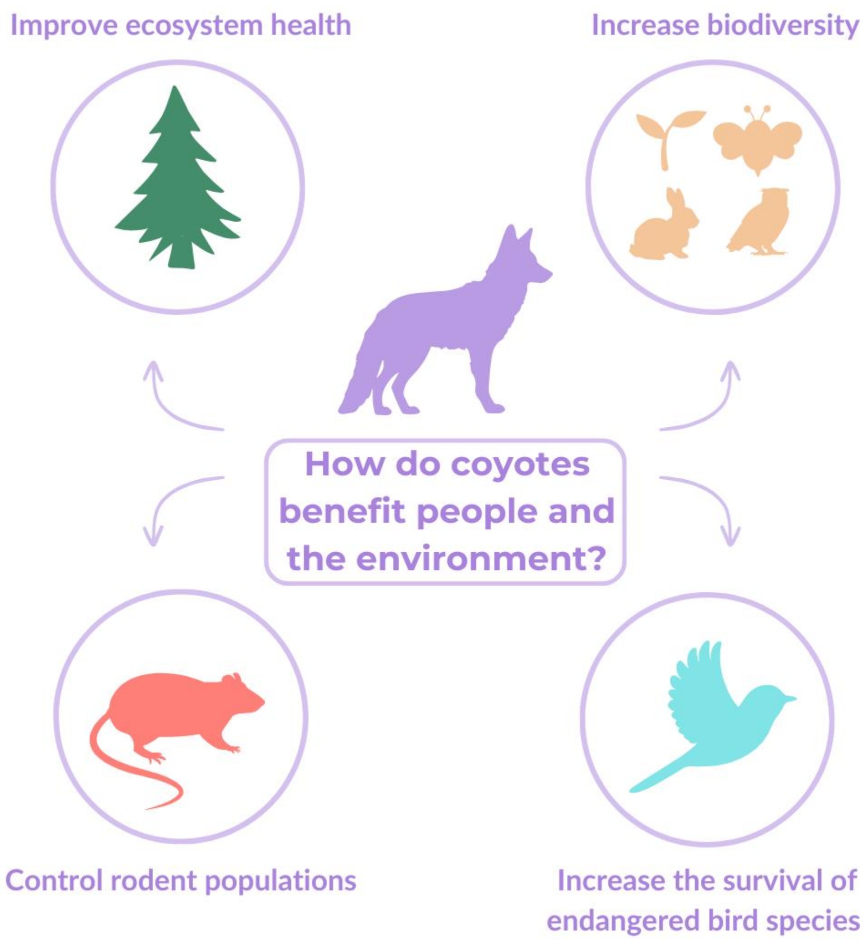

Figure 17: Infographic describing the benefits coyotes provide for people and ecosystems including improving ecosystem health, increasing biodiversity and the survival of endangered bird species, and controlling rodent populations.

2. **Video – *Wild* (Dickson, 2024):** I was selected as a Social Sciences and Humanities Research Council (SSHRC) Storyteller Finalist (2024) for *Wild*. The video can be viewed online in SSHRC's 2024 Storytellers Gallery (Dickson, 2024). Additionally, *Wild* was shared across SSHRC's social media channels, allowing the video to reach a wider audience. I also had the opportunity to present a live talk about the research in *Wild* to an audience of high school students, researchers, science communicators, and members of the public during the SSHRC Storytellers Showcase at the Science Writers and Communicators of Canada Conference on May 6, 2024, in Saskatoon.
3. **Video – *Birdy* (Dickson, 2023):** *Birdy* won second place at the University of Calgary's Science Communication Film Festival (2023), where it was viewed by a live audience of graduate students, faculty, staff, and members of the public. I also presented *Birdy* live and spoke about my research as a panel member at the University of Calgary Sustainable Development Goals Alliance's storytelling event on February 7, 2024. During this event, I was able to share my research with an audience of undergraduate and graduate students from the university, as well as members of the public.

