WESTERN COLORADO CARNIVORE COEXISTENCE: GOLD-STANDARD NON-LETHAL DETERRENT EXPERIMENTS AND HUMAN-CARNIVORE COEXISTENCE IN MONTROSE, COLORADO

By

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Abstract

Human-wildlife conflict and coexistence (HWCC) encapsulates all positive and negative interactions between humans and wildlife. While there are many examples of positive HWCC, sometimes coexisting on shared landscapes can be difficult, especially when considering carnivore-livestock interactions. When managing carnivores, peer-reviewed research not only shows public preference for non-lethal methods in the United States but finds lethal control of carnivores may not have the same efficacy as preventative interventions. However, while many methods exist around the world for protecting domestic animals from predators, few researchers have used robust experimental designs such as the gold-standard of randomized, controlled trials. Here, I conduct a gold-standard (randomized, controlled trial) experiment with an additional crossover design in western Colorado, United States, while using two previously researched non-lethal deterrent methods: fladry and Foxlights®. I ran the experiment on five separate farms and interviewed private landowners to measure the functional and perceived effectiveness of the non-lethal deterrent methods. I hypothesized that the non-lethal deterrent methods would reduce western Colorado carnivore visits to the private properties, and that landowner attitudes would become significantly more positive as the experiment progressed. In addition to the results, I provide specific recommendations for future researchers to continue this work to achieve a better relationship between humans, carnivores, and livestock.

Keywords: Carnivore Coexistence, Non-Lethal Methods, Randomized Control Trial, Survey, Colorado, Attitudes Toward Wildlife, Carnivore Conservation, Fladry, Foxlights®.

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Introduction

Human-Wildlife Conflict & Coexistence

The coexistence of humans and wildlife is understood to be the interactions between the two groups in areas where their activities overlap. Scientists categorize these interactions as human-wildlife conflict and coexistence (HWCC)—an all-encompassing term for both positive and negative scenarios with wildlife, usually defined from the human perspective. HWCC is widespread, it affects multiple species of wildlife across all trophic levels (Marchini, 2014). Carnivore coexistence is a type of HWCC. Most peer-reviewed research relating to HWCC fails to define carnivore coexistence (Venumière-Lefebvre et al., 2022). While other authors offer a plethora of definitions, I use the following: “the lasting persistence of self-sustaining large carnivore populations in human-dominated landscapes. In such landscapes…coexistence is similar to the maintenance of a community of predatory species comprising of large carnivores and humans” (Chapron & López-Bao, 2016). The lack of instances that meet this definition reinforces that large carnivore coexistence is suffering around the world amid a sixth mass extinction.

Large carnivores are apex consumers, meaning they sit atop of their respective ecosystem trophic pyramids (models of biomass and energy exchange between food webs) (Estes et al., 2011). Apex consumers exert incredible top-down pressure in their ecosystems, providing both indirect and direct trophic cascades. Due to human-caused modern extinction, already small populations of apex consumers are shrinking (Ripple et al., 2014). This widespread trophic downgrade—the mass removal of apex consumers— reduces complexity and reverberates throughout ecosystems. For example, trophic downgrade correlates with increased herbivory, wildfire frequency, disease spread, and decreased biodiversity (Estes et al., 2011). Ripple et al. (2014) suggests large carnivore conservation should follow a two-pronged approach. First, increase the focus on conserving the full native range of apex consumers to maximize potential ecological benefits. Next, reintroduce apex consumers to their native landscapes while minimizing impacts on humans and increasing carnivore coexistence. Therefore, it may be in the best interest of researchers to investigate approaches which promote a win-win-win (humans, livestock, carnivores) scenario for all groups.

While there are many examples of beneficial relationships between humans and wildlife, sometimes coexistence can be difficult (Messmer, 2000). From the human perspective, HWCC can diminish livelihoods in a variety of ways, such as through wildlife-vehicle collisions, crop destruction, or domestic animal predation—when wildlife attacks a companion or livestock animal. The more specific HWCC of domestic animal predation occurs across shared landscapes and manifests in a struggle for resources. At times, carnivore-livestock interactions reach a point of injury or death, which makes coexistence difficult.

Opinions on the proper way for humans to manage the complex relationships between themselves, domestic animals, and carnivores may not align with the best available science. For one, lethal methods—which result in the death or injury of carnivores through activities like shooting, trapping, or poisoning—create perceived simplicity by removing the carnivore (individual or local population) from the landscape. Previous reviews showed livestock loss could increase after government-sponsored predator removal (i.e., hunting, culling) when evaluating rigorous experimental methods (Khorozyan, 2022; Treves et al., 2016, 2019; van Eeden et al., 2018). An empirical study found lethal removal of gray wolves (*Canis lupus*) in Michigan did not lead to a significant decline in the risk of recurring cattle losses when compared to non-lethal interventions (i.e., no predators removed), and found no statistical evidence of lethal methods preventing future livestock losses. Furthermore, the same study suggested the lethal removal of wolves could lead to increased predations on domestic animals in neighboring farms, thus, not preventing livestock loss (Santiago-Avila et al., 2018). Therefore, I suggest lethal methods may not meet what is in the best interest for people, domestic animals, or carnivores when sharing landscapes.

Alternatively, non-lethal methods—where, when effective, neither carnivores nor livestock experience any harm, or experience sub-lethal harm (i.e., stress)—show a higher rate of success and a lower rate of livestock loss (Bruns et al., 2020; Khorozyan & Waltert, 2021; Treves et al., 2016). Property owners may have an increasing, vested interest in managing carnivores with non-lethal methods, as evidenced by recent surveys in the United States (2013, 1995 and 2014, 2008-2014) (Liu & Sharp, 2018; Slagle et al., 2017; Stone et al., 2017). Growing public preference for non-lethal methods, coupled with the suspected long-term ineffectiveness of lethal methods (Bruns et al., 2020; Khorozyan & Waltert, 2021; Santiago-Avila et al., 2018), inspires interest from some livestock owners to pursue safe and successful solutions for better outcomes between humans, domestic animals, and wildlife.

Non-Lethal Deterrent Methods

Given the potentially detrimental consequences from interspecies conflict for humans, domestic animals, and wildlife, researchers have pursued a variety of solutions benefitting all involved. One area of experimental research is non-lethal deterrents (NLDs), or preventative methods promoting the physical separation of wildlife and livestock without significant harm taking place (Treves et al., 2016). Many methods exist for protecting domestic animals from predators, such as barriers, guards (animals or people), supplemental feeding, or acoustic deterrents (Khorozyan & Waltert, 2020; Louchouarn & Treves, 2023; Treves et al., 2016). In this research I explored visual deterrents because of their relative inexpensiveness, feasibility, and efficacy at small farms (Stone et al., 2017). While humans use many strategies to non-lethally deter wildlife from their livestock, few have been evaluated with robust experimental designs such as the gold-standard of randomized, controlled trials (RCTs) (Khorozyan, 2020; Treves et al., 2019). Used across disciplines, RCTs randomly assign subjects to treatments and controls without overwhelming biases during experiments (sampling, treatment, measurement, reporting, and review) (Ohrens et al., 2019b; Treves et al., 2019). RCT use in NLD research also allows someone to discriminate between the impacts of preventing future livestock losses (a functional effect) and the belief in a preventative non-lethal tactic observed through a shift in behavior or attitude by humans (a perceived effect) (Ohrens et al., 2019b). Researchers can further strengthen an RCT experiment by adding a crossover design, where randomly assigned subjects experience both a treatment and placebo control condition. A crossover design not only strengthens inferences, but continues to remove biases and promotes transparent, reproducible science (Gernsbacher, 2018; Treves et al., 2019). Strong-inference experiments that utilize both an RCT and a crossover design can help demonstrate the potential preventative aspects of NLDs to decrease domestic animal attacks by carnivores.

Scientists evaluated one NLD recently known as fladry—flags attached to nylon rope hanging from a fence line above the ground. Building on anecdotes from eastern European hunters who reported gray wolves would avoid crossing fladry (Okarma, 1993), Dr. Marco Musiani began a program of field and captive studies. The earliest experiments took place in European zoos, where researchers showed the NLD significantly reduced captive wolves crossing the flag lines (Musiani & Visalberghi, 2001). Experiments also took place in field settings, strengthening evidence for its use to keep wolves from approaching livestock (Davidson-Nelson & Gehring, 2010; Iliopoulos et al., 2019; Musiani et al., 2003). Shivik et al. (2003) found the NLD use significantly reduced wolf approaches to white-tailed deer (*Odocoileus virginianus*) carcasses in Wisconsin.