6 Discussion

The outcomes of my study have provided insight into some of the different factors that contribute to peaceful human and coyote coexistence. In particular, the impact of these factors on coexistence values, any kind of predation on pets and/or livestock, and livestock predation specifically were examined, due to the anticipated importance that people's coexistence values and their prior experiences of predation have on human-wildlife interactions. This section of my thesis reflects on the research process pertaining to each of my main objectives, which are restated below:

Objective 1: Identify causal relationships between coexistence values (kill/no kill) and demographics, livestock and pet ownership, predation experiences, and geospatial factors.

Objective 2: Identify causal relationships between pet and/or livestock predation by coyotes and demographics, livestock and pet ownership, biodiversity, and geospatial factors.

Objective 3: Identify causal relationships between livestock predation by coyotes and demographics, livestock and pet ownership, biodiversity, and geospatial factors.

For each of these three objectives, I discuss my results and their implications for human-coyote coexistence. The limitations and potential consequences of this research are also discussed. This section ends with recommendations for future research, based upon the findings of all three objectives and their impact on our understanding of coexistence.

6.1 Objective 1 Discussion

The goal of objective 1 was to identify causal relationships between coexistence values (kill/no kill) and demographics, livestock and pet ownership, predation experiences, and geospatial factors. When testing null hypothesis 1, the strongest predictor ($p < 0.05$) of a willingness to kill coyotes was having experienced any kind of prior predation (either pet predation, livestock predation, or both kinds of predation). The results also indicated that participants who had barn cats on their property were more likely to be willing to kill coyotes.

In line with my research, prior predation by coyotes on pets and/or livestock was found to be a key predictor of the killing of coyotes. My findings build on existing evidence about the impact of predation on coexistence values towards predators (Naughton-Treves et al., 2003). This work also supports research by Alexander and Quinn (2011), which show that predation can cause emotional trauma that negatively impacts views about coexistence. Furthermore, these results provide important context in helping to understand the prevalence of lethal methods used to manage coyote populations in situations when people raise concerns regarding the safety of pets, people (Alexander and Quinn, 2011), and livestock (Mitchell et al., 2004).

The second relationship I found was that the presence of barn cats on a property also predicted the killing of coyotes. Previous studies have demonstrated that free-ranging outdoor cats are sometimes eaten by coyotes (Crooks and Soulé, 1999). Barn cat presence may be related to overall predation through barn cat predation specifically. As my findings indicate that experiencing predation has a strong causative effect on killing coyotes, individuals who have witnessed a predation event on cats or who are worried about the possibility of coyotes eating cats may be more likely to kill coyotes.

As highly effective mesopredators, barn cats contribute to the decline of bird and small vertebrate diversity and abundance (Crooks and Soulé, 1999). Through trophic cascades, this may indirectly allow other species to flourish (Ripple et al., 2016). It is possible that by removing small prey, medium-sized prey is better able to flourish near barns. While coyotes can eat a variety of natural prey items across a wide range of sizes (Lukasik and Alexander, 2012), an increase in medium-sized prey availability may draw coyotes closer to barns. This might bring coyotes into the critical distance space (Brighenti and Pavoni, 2008), where the coyotes are viewed as being out of place in human spaces (Alexander and Draper, 2019b; Ojalammi and Blomley, 2015). Previous research by Alexander and Draper (2019a; 2019b) has demonstrated that when humans view coyotes as being out of place, they are more likely to kill them. This analysis supports the theory that barn cats could also be predictive of killing when the impact of barn cats on an environment draws coyotes closer to the environments that overlap with people and livestock.