Fladry also shows mixed results for species other than wolves. There is evidence supporting the use of the NLD against coyotes (*Canis latrans*) in field and captive settings (Mettler & Shivik, 2007; Young et al., 2019) and wild boars (*Sus scrofa*) (Iliopoulos et al., 2019). Some studies found the NLD had little to no effect on deterring black bears (*Ursus americanus*) or brown bears (*U. arctos*) (Davidson-Nelson & Gehring, 2010; Iliopoulos et al., 2019; Shivik et al., 2003). Many studies suggest wildlife eventually habituate to NLDs. Therefore, when attempting to increase time to habituation on multi-carnivore landscapes, some researchers are exploring ways to strengthen this NLD, such as adding electrical wire (Lance et al., 2010), or electrifying the fladry itself (Windell et al., 2022). NLD researchers also recommend combining two or more methods of deterrence to increase effectiveness and time to habituation (Khorozyan & Waltert, 2019; Koehler et al., 1990; Linhart et al., 1992; Moreira-Arce et al., 2018; Zarco-González & Monroy-Vilchis, 2014). Khorozyan and Waltert (2019) found wildlife habituate quickest to light and noise deterrents alone.

Furthermore, scientists recently investigated lights as an NLD. Dr. Samuel Linhart and colleagues first found success in reducing coyote attacks on private sheep ranches with strobe lights and siren devices (Linhart et al., 1984). These results were later replicated on large grazing allotments in the Rocky Mountains of Colorado, where researchers found declines in sheep predation with the use of "coyote scare devices"—a newer, more compact model of the original materials (Linhart et al., 1992). Likewise, Shivik et al. (2003) reported another visual/sound NLD—movement activated guard (MAG) devices—showed effectiveness in repelling carnivores from deer carcasses. In fact, the researchers observed that the carcass consumption significantly dropped for seven different species when operating the MAG devices (Shivik et al., 2003). Additionally, researchers found a combined light- and sound-deterrent or a light only deterrent repelled captive coyotes more than a sound deterrent by itself (Darrow & Shivik, 2009). Therefore, this further strengthens the need for researching paired NLDs because scientists can infer relying on multiple NLDs is more effective than a single device or strategy. It is more worthwhile to both researchers and livestock owners if new experiments closer exhibit a more realistic scenario. Following the existing research on paired NLDs, there remains a variety of results relating to the success of visual deterrents. Two meta-analyses show mixed results for various sight and sound NLDs against felids and ursids, respectively, worldwide (Khorozyan & Waltert, 2020, 2021).

Foxlights® are a commercially available, solar-powered light device designed to simulate a person walking around with a flashlight. The device produces flashing lights 360° at random time intervals during nighttime (*Solar Foxlights Instructions*, 2023). As part of the largest NLD RCT in Latin America, Foxlights® were found to deter mountain lions (*Puma concolor*) in Chile, while suggesting a non-significant increase in approaches to livestock by Andean foxes (*Lycalopex culpaeus*) (Ohrens et al., 2019a). A non-RCT found the light devices to significantly reduce leopard (*Panthera pardus*) predations on livestock in India, but did not show a change in leopard visits to a multiple-use landscape (Naha et al., 2020). At least one experiment found an increase of red fox (*Vulpes vulpes*) visits while testing the effectiveness of the lights on a free-range piggery (Hall & Fleming, 2021). Hall and Fleming

(2021) could not determine if this finding also equated to more livestock predation but did find light treatments correlated with fewer piglets born per sow. Uncertainty remains around light device efficacy. By combining two NLDs—fladry and Foxlights®—I can evaluate if there is a change in carnivore behavior through an RCT crossover design.

Improving carnivore coexistence may also demand perceived effectiveness alongside functional effectiveness of NLDs. Perceived effectiveness, as a cognitive state, measures the apparent reduction in damages via any intervention. Rapid responses to a situation (primary/rapid appraisal, such as seeing a large carnivore in the wild) combined with conscious reasoning (secondary/slower appraisal, such as evaluating coexistence options with large carnivores) informs individual's cognitive states related to carnivores (i.e., their attitudes) (Johansson et al., 2012; Ohrens et al., 2019b). I can estimate perceived effectiveness by measuring attitudes of landowners and community members toward carnivores and management practices through time. Ohrens et al. (2019b) suggested collecting perceived effectiveness data before the intervention is implemented (pre-conceived attitudes, influences from social norms, etc.), during the intervention experiment (short-term observations, tolerance for uncertainty, etc.), immediately after the intervention experiment concludes (rapid appraisals of outcomes and unexpected consequences, etc.), and long after the intervention experiment concludes (slower appraisals of outcomes relative to unexpected consequences, etc.) (Ohrens et al., 2019b).

Surveys may inform researchers on the public opinions of wildlife, including preferences for non-lethal methods (Liu & Sharp, 2018; Slagle et al., 2017; Stone et al., 2017). Though a decline in future wildlife visits or attacks after rigorous evaluation solely indicates the functional effectiveness of NLDs, researchers can observe perceived effectiveness whether the NLDs exhibit a functional effect or not. This, then, informs hypotheses around carnivore coexistence when exploring NLDs; carnivore coexistence values and non-lethal methods may be adopted or improved if researchers observe either a functional or perceived effect, or both (Ohrens et al., 2019b).

While NLD experiments designed for strong inference have increased in frequency and strength (Fergus, 2020; Louchouarn & Treves, 2023; Ohrens et al., 2019a), they remain scant compared to other HWCC work (Eklund et al., 2017; Khorozyan, 2022; Ohrens et al., 2019b). Carnivore conservation researchers suggest rigorous NLD experiments are a high-priority research topic because of observed functional effectiveness, low sample size of existing robust research, and the strength of statistical power if properly designed (Díaz-Uriarte, 2002; Khorozyan, 2022; Treves et al., 2016, 2019; van Eeden et al., 2018). Therefore, I investigated if the NLDs of fladry and Foxlights® impact carnivore behavior on the Colorado western slope (a functional evaluation of NLDs), and if private landowner carnivore social tolerance rose during the experiment (a perceived evaluation of NLDs).

I conducted a gold-standard (randomized, controlled trial; RCT) experiment with crossover design on five separate private properties in western Colorado to determine if Foxlights® and fladry reduce the frequency of visits to experimental sites within each property. I predict the NLDs will decrease the frequency of visits for the native Colorado carnivores—coyotes, black bears, mountain lions, and red foxes. If successful, the experimental methods could assist livestock owners in coexisting with wildlife and benefit carnivores by avoiding human-wildlife interaction leading to lethal removal. The results contribute to limited scientific literature on evaluating NLDs through RCTs.

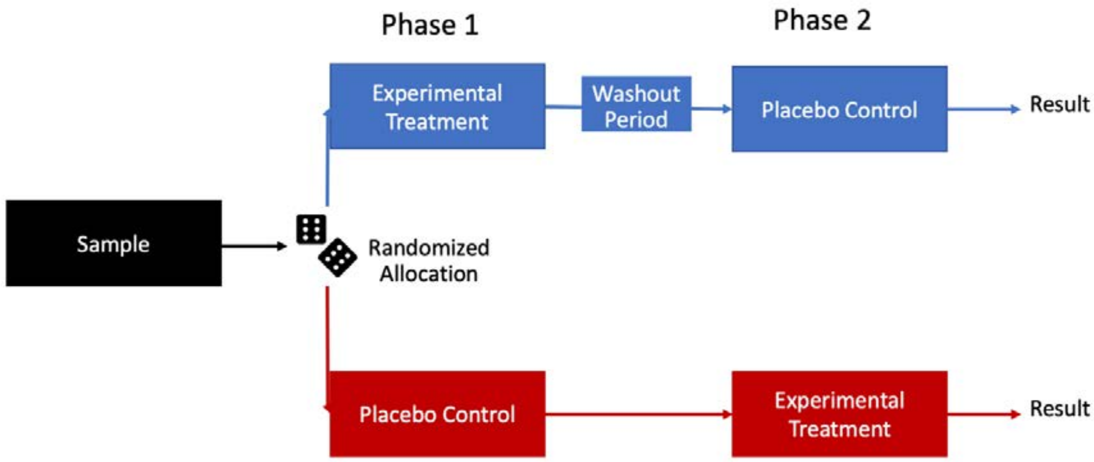
Methods

Experimental Design

The experiment follows a better than gold-standard (randomized, controlled) experimental design, and adds a 2 x 2 crossover trial (Figure 1). I split farms into two separate groups that experience both the treatment (fladry deployed, lights devices operating) and the placebo control (fladry rolled up/ropes without flags deployed, light devices present on study area but turned off) condition. Farms either experienced P/T (control-treatment) or T/P (treatment-control) and approximately equal length phases. This research design produces more transparency and statistical power while aiming to minimize bias produced from a phase or carryover effect.