Coyotes support healthy ecosystems by maintaining biodiversity (Crooks and Soulé, 1999). They also are highly intelligent (Young et al., 2019), social (Atwood, 2006; Mastro, 2011), and deeply feeling animals (Bekoff, 2013) that possess intrinsic value outside of the benefits that they provide to people (Manfredo and Dayer, 2004; Knauß, 2018). Our views on sharing our world with wildlife are in the process of shifting in favour of more ethical paradigms that emphasize coexistence (Elliot et al., 2016). Therefore, our coexistence values, or whether we choose to live peacefully alongside or kill coyotes, are critically important to the creation of peaceful coexistence strategies. The data from this study contribute a clearer understanding about two important factors that impact our ability to coexist with coyotes: any predation and presence of barn cats. I believe that this research can be used to inform strategies to improve coexistence strategies, such as by educating people about how to reduce predation risk on their property.

6.2 Objective 2 Discussion

The goal of objective 2 was to identify causal relationships between pet and/or livestock predation and demographics, livestock and pet ownership, biodiversity, and geospatial factors. When testing null hypothesis 2, the strongest predictor ($p < 0.05$) of having experienced predation of any kind was a larger property size. The results also indicated that participants were more likely to have experienced predation when there was less tree cover within 100 m of their primary residence ($p < 0.20$). Although not statistically significant within the models, increased ungulate richness did show a potential relationship with predation when tested alone.

The first relationship I found was that predation increased alongside an increase in property size. Properties in the study exhibited a large range of sizes (Figure 4), ranging from 0-20 acres on the small end to over 12,000 acres on the largest end. As coyotes typically avoid people (Fox, 2006), coyotes may prefer to avoid areas on properties where they may be more likely to encounter humans. A smaller property necessitates that people, buildings, and livestock are kept closer together. This increases the likelihood that a coyote would encounter people, which they may try and avoid. Conversely, coyotes would be less likely to encounter people on larger properties. This may result in reduced caution and increased incorporation of these larger properties into their habitat. In turn, these coyotes would be more likely to encounter livestock and pets while using the space on properties as part of their habitat. As coyotes are opportunistic predators (McKinney and Smith, 2007), an increased number of encounters with pets and livestock may contribute to increased instances of opportunistic predation.

Another explanation for why predation increases alongside property size has to do with herd density. When prey is more spread out, they are more vulnerable to predation (Barnes, 2015). Conversely, larger and more spatially constrained herds are harder to sneak up on, which make it more challenging to identify vulnerable individuals, and are overall less likely to be attacked by predators (Barnes, 2015). My results may fit with this theory of herd density dynamics, as the livestock kept on larger properties within my study group may have been more spread out, and thus more prone to predation, though this factor was not captured in the research data.

Although only statistically significant when tested alone, there is a potential relationship between increased ungulate richness and predation. A possible explanation for this association is that increased numbers of ungulates support a higher population of coyotes. Ungulates are a food source for coyotes (Bekoff and Gese, 2003), though they are better at hunting smaller prey sources, such as newborn ungulates (Levi and Wilmers, 2012). Thus, an increase in ungulate richness could directly increase ungulate food availability for coyotes. Higher ungulate populations also cause an increase in rodent populations due to the impacts of a trophic cascade (Katona and Coetsee, 2019). As rodents are a preferred food source for coyotes (Miller et al., 2012), higher rodent populations would lead to increased food availability for coyotes. This increase in food availability could directly result in a higher coyote population. As opportunistic predators (McKinney and Smith, 2007), a larger coyote population may result in more frequent encounters with pets and livestock, leading to more opportunities for coyotes to engage in pet and livestock predation.

The second relationship suggested by the data is that predation increases as the percent of tree cover within 100 m of residences deceases. Despite showing statistical significance, the regression coefficient is relatively close to zero and the p-value is around the maximum p-value model of $p < 0.20$. This indicates that there is not the strongest correlation between predation and the percent tree cover within 100 m of residences. Even so, previous studies have shown that coyotes prefer open spaces and perimeter areas, especially for foraging and play (Schultz and Young, 2018). Hinton et al., (2015) found that coyotes generally preferred areas that were open and treeless, and on the edges of agricultural fields. As most of residences have low tree cover within 100 m (Figure 16) this would mean that most of these spaces are also relatively treeless, and coyotes may prefer the forage and play within these areas. This would bring coyotes closer to residences, increasing the likelihood of opportunistic predation by coyotes of pets and livestock living near homes.

As seen in objective 1, predation is a major factor in determining whether people kill coyotes. Thus, if we hope to reduce killing of coyotes, we need to reduce predation. The data from this study contribute to a better understanding of the causes of predation. My results suggest that possible risk factors include larger property sizes and less tree cover within 100 m of properties. I believe that these risk factors could be mitigated through actions that aim to reduce predation risk. These actions might include educating landowners about the increased risks of predation associated with larger property sizes and reduced tree cover, alongside education about the effectiveness of non-lethal control methods, so that individuals most at risk can be better prepared to utilize ethical and effective methods to reduce predation risk. Considering that witnessing predation can have a measurable negative impact on coexistence values (Alexander and Quinn, 2011, this study), communicating with the public about strategies that reduce predation is crucial to human and coyote coexistence. Collaborating with long term residents, who often are more willing to apply new, scientifically backed coexistence strategies to prevent predation (Alexander and Draper, 2019a), may be a useful partnership to successfully share predation mitigation strategies with communities.

6.3 Objective 3 Discussion

The goal of objective 3 was to identify causal relationships between livestock predation and demographics, livestock and pet ownership, biodiversity, and geospatial factors. When testing null hypothesis 3, the strongest predictor ($p < 0.05$) of having experienced livestock predation was the presence of house and/or barn cats on the property. Less tree cover within 100 m of a primary residence was also associated with having experienced livestock predation.

Living at the study site for a longer period (Alexander and Draper, 2019a) and having guard animals (McManus et al., 2015) have both been associated with a reduced risk of livestock predation, though I was unable to investigate these relationships in more detail during my study.

While my study found a connection between longer times in situ and predation (Table 11), this does not mean that living on site for longer periods of time creates a higher vulnerability for predation. This result most likely occurred because with longer time in situ, there has been more time for predation to occur in these instances. In fact, participants who have lived at the site for longer periods of time tend to be more likely to integrate new scientific information about coexisting peacefully with wildlife (Alexander and Draper, 2019a), increasing the likelihood of incorporating methods and practices that reduce their vulnerability to predation. As 60% (Figure 8) of the study participants had experienced predation at some point, predation itself does not seem to be an uncommon event. Therefore, the longer a person has been exposed to potential predation events, the higher the likelihood becomes of witnessing an event, though the risk of predation is reduced overall (Alexander and Draper, 2019a).

Similarly to the results for time in situ, the connection between guard animals and livestock predation in my research suggests that people who utilize guard animals on their property were more likely to have experienced livestock predation in the past. Previous research has demonstrated that guardian animals have been associated with decreased livestock predation (McManus et al., 2015). My research likely suggests that people who have experienced livestock predation in the past are more likely to utilize guard animals to prevent predation in the future.

The first relationship suggested by the data is that the presence of house and/or barn cats on a property increases the risk of livestock predation. While house cats are primarily thought of as indoor cats (Lepczyk et al., 2004) and barn cats are considered free roaming (Bissonnette et al., 2018), both kinds of cats often have access to the outdoors (Bissonnette et al., 2018; Lepczyk et al., 2004). While roaming outdoors, cats may become a prey source for coyotes (Crooks and Soulé, 1999). While current evidence suggests that coyotes preferentially eat natural food items (Lukasik and Alexander, 2012), it is possible that cats could act as an attractant for coyotes (Mitchell et al., 2022) and draw coyotes closer to livestock, particularly if their preferred food sources such as rodents were less abundant. In line with this theory, cats strongly contribute to the decline of bird and small vertebrate populations (Crooks and Soulé, 1999). This decline may impact coyote prey populations enough that their diet might shift (McKinney and Smith, 2007), increasing their likelihood of turning to livestock for subsistence.