A phase effect might emerge in my experiment from time progression during the research period, which could be seasonal or phenological. It could also occur if carnivores habituate to the experimental treatment (Díaz-Uriarte, 2002; Jones & Kenward, 1989). The possible significant impact of a phase effect—which would appear as substantial change in carnivore behavior between phases, not conditions—could confound the results of the experiment. Therefore, I attempted to minimize this bias with random-assignment and the Hills-Armitage approach to within-subject analysis. This approach evaluates the difference between conditions within-subjects and also examines the difference between phases within-subjects, so I can detect separate effects of phase or treatment (Díaz-Uriarte, 2002; Hills & Armitage, 1979). The treatment effect measures the change in livestock losses due to intervention. Treatment and phase effects can be difficult to differentiate from each other because of the accumulated mean observations (i.e., farms experiencing positive or negative differences between phases). Additionally, this analysis inflates statistical error, meaning its conservative nature requires a large difference between the treatment and placebo control to reach a level of significance. Inflated statistical error may protect analyses from encountering phase effects, however, researchers must assume a phase effect is present until their statistical analysis indicates otherwise (Díaz-Uriarte, 2002).

Figure 1*: This figure visualizes a randomized control trial with a crossover design. Note the washout period lasts three days.*



A carryover effect might appear in crossover experiments when the result of a treatment in the first phase persists in the next phase (Fergus, 2020; Jones & Kenward, 1989; Ohrens et al., 2019a). In my experiment, the carryover might occur if carnivore behaviors from a Phase 1 treatment condition seeps into the data for a Phase 2 placebo control. A washout period may prevent a treatment from affecting a subsequent placebo control phase. Therefore, I use a period of three days to negate any carryover visits from Phase 1 (Díaz-Uriarte, 2002; Fergus, 2020; Ohrens et al., 2019a).

<u>Study Area</u>

The study area consisted of livestock farms in Montrose and Ouray Counties (Table 1, Figure 2). These counties are ideal settings for a NLD experiment given the proximity to public lands shared between humans, livestock, and wildlife. The state of Colorado experienced a massive human population increase of one million people in the last decade (*U.S. Census Bureau QuickFacts*, 2022). This creates a scenario of higher demand from agricultural professionals in an area experiencing wildfire increases fueled by climate change related drought and changes in seasonality (Wright & Roy, 2022). Higher demand from agricultural professionals could equate to more livestock, perhaps in the highlands of Montrose and Ouray Counties. Additionally, higher herbivory rates in trophic-downgraded ecosystems—such as, those found within Montrose and Ouray Counties—could be connected to more frequent, widespread wildfires (Estes et al., 2011; Holdo et al., 2009). The convergence of geography, agricultural production, and nature within Montrose and Ouray Counties provided an ideal opportunity for carnivore coexistence and NLD research.

Figure 2: *A map of Montrose and Ouray Counties. Created by SH using ArcGIS Online.*

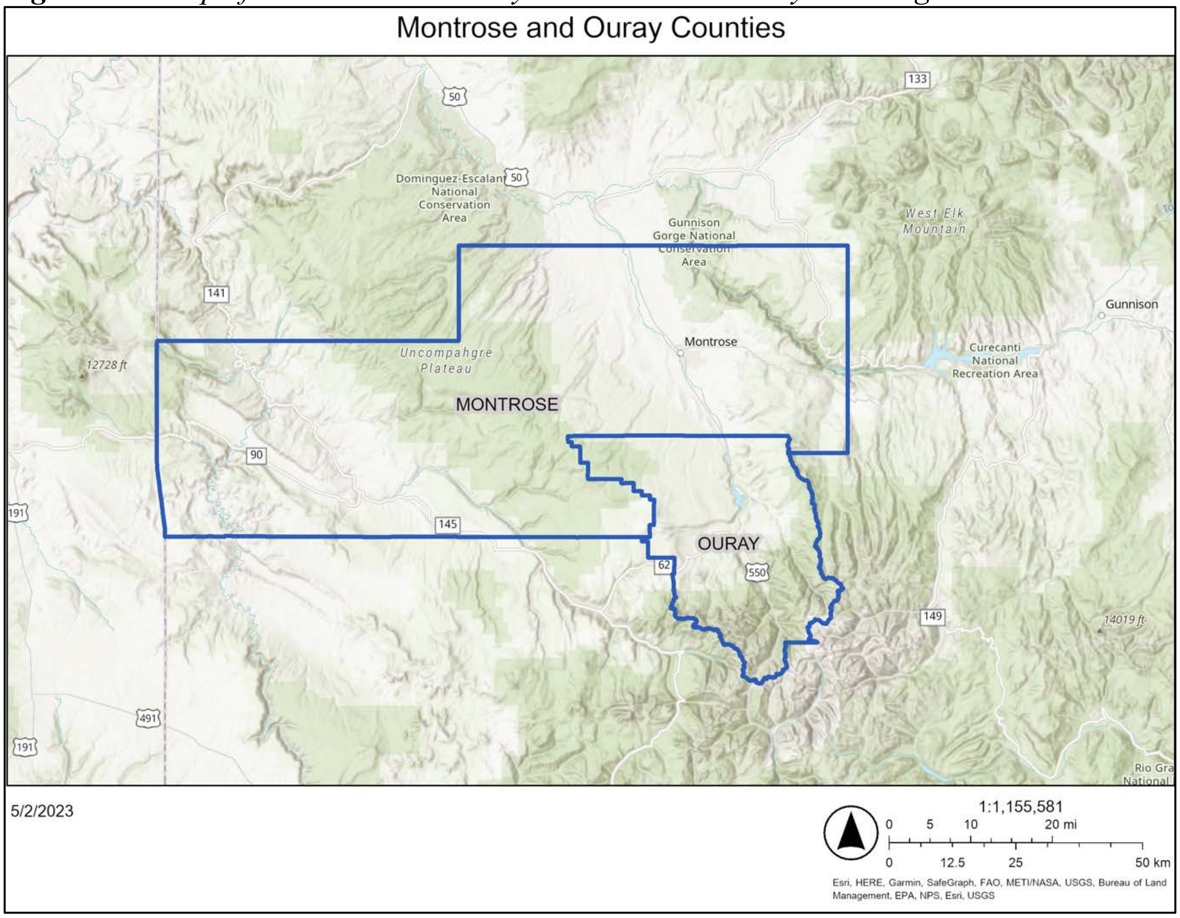


Table 1: *All participating farms, their County, livestock type, and NLDs allocated.*

Farm Name	**County**	**Livestock**	**Number of Lights**	**Fladry (m)**	**Condition Order** P=Placebo control T=Treatment	**Cameras** HF=HyperFire™ HC500 PC=RapidFire™ PC85
Farm Bri	Montrose	Assortment (Cows, Goats, Sheep, Donkey, Alpacas)	3	Partial (95.9 m)	(P/T)	5 (1 HF, 4 PC)
Farm Coy	Ouray	Chickens	4	Y (37.5 m)	(P/T)	4 (3 HF, 1 PC)
Farm Erg	Ouray	Ducks	4	Y (125.7 m)	(T/P)	4 (2 HF, 2 PC)
Farm Fir	Montrose	Llamas	4	Y (201.5 m)	(P/T)	4 (2 HF, 2 PC)
Farm Hay (Dropped)	Ouray	Sheep	-	-	-	-
Farm Mar	Montrose	Alpacas	4	Y (482.8 m)	(T/P)	4 (3 HF, 1 PC)

Landowner Recruitment

The approved University of Wisconsin-Madison Institutional Review Board (IRB) Protocol #2021-0923 protects landowner identities. To find landowners for this experiment, I networked through personal contacts and recruited six (three in Montrose County, and three in Ouray County) between April 2022 and June 2022. I dropped one Ouray County landowner from the experiment due to communication issues, uncertainty of when livestock would be present on the property and for how long, and property size (161 hectares). Also, I connected with one of the participating landowners through an already-existing participant.