Secondly, the factors that predict livestock predation overlap with some of the factors that predict any kind of pet and/or livestock predation, as explored in objective 2. Less tree cover within 100 m of residences was associated with a greater likelihood of livestock predation, which is most likely caused by the same mechanisms as in objective 2. As discussed, previous studies have shown that coyotes prefer to utilize open, treeless spaces for foraging and play (Hinton et al., 2015; Schultz and Young, 2018). Most residences in this study exhibit lower tree cover percentages (0-23%) within 100 of the residences (Figure 16), suggesting that these areas have less trees and more open space. Therefore, coyotes may be attracted to the open spaces near homes, increasing the opportunistic predation by coyotes on livestock living nearby.

Given that predation of livestock by predators has been estimated to cost ranchers in Alberta $22 million per year (Lee et al., 2017), as well as the impacts that predation has on coexistence values (see objective 1), preventing livestock predation is important for both economic reasons as well as for human and coyote coexistence. The data from this study contribute to a better understanding of the causes of livestock predation. My results suggest that likely risk factors of livestock predation include the presence of house or barn cats on properties and less tree cover within 100 m of properties. I believe that these predation risk factors could be mitigated through strategies which share similarities with the recommendations for objectives 1 and 2, including communicating with the community about the risk factors for predation such as outdoor cats and reduced tree cover.

6.4 Limitations

The participants of this study were rural residential and agricultural landowners from one subregion of Alberta (the Foothills Parkland Natural Subregion), and therefore these results should not be generalised to other populations. Coyotes are widespread across North America (Wang et al., 2010; Hinton et al., 2019) and as a result, human and coyote interactions occur with people from many different cultures and backgrounds, who are engaging with the land for different land use purposes across diverse physical locations. These differences are likely to impact coexistence values and predation risk. Despite these limitations, the study size (48 participants) and sampling techniques resulted in a sufficient sample size for conducting mixed-methods research on the two types of landowners being evaluated. Future research into coexistence values and predation risks in other populations would contribute to understanding these drivers better.

6.5 Recommendations

An interesting direction for future studies would be to test whether the frequency and intensity of predation events decreases over time, as participants learn new strategies to prevent predation. Based on previous research, as the time spent in an area increases, the frequency and intensity of predation events would be expected to decrease due to knowledge about how to mitigate predation (Alexander and Draper, 2019a). The USDA classifies farmers and ranchers based on time in situ (Ahearn, 2011) as either being a beginning (<10 years) or an experienced rancher (10+ years). It may be beneficial to determine if these categories align with a reduction in predation events, and if not, whether there are different time categories that could help researchers and ranchers determine their predation risk based on time in situ.

Furthermore, it would also be interesting to examine the impacts of human tolerance of predators on coexistence values, as it is possible that some individuals who view predation as a natural event may tolerate predation without believing that coyotes need to be controlled. These differences in predation management would be aligned with the worldviews explored by Alexander and Draper (2019a).

One possible avenue to improve human and coyote coexistence is education (Alexander and Draper, 2019a). Based on my findings about coexistence values and predation risks, I would recommend the following three education-oriented strategies to mitigate predation risks and encourage peaceful coexistence in rural-residential and agricultural communities:

- Educate landowners about the risk factors for pet and livestock predation, including having cats on properties, less tree cover near homes, and larger property sizes. Education may help landowners evaluate their individual risk levels.
- Teach communities about the importance of coyotes to people, ecosystems, and the economy, including discussing the ecosystem services that coyotes provide.
- Work with key experienced landowners to develop science communication materials for use in the community, to make sure that communication materials are meaningful, relevant, and useful for their intended audiences and that community concerns are centered and addressed.

7 Conclusion

Humans share this planet with a dazzling variety of life. We have a profound impact on all the animals, plants, and ecosystems on Earth. However, the animals, plants, and ecosystems all have a profound impact on us as well. Ecosystems influence human health, happiness, and well-being. In turn, our actions can either threaten the survival of these ecosystems or help to conserve them.

Aside from the benefits they provide to people, coyotes, like every other living creature, deserve respect, compassion, and ethical treatment. However, there are barriers to peaceful human and coyote coexistence. One of these barriers is wildlife conflict, when coyotes are perceived to pose a threat to humans, pets, or livestock. The goal of my research was to reduce conflict and promote peaceful coexistence by understanding what factors influence coexistence values, as well as identifying risk factors for predation on pets and/or livestock. Amongst rural-residential and agricultural populations within the Foothills Parkland Natural Subregion, I determined that experiencing predation and having barn cats on a property both increased the likelihood that residents had killed coyotes in the past or would be okay with killing coyotes in the present. This finding emphasized how important it is to reduce predation if we hope to change coexistence values and encourage people to coexist peacefully with coyotes. Pet and/or livestock predation risk factors I identified included increased property size, and the percentage of tree coverage within 100 m of residences. Livestock predation risk factors I identified included the percentage of tree coverage within 100 m of residences, as well as the presence of house and barn cats on a property.

Suggestions to reduce predation risk and encourage peaceful coexistence include educating landowners about these predation risks, developing meaningful educational initiatives alongside experienced landowners, and teaching communities about the benefits that coyotes provide to people, the ecosystem, and the economy. Reducing predation in the Foothills Parkland Natural Subregion will reduce conflict between people and coyotes, setting an example for other rural-residential and agricultural communities. Coyotes, as well as other animals, are critical to human health and the health of our planet. By choosing to take steps to reduce conflict, we are contributing to a healthier planet where humans, coyotes, and ecosystems can thrive together long into the future.

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9 Appendix: FCI Interview Script

Designed and implemented by S. Alexander and D. Draper

SITUATIONAL (5-10 minutes)

1) Homeplace:
   - size of property
   - livestock (Y / N) - size of herd?
   - number of dogs (pets vs working) and cats
   - household garbage disposal practices
   - guard animals? (which)
   - exclusionary fencing or other deterrents
   - wildlife corridors
2) Demographics:
   - Gender
   - Employment
   - Education (highschool college university other______)
   - place of residence as youth (aged 0-12 yrs)
   - time in-situ (current property)
   - age range of participant (categories: <25, 25-54, 55+) [actual age]
3) Landscape modification (observation by interviewer in situ): attractants (e.g. fruit trees)
   - groomed vs natural vegetation surrounding home site
   - water feature(s)
   - bird feeders
   - other (e.g. garbage disposal site)
4) Landscape elements from GIS analysis and ortho (not interview): topographic complexity, distance to forest edge from house, distance grazing to homeplace, calving pens proximity to homeplace, river or creek, natural water body, dugout, ridge lines, etc.

EXPERIENTIAL: LIVING WITH COYOTES (15 min)

1) When I say coyote – what are the first few words you think of to describe them?
2) How frequently do you see coyotes on your property? (daily /weekly /monthly) (night/day)
3) Can you describe one or two key experiences that you had with coyote(s) in the past 10 years that stand out in your mind (were the most memorable)?
4) What behaviours signal to you that you have a “problem coyote”?
5) Have coyotes caused you problem in the last 10 years? Y / N what type? increasing or decreasing? Thoughts as to why?
6) Do you notice any other trends in wildlife in the immediate area? On your property?
7) On a scale of 1 to 5 (where 1 is totally unable and 5 is totally able), how able do you feel to deal with problem coyotes? 1 2 3 4 5
8) What behaviours would signal to you that a coyote needs to be killed?
9) Would you recommend killing coyotes before they become a problem? Y / N
10) Who taught you what you need to be aware of when living with coyotes? What were the main things you learned to watch out for?