I met with each landowner to discuss the experiment and provided them with the recruitment document (Appendix A). Each participant signed an IRB-approved consent form, granting me permission to conduct my experiment on their property. Landowners also agreed to three interviews throughout the summer (pre-experiment, crossover, and post-experiment).

In exchange, they would receive wildlife photos from their property and NLDs used on their land.

Landowner Interviews

To measure the perceived effectiveness of the NLDs and the potential change in carnivore coexistence attitudes, I asked the partner landowners to complete three interviews to determine if their coexistence views changed over time; before (pre-exp), during (mid-exp), and after (post-exp) the NLD experiment (Ohrens et al., 2019b). I used both three-point Likert scale questions and open-ended questions modeled after other survey instruments on carnivore coexistence (Agan et al., 2021; Shelley et al., 2011; Treves et al., 2013) (See Appendix B). Questions spanned topics such as attitudes toward carnivores and livestock management methods. The survey instrument used the same questions across all three interviews outside of a few instances. When conducting the pre-exp interview, I collected demographic information from each of the landowners; age, gender, years of residence in respective county, property size, and herd demographics/size. Next, when I met landowners for the post-exp interview, I included questions to conclude the experiment, such as recommendations for future research, reflections on if the landowners learned anything new, and if they'd be interested to participate in the experiment again. To evaluate for significant changes from the pre-exp to the post-exp interview, I used non-parametric Friedman tests.

Additionally, I administered a community-wide survey with some identical questions in Montrose, Colorado, to provide a backdrop to the perceived effect of the NLD experiment. I asked community respondents about their attitudes toward carnivores and management method preferences. I made no predictions on the potential relationships between landowners and the community, but instead provide a simple data assessment and post-hoc analysis.

Materials

I evaluated two NLDs (fladry, Foxlights®) and two types of field cameras (RapidFire™ PC85 and HyperFire™ HC500) to record data. Traditional fladry uses a canvas-like material attached to a rope spaced 35-50 cm apart (Musiani & Visalberghi, 2001; Okarma, 1993). When modified, it can deter more wildlife like coyotes by narrowing the gap between flags to 10 cm, or the width of an average coyote skull (Fergus, 2020; Young et al., 2019). I constructed fladry with barricade tape and adhered it to 1/8-inch arborist throw rope. Volunteers and I cut each flag to approximately 50 cm and attached them to the rope with 6 mm high carbon steel wire staples. Recent research shows attaching two ropes—one rope at each end of the flag—can reduce flag furling in the wind and wrapping upon itself, leaving it dysfunctional until researchers correct it (Fergus, 2020; Young et al., 2015). There is no peer-reviewed research comparing single-stranded and double-stranded fladry use.

Volunteers and I created all the fladry in this experiment. It took about 45 minutes to produce 20 meters of this NLD. The cost per meter is $1.03 to $1.14 USD, depending on the length of cable ties used (11-inch cable ties: $0.045/m, 8-inch cable ties: $0.163/m) (Appendix C). Throughout the summer, we created 943.4 meters of fladry, meaning we spent between $971.70 and $1,075.48 USD and an estimated 40 hours of work to attach flags to the throw rope. This does not include the time it took to cut 50 cm long flagging tape. I purchased and shipped 20 solar-powered Foxlights® from Australia and Taiwan, respectively, for $1445 USD. Prior to deployment, I charged the light devices for 48 hours in a sunny, outdoor area.

Deployment

After landowners signed the informed consent forms, I began deploying the research materials (fladry, light devices, camera traps). I use motion-activated cameras to remove the confounding variable of in-person monitoring; wildlife behavior could change through presence of specific scents and odors in an area, and this is not the focus of my experiment (Schulte, 2016). Researchers also view camera traps as the best tool for monitoring large mammals because they are easy to use, broadly available, cost effective, and study design standards (Rovero et al., 2013). Deployment of cameras, regardless of treatment or placebo control condition, was the same across all farms. I placed a camera on each side of the NLD perimeter in areas I thought wildlife would frequent (wildlife trails, near water sources, areas without thick vegetation). Cameras remained outside of the perimeter but close enough to the enclosed study areas (within eyesight). In some cases, I placed cameras on the same structures as the NLDs. Also, I cleared vegetation around the fladry and cameras once a week via a handheld grass whip. I checked each camera once per week to ensure they were capturing photos. Furthermore, I replaced batteries when levels reached 20% or lower, and changed out memory cards every week; if I observed an elevated number of carnivore visits during either phase, I would have alerted the landowner(s). However, this never happened.

I installed fladry so that each 50 cm-long flag hung between 2.5-8 cm off of the ground depending on the topography of the study area; meaning, the top of the fladry line was approximately 52.5-58 cm from the ground (Young et al., 2019). The flags encompassed the entire perimeter of animal areas for all farms except for Farm Bri, where I focused the materials to the area of highest landowner concern. I made a distinct effort to line the entire perimeter of the participating properties not only to match similar studies (Fergus, 2020;

Windell et al., 2022), but to ensure if wildlife were to interact with the livestock, they must first go through the fladry we created. A significant rise in carnivore presence or livestock attacks on a farm deployed with NLDs would provide strong inference that they could attract predators rather than deter them.

The light devices were attached via cable ties (30 and 45 cm lengths) to available fencing (wood posts, T-posts, chicken wire, etc.) of the property on all sides of the study area. The manufacturer recommends placing the Foxlights® at a height visible to the predator species of interest, especially as the device intends to simulate a person moving around with a flashlight (*Solar Foxlights Instructions*, 2023); I deployed devices 0.9-1.8 meters off the ground as a estimate median height for carnivores I may encounter (Ohrens et al., 2019a). Deployment height also varied with site-specific conditions, though I attempted to be as consistent as possible.

Setting up the three major components of the research required the assistance of volunteers. Volunteers assisted with all three phases of research: set up of NLDs or placebo control materials at the beginning of Phase 1, changing from Phase 1 to Phase 2, where we would flip the condition to either placebo control or treatment; and clean up, where we removed all materials from the study area.

No equipment experienced major malfunctions as found in Linhart et al. (1992). I did not find any uncharacteristically long periods of time without photos from the camera traps. Additionally, I asked landowners to ensure the lights worked at night; I received no reports of non-functional devices. The llamas at Farm Fir provided some difficulties during the experimental phase—at times, they separated the individual flags from the rope(s). While Fergus (2020) raised concerns with animals chewing on the fladry, I found no evidence of this at Farm Fir. I fixed the flags as needed across all farms and do not consider this a major equipment malfunction.

Ethics Review

This research operates under the approved University of Wisconsin-Madison IRB Protocol #2021-0923 for human subject research (landowner interviews). We also filed and followed our animal (livestock and wildlife) protocols with the University of Wisconsin-Madison Institutional Animal Care and Use Committee to ensure the safety and well-being of all beings in my research.

Visit Definition

The following procedures occurred after I collected all field data. No matter how many photos of the same species were taken, I scored the day-long periods as "1" for presence and "0" for absence on the corresponding farm. I sorted the data in this way due to the low number of carnivores I observed; multiple photo bursts rarely occurred within the same daylight period. Therefore, in the case multiple photos occurred in the same daylight period, I grouped them together as a single visit (See fox visits on Farm Fir, Appendix D). To analyze the number of visits at each farm, I summed the "0"s and "1"s for each day, separated by the two phases—one period for treatment, and another for placebo control in the order the farm is assigned at the beginning of the experiment. I standardized the farms and phases of different lengths by dividing the presence/absence sum by the number of camera trap days (24-hour periods where cameras were active), then multiplied by 100 for ease of visualization and calculation.

I used TimeAndDate.com to log the sunrise and sunset times for each day I deployed the experiment (June 2nd, 2022, to August 17th, 2022). I then found the average sunrise and sunset times and defined photos as “daytime” or “nighttime” according to the calculated means. I classified photos of wildlife between 6:00 am and 8:29 pm as “daytime”, and photos between 8:59 pm and 5:59 am as “nighttime”. Also, to support this decision, none of the observed wildlife visits occurred on the cusp of changing from daytime to nighttime, therefore changing daylength does not confound my analysis.

Effectiveness Analysis

I removed Farm Bri from the full NLD analysis due to the lack of uniformity with the rest of the study farms (I only deployed fladry to a quarter of the property perimeter, compared to the entirety of the remaining farms). Prior to analysis, I checked my data for normality with Shapiro-Wilk tests. The small sample sizes within my experiment may have impaired the W statistic, leading to under or overestimated values. The W statistic estimate is improved with greater sample size (Souza et al., 2023). Even so, I proceeded with the normality tests and found mixed results in the various ways I categorized the data. Therefore, with invalidated test parameters and mixed results, I concluded the data as non-normal for all further analyses. I ran a Wilcoxon signed rank test with a Hills-Armitage approach (Díaz-Uriarte, 2002) to detect difference between placebo control and treatment within farms. A sample size of four subjects permits a Wilcoxon signed rank test but with low power to discriminate between the two phases. Therefore, I do not put all my faith in the statistical tests of significance and report the raw data so readers can draw their own conclusions (Appendix E).

To first test for a phase effect, I ran a paired response Wilcoxon signed rank test (Phase 1 minus Phase 2). If the data did not indicate a phase effect, I then tested if there was a treatment effect. To do so, I ran a Welch’s t-test, because I assumed unequal variances

(Treatment and Control). The hypothesized mean for the t-test is 0, meaning, no difference between the treatment and control phases. The alpha level is $p<0.05$. I noted a tendency when $0.05<p \leq 0.1$.

Additionally, since Foxlights® only operate at night, I ran a separate analysis for nighttime visits to the farms. I re-included Farm Bri for this sub-analysis as it only evaluates the effectiveness of light devices, and I allocated and deployed them equally across all farms. I conducted this analysis to further explore if the lights alone are a sufficient NLD, as debated among peer-reviewed articles (Hall & Fleming, 2021; Ohrens et al., 2019a). I isolated this variable by only analyzing the nighttime visits and approached this data as non-normal. Once again, I tested for phase and treatment effects of the data using a Hills-Armitage approach—a Wilcoxon signed rank test and a Welch's t-test.

Results

Carnivore Presence

I studied five farms (Table 2) over 77 days (Median=55 days, Interquartile Range (IQR)= 43 to 62 days) and recorded no attacks on domestic animals or people. In all, I observed four different carnivore species 112 times: black bears (7 visits), mountain lion (one visit), outdoor cats (59 visits), and red foxes (45 visits) (Table 3, Appendix D). I did not detect coyotes during the experiment through the motion-sensing cameras, although two landowners reported hearing coyotes at night during the study on multiple occasions. One carnivore visited during a washout period, meaning the visit was excluded from analysis to reduce the potential bias of a carryover effect.

Table 2: *Participating farms with detected carnivores.*

ID	Livestock	# Animals	Existing Protections	Condition Order	Carnivores Detected	Total Photos Used
Farm Bri	Assortment (Cows, Goats, Sheep, Donkey, Alpacas)	11	Various fencing, guard animal, noise deterrent	(P/T)	*Felis catus, Ursus americanus, Vulpes vulpes*	74
Farm Coy	Chickens	8	Various fencing, husbandry strategies	(P/T)	*Felis catus, Panthera concolor, Ursus americanus, Vulpes vulpes*	412
Farm Erg	Ducks	12	Electric fencing, husbandry strategies	(T/P)	*Vulpes vulpes*	42
Farm Fir	Llamas	5	Guns, husbandry strategies, yelling/floodlights	(P/T)	*Ursus americanus, Vulpes vulpes*	114
Farm Mar	Alpacas	33	Guard animal, fencing	(T/P)	*Vulpes vulpes*	3

Table 3: *All carnivore visits by farm, treatment phase, and order of placebo control (P) and treatment (T) conditions. I also included number of camera trap days. The Treatment-Placebo Control column reflects the difference between the two experimental conditions and ignores phase order.*

Farm	Camera Trap Days (Phase 1, Phase 2)	Phase 1 Visits	Phase 2 Visits	Phase 1-Phase 2	Treatment-Placebo Control	Order
Bri	44 (22, 22)	10	12	-2	2	P/T
Coy	62 (29, 33)	32	26	6	-6	P/T
Erg	45 (22, 23)	7	3	4	4	T/P
Fir	55 (26, 29)	13	8	5	-5	P/T
Mar	57 (28, 29)	0	1	-1	-1	T/P

Non-Lethal Deterrent Results

I removed Farm Bri from the full NLD analysis because I treated it differently from other farms. A Wilcoxon signed rank test indicated no phase effects in each of the 10 categories analyzed (Table 4). I found no treatment effect in these breakdowns, either. (Table 5, Figure 3).

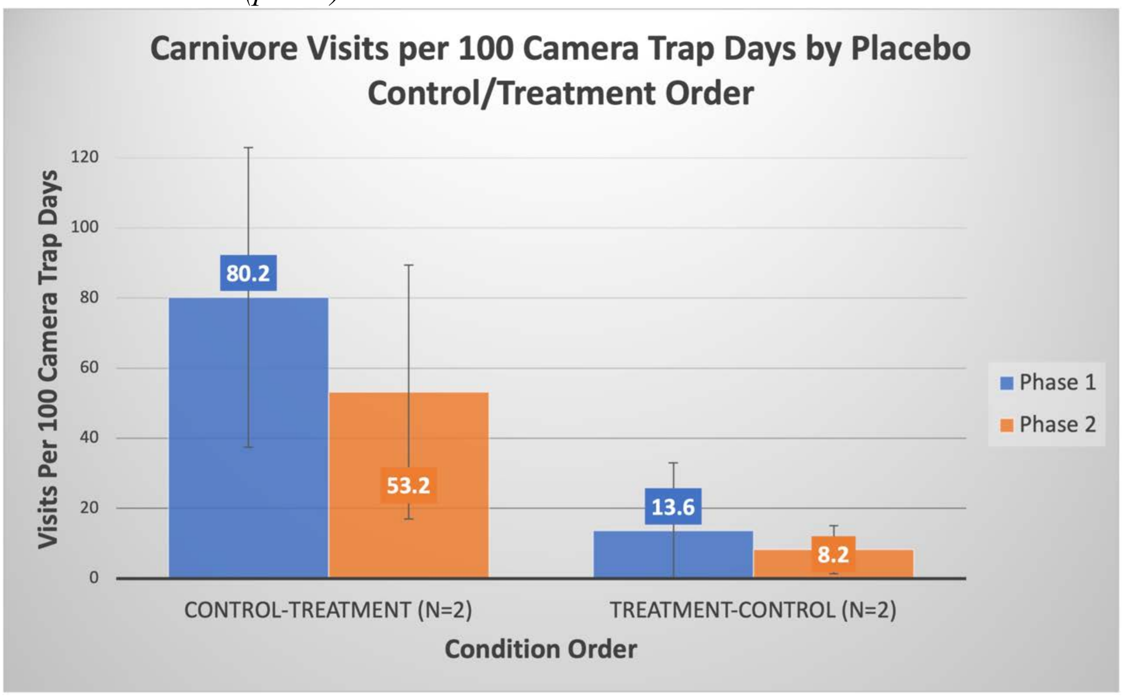
Table 4: *Test statistics for all categories tested in the phase effect analysis. I observed high enough visits from both foxes and outdoor cats to run additional analyses on their nighttime activities which are included below.*

Species Analyzed	Wilcoxon Signed Rank S Statistic (S)	P-Value (p)
All Carnivores	-4.0	0.2
All Large Carnivores	3.5	0.5
Fox (Overall)	-3.0	0.4
Fox (Day)	-3.5	0.5
Fox (Night)	-2.0	0.6
Mountain Lion	2.0	1.0
Black Bear	3.5	0.5
Outdoor Cat (Overall)	-0.5	1.0
Outdoor Cat (Day)	-0.5	1.0
Outdoor Cat (Night)	-2.0	1.0

Table 5: *Treatment effect of fladry and light devices using Welch's t-tests.*

Species Analyzed	Welch's t-test (t)	Degrees of Freedom (df)	Critical Value (CV)	P-Value (p)
All Carnivores	-0.37	5	2.6	0.7
All Large Carnivores	1.4	3	3.2	0.2
Fox (Overall)	-0.23	5	2.6	0.8
Fox (Day)	-1.0	3	3.2	0.4
Fox (Night)	0.53	6	2.4	0.6
Mountain Lion	1.0	3	3.2	0.4
Black Bear	1.2	4	2.8	0.3
Outdoor Cat (Overall)	-0.45	5	2.6	0.7
Outdoor Cat (Day)	-0.57	5	2.6	0.6
Outdoor Cat (Night)	-0.39	5	2.6	0.7

Figure 3: *All carnivore visits across all farms except for Farm Bri (N=4). Note standard error bars are not normally appropriate for a sample of N=2 but are included to illustrate the high variability of data. I found no significant difference between treatment and placebo control conditions (p=0.7).*



<u>Foxlight® Analysis Results</u>

I re-included all farms because they all received the same deployment of light devices (N=5). I excluded any daytime visits (Table 6) and found no phase effect at night (Table 7). The Welch's t-tests I ran revealed no treatment effect between conditions (Table 8).

Table 6: *Night carnivore visits by farm, treatment phase, and order of control (P) and treatment (T).*

Farm	Camera Trap Days (Phase 1, Phase 2)	Phase 1 Night Visits	Phase 2 Night Visits	Night Phase 1-Phase 2	Night Treatment-Placebo Control	Order
Bri	44 (22, 22)	8	9	-1	1	P/T
Coy	62 (29, 33)	23	20	3	-3	P/T
Erg	45 (22, 23)	7	1	6	6	T/P
Fir	55 (26, 29)	6	6	0	0	P/T
Mar	57 (28, 29)	0	1	-1	-1	T/P

Table 7: *Test statistics for all categories tested in the phase effect of light devices.*

Species Analyzed	Wilcoxon Signed Rank S Statistic (S)	P-Value (p)
All Carnivores (Night)	-2.5	0.6
All Large Carnivores (Night)	6.0	0.2
Fox (Night)	-4.5	0.3
Mountain Lion (Night)	2.5	1.0
Black Bear (Night)	6.0	0.2
Outdoor Cat (Night)	-0.5	1.0

Table 8: *Treatment effect for light devices. I found no evidence of behavior change in the Welch's t-tests.*

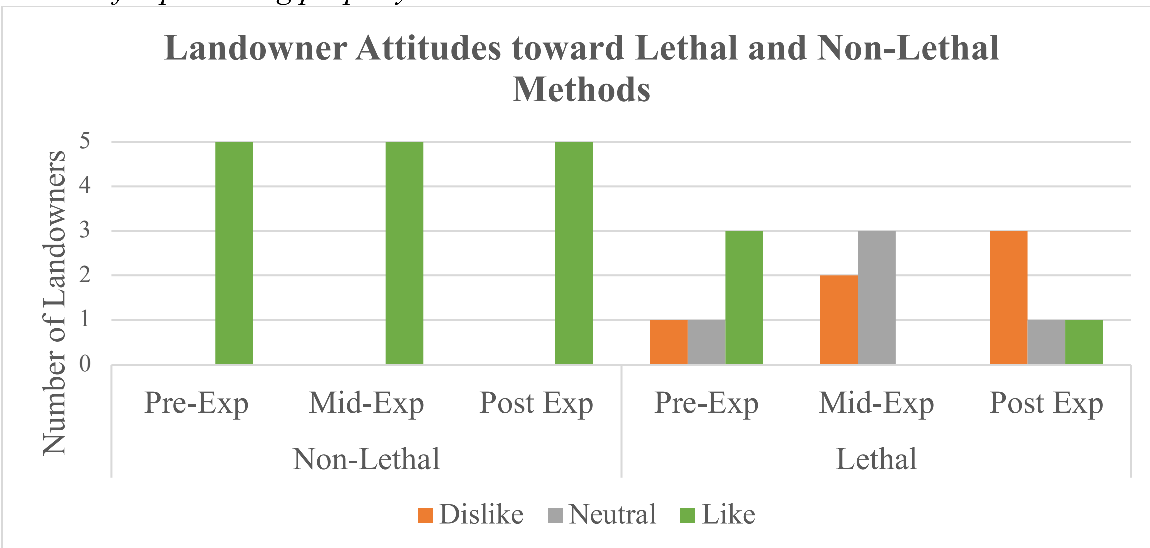
Species Analyzed	Welch's t-test (t)	Degrees of Freedom (df)	Critical Value (CV)	P-Value (p)
All Carnivores (Night)	0.06	7	2.4	1.0
All Large Carnivores (Night)	1.1	5	2.6	0.3
Fox (Night)	0.24	8	2.3	0.8
Mountain Lion (Night)	1.0	4	2.8	0.4
Black Bear (Night)	1.1	6	2.4	0.3
Outdoor Cat (Night)	-0.21	6	2.4	0.8

<u>Landowner Interviews</u>

The five participating landowners varied in age (Median=70, IQR=63 to 77 years), length of residency in Montrose or Ouray County (Median=22, IQR=10 to 52 years), total property size (Median=28, IQR=8 to 295 acres), and experimental property size—meaning, the area in which we set up the NLD experiments (Median=0.69, IQR=0.02 to 2.4 acres). Additionally, each farm ran different livestock (Table 2).

All five of the participating landowners supported effective, safe, non-lethal management of wildlife throughout the experiment without variation in attitude (-1=Dislike, 0=Neutral, +1=Like) (Pre-Exp Median=+1; Mid-Exp Median=+1; Post-Exp Median=+1; N=5). Negative views of effective, safe, lethal management of wildlife appeared to increase as time progressed (Pre-Exp Median=+1, IQR=0 to +1; Mid-Exp Median=0, IQR=-1 to 0; Post-Exp Median=-1, IQR=-1 to 0; N=5) (Figure 4). A nonparametric Friedman test tells me these changes are non-significant (Q=1.9, df=2, p=0.4). All landowners agreed with zero variation that effectiveness in reducing future threats to their land and livestock matters to them (Pre-Exp Median=+1; Mid-Exp Median=+1; Post-Exp Median=+1; N=5). All but one landowner expressed interest in continuing to protect their property with the tested NLDs after the experiment, regardless of the results. The landowner stated, "most of my other animals use a lot of acreage and are always moving. Even though I support non-lethal methods it's not feasible for me to use [the tested NLDs]." Additionally, all landowners were interested in participating in an experiment like this again in the future, and most (80%) stated they learned something new during the research. No landowners indicated they believed the NLDs were ineffective or attracted carnivores rather than repelled them (Appendix B).

Figure 4: *Landowner responses regarding their attitudes about lethal and non-lethal methods for protecting property.*



Landowners also shared their feelings about carnivores. Overall, I observed favorable views of carnivores from the landowners (Pre-Exp Median=0.8, IQR=+0.5 to +1; Mid-Exp Median=0.8, IQR=+0.2 to +1; Post-Exp Median=0, IQR=-0.5 to +0.5; N=5) (Table 9). I found no significant changes over time using a nonparametric Friedman test and found no significance when pooling all carnivores (Q=0.7, df=2, p=0.7). I observed changes in attitude for coyotes (Pre-Exp Median=+1, IQR=0 to +1; Mid-Exp Median=+1, IQR=0 to +1; Post-Exp Median=0, IQR=-1 to +1; N=5), mountain lions (Pre-Exp Median=+1, IQR=0 to +1; Mid-Exp Median=+1, IQR=0 to +1; Post-Exp Median=0, IQR=-1 to +1; N=5), and gray wolves (Pre-Exp Median=0, IQR=0 to +1; Mid-Exp Median=0, IQR=0 to +1; Post-Exp Median=0, IQR=0; N=5). Friedman tests completed for coyotes (Q=0.9, df=2, p=0.6), mountain lions (Q=0.7, df=2, p=0.7), and gray wolves (Q=0.1, df=2, p=1.0) indicated the changes in attitude I observed were non-significant. Views toward black bears remained positive and consistent during the interviews (Pre-Exp Median=+1, IQR=0; Mid-Exp Median=+1, IQR=0; Post-Exp Median=+1, IQR=0).

Table 9: *The summarized data of responses for each of the carnivores I asked about in the landowner interviews.*

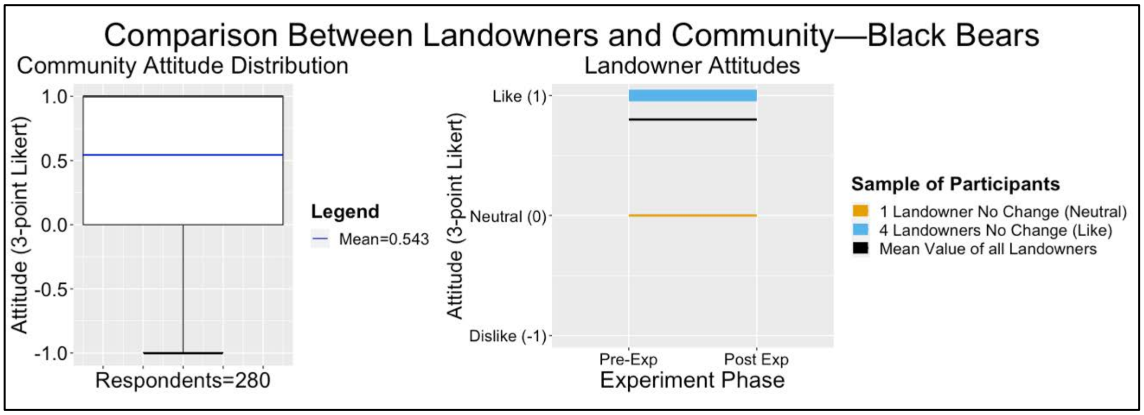
Species	Experiment Phase	Landowner Responses (n=5)		
		Dislike	Neutral	Like
Coyotes	Pre-Exp	0	2	3
	Mid-Exp	1	1	3
	Post Exp	2	1	2
Black Bears	Pre-Exp	0	1	4
	Mid-Exp	0	1	4
	Post Exp	0	1	4
Gray Wolves	Pre-Exp	1	2	2
	Mid-Exp	1	2	2
	Post Exp	1	3	1
Mountain Lions	Pre-Exp	0	2	3
	Mid-Exp	1	1	3
	Post Exp	2	1	2

Landowner Interview Comparison with Community Survey Data

I evaluated the perceived effect of the NLDs through attitude surveys of landowners and community members. For the landowner interview-community survey comparisons, I interpreted the data post-hoc.

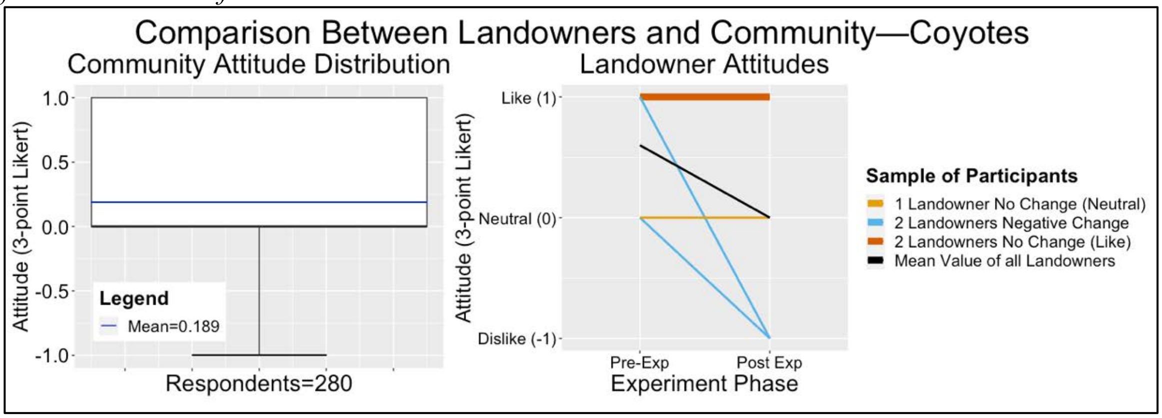
Black bears (Median=+1, IQR=0 to +1, Mean=+0.5): I observed 4/5 landowners rate black bears as "like" and one respondent rated them as "neutral" (Median=+1, IQR=0) through the experiment. When comparing landowners to the community data, I observed a similar approval of black bears—most respondents stated they "like" the Ursid (Figure 5). A post-hoc Wilcoxon ranked-sum test indicated the post experiment landowner attitudes were not significantly different than the community attitudes (T=782, z=0.4, p=0.6).

Figure 5: *Boxplot comparison of community and landowner attitudes. Most of the community appears to like black bears (M=0.5) and most landowners like black bears as well.*



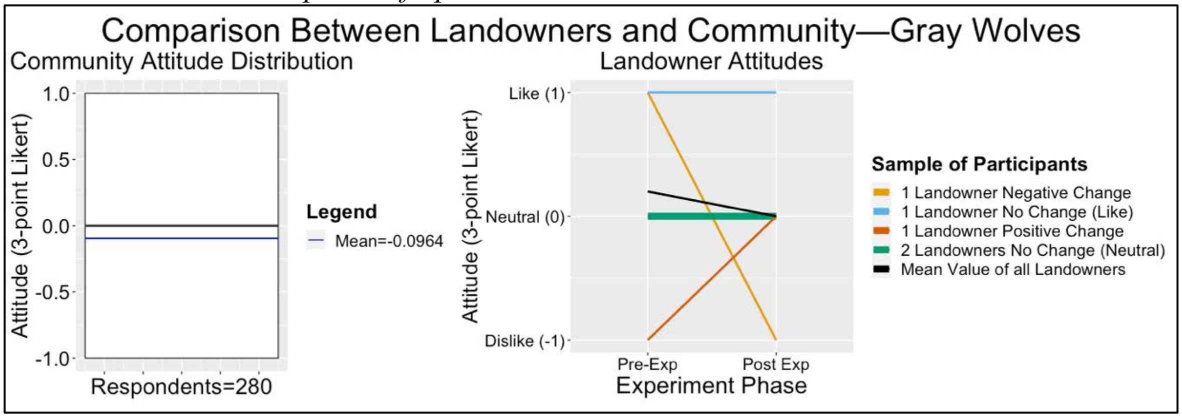
<u>Coyotes (Median=0, IQR=0 to +1, Mean=+0.2)</u>: I observed a decline in approval from the landowners regarding coyotes. There were no coyote visits in the NLD experiment, or a reported conflict from the landowners. I observed a large spread in the community survey with a median of neutral attitudes (Figure 6). The mean value of the community attitudes still resided above 0, meaning most respondents held neutral-to-favorable views of coyotes. A post-hoc Wilcoxon ranked-sum test indicated the post experiment landowner attitudes were not significantly different than the community attitudes (T=635.5, z=-0.4, p=0.3).

Figure 6: *Comparison of landowner and community attitudes. Most of the community "liked" coyotes (M=0.2), but by the end of the landowner interviews, there is an even spread of favorable and unfavorable views.*



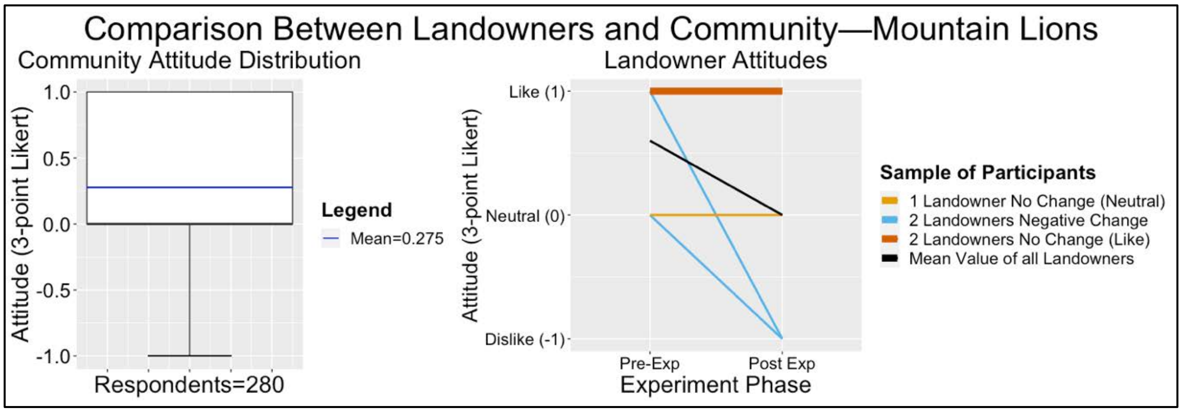
<u>Gray wolves (Median=0, IQR=-1 to +1, Mean=-0.1):</u> Gray wolves are the most controversial animal in my dataset. At the beginning of the landowner interviews, there was a spread of opinions. By the end, the variability persisted. Most respondents replied "neutral" during the post-experiment interview. The community survey was similar to the results from the landowners—a spread of opinions, with an IQR from -1 to +1 (Figure 7). The gray wolf was the only animal with most respondents stating they did not like them (mean<1, indicating the response is below "Neutral (0)"). A post-hoc Wilcoxon ranked-sum test indicated the post experiment landowner attitudes were not significantly different than the community attitudes (T=612.5, z=-0.6, p=0.3).

***Figure** 7: Comparison between landowners and the community for gray wolves. In both instances, there was a spread of opinions.*



Mountain lions (Median=0, IQR=0 to +1, Mean= +0.3): Landowners held a large spread of attitudes in the interviews. The data indicated a decline in mountain lion attitudes overall. As a community, the respondents' attitudes were neutral (Figure 8). There is a positive mean associated with mountain lions. Some individuals believed they pose a bigger threat to livestock than gray wolves—several times landowners and community members commented on the size of the mountain lion population and how it creates an unsafe landscape due to the secretive nature of the big cat. A post-hoc Wilcoxon ranked-sum test indicated the post experiment landowner attitudes were not significantly different than the community attitudes (T=495, z=-1.2, p=0.1).

Figure 8: *Comparison between landowners and community on their attitudes toward mountain lions.*



Lethal methods (Median=0, IQR=-1 to +1, Mean=+3.6X10^{-3}): Landowner support for lethal methods declined, indicating possible growth of coexistence values. The community appeared to have a wide division of views when it comes to lethal methods. Proximity to lethal method use may vary for community members (Figure 9). A post-hoc, one-tailed Wilcoxon ranked-sum test indicated the post experiment landowner attitudes were significantly different than the community attitudes (T=396.5, z=-1.7, p=0.04), meaning, landowners at the end of the experiment disliked lethal methods more than their community counterparts. This result is reflected in the change of attitudes from two farmers.

Non-lethal methods (Median=+1, IQR=0 to +1, Mean=+0.4): There appeared to be a higher degree of support across the community and landowners for non-lethal methods. This indicates there may be support amongst the community to implement the experimental NLDs. Landowners supported NLDs throughout the experiment (Figure 9). A post-hoc Wilcoxon ranked-sum test indicated the post experiment landowner attitudes were not significantly different than the community attitudes (T=810, z=0.5, p=0.7).

Figure 9: *Comparison of community and landowner views on lethal methods. While landowners decreased their support for lethal methods, the community is divided.*

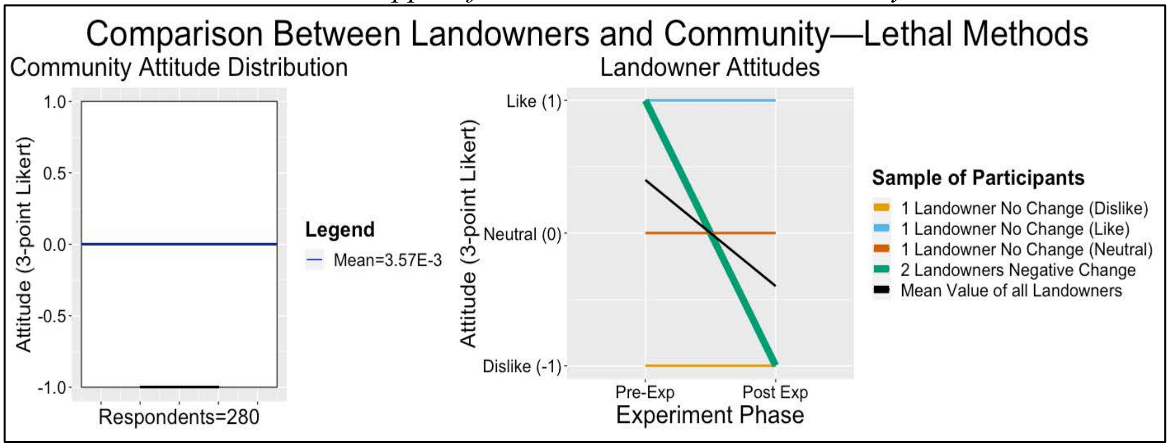
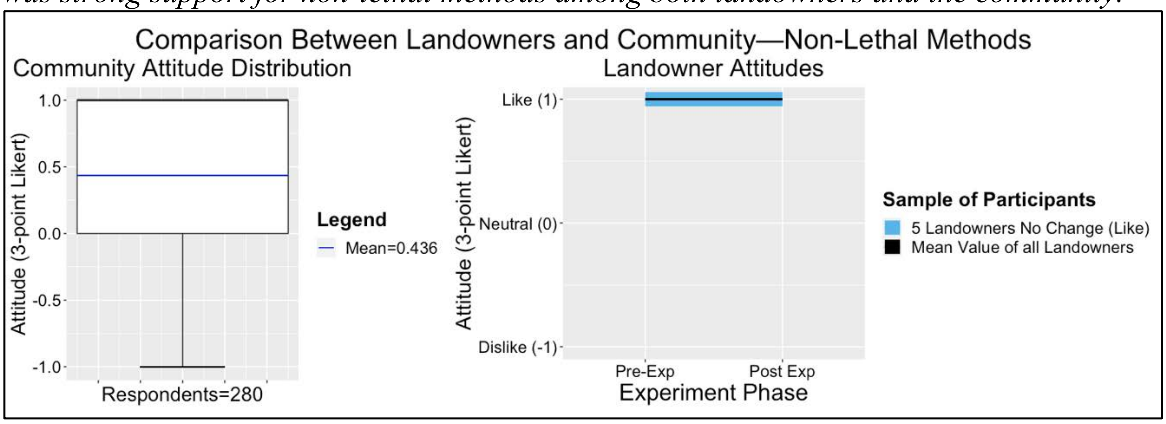


Figure 10: *Comparison of community and landowner views on non-lethal methods. There was strong support for non-lethal methods among both landowners and the community.*



Discussion

Non-Lethal Deterrent Experiment Evaluation

In this experiment, I investigated if the non-lethal deterrents (NLD) of fladry and Foxlights® affect carnivore behavior on the Colorado western slope. During the summer of 2022, four different carnivore species visited the five study areas. No livestock attacks occurred during the experiment. I predicted the NLDs would significantly reduce carnivore visits to the farms. After analyzing the data, I cannot support nor refute this hypothesis because of the short time span and small sample size of the experiment.

My results are comparable to Fergus (2020) because they also found insignificant changes in carnivore visits (black bears, coyotes). The findings from my experiment do not align with earlier research demonstrating that Foxlights® attracted foxes to outdoor pig paddocks in Australia (Hall & Fleming, 2021) or Andean foxes to alpacas and sheep in Chile (Ohrens et al., 2019a). Hall and Fleming (2021) raised concerns over the potential hastened habituation deriving from prolonged exposure to light devices. Likewise, Ohrens et al. (2019) reported Andean fox behavior did not change in response to light devices, given observed attacks in both treatment and placebo control phases. Therefore, while my experiment yields no significant findings, the results may align with the strategy to combine two or more NLDs to increase effectiveness and decrease time to habituation (Khorozyan & Waltert, 2019; Koehler et al., 1990; Linhart et al., 1992; Moreira-Arce et al., 2018; Zarco-González & Monroy-Vilchis, 2014). Multiple NLDs incorporated on a study area may significantly limit attacks on livestock versus a single NLD (i.e., lights), but researchers have yet to evaluate this potential using RCT-crossover experimental design.

While I am confident in the experimental methods, some limitations of this study exist. First, while motion-activated cameras offer great opportunity to decrease evidence of human presence, cameras are fixed in a single position and are unable to capture possible carnivore visits which occur outside of the respective photo frames. I attempt to cover as much of the farm perimeter as feasible, but it is likely some carnivore visits were undetectable by the cameras. Next, the small sample size of five farms reduced the statistical power of my experiment. Adding a single farm to this analysis with a similar number of carnivore visits could alter the outcomes of the experiment entirely. Therefore, it is crucial to follow up this experiment with a meta-analysis of similar research. Last, the experiment did not last long enough nor was there enough carnivore visits to consider carnivore habituation, a recurring issue in NLD research (Khorozyan & Waltert, 2019). Completing longer experiments with more farms may not only provide more insight into the effectiveness of these NLDs but could also provide more helpful information for livestock owners using visual deterrents on their property.

By providing possible explanations for my observations, I could help researchers determine the future of NLD experiments. First, the data shows a pattern of black bears visits in the experiment. My study produced no significant evidence that the NLDs attracted black bears; however, more black bears visited the properties during the second phase of the experiment. This could indicate the presence of long-range movements by individual bears (Schuyler et al., 2021). The late summer may prompt bears to journey down from the highlands back to the river basin like other large ungulates and carnivores in this region. Therefore, carnivore visits