11) Who do you trust to help you with a coyote problem:
friend(s), family, neighbour(s), government agent, other______
12) Have coyotes ever denned on your property -Y/N -please describe this – i.e. where
13) Have you faced any safety issues because of coyotes denning on your property? Y / N Please describe…?
14) Are you concerned about attacks on pets (Y / N), livestock (Y / N), children (Y / N)
15) What are your main methods for protecting your pets from coyotes?
16) What are your main methods for protecting your livestock from coyotes?
17) What are your main methods for protecting children from coyotes?
18) In the past 10 years, have any of your domestic animals (Y / N pets Y / N livestock) been attacked by coyotes?
19) If yes, how many pets___/___and livestock___/___ were attacked and how many were killed by coyotes?
20) On average, about how many coyotes do you (or a hired person) kill each year? Which methods do you use most? Are all killed on the property?
21) Do you ever use strychnine or compound 1080? Y / N Please explain …
22) Have you used any of the following non-lethal deterrents:
Guardian dogs Y / N , donkeys Y / N , lamas Y / N , electric fencing Y / N, calving pens Y / N , other _____
23) If no, is there something that makes it challenging to use these methods?)

SENTIMENTAL (15 min)

1) What few words that tell me how you feel about coyotes?
2) Could you please describe your earliest memory of encountering a coyote (close proximity)/about how old were you/ what were your feelings about the coyote at the time?
3) Please describe an interaction you have had with a coyote that stands out in your mind as really interesting (can be same as 1)? - Was there something in the coyote's behaviour that led you to describe that particular interaction?
4) Have you seen a coyote do something that surprised you (was smart or unexpected)?
5) Do coyotes ever make you feel fearful if you are alone with them? Y / N (probe – what is the fear about?)
6) Is there anything about coyotes that makes you laugh or smile?
7) Thinking about coyotes, is there anything they do that makes you angry?
8) If you had to (Y / N) , or when you have kill(ed) (Y / N) a coyote, please tell me how would that make you feel (few words)?
9) Would you support a coyote cull (killing in large numbers) in this area? (Y / N) please explain why or why not?
10) Would you support a coyote killing contest in this area (prize for most dead, biggest, smallest, etc.)? please explain

PERCEPTUAL (15 min)

1) In your opinion, has the frequency of attacks by coyotes on domestic animals increased, decreased or stayed about the same over the past 5 years?
2) Which domestic species seem most susceptible to attack?
3) From your perspective, has the conversion of land from rural to urban (or large acreages) changed coyote behaviour in any way? Explain a bit – where is the change?
4) If you were alone and you encountered some coyotes, how many would make you concerned for your personal safety (not an issue, one, two, three or more)?
5) In your opinion, are coyotes trespassing when they hunt domestic animals on your private property?
6) Do you feel it is natural if a coyote eats a cat? Y / N a dog? Y / N that is close to home?
7) Do you feel it more natural if a coyote eats a cat or dog that is far from home? Y / N
8) On a scale of 1 to 5 (1 being totally ineffective and 5 being totally effective) how effective is killing coyotes as a means to stop coyote problems in the long term? 1 2 3 4 5
9) Do you have any final thoughts on what are the most important things to know about living with coyotes?
10) Do you have any questions for me?
    Thank you for your time….

BIODIVERSITY CHECKLIST

Identify which of the following species you have seen on your property in the last 5 years.
Also, identify which have been actively controlled for agricultural/livestock purposes at any time.
Species: On property? Controlled?:

- Black Bear ________________
- Grizzly Bear ________________
- Cougar ________________
- Wolf ________________
- Lynx ________________
- Bobcat ________________
- Fox ________________
- Badger ________________
- Deer ________________
- Elk ________________
- Moose ________________
- Owls ________________
- Eagles (Golden or Bald) ________________
- Hawk(s) ________________
- Magpies ________________
- Crows ________________
- Ravens ________________

- Mice/Voles ________________
- Rabbits (hare) ________________
- Gophers (Ground Squirrel) ________________
- Weasel ________________
- Squirrel (red) ________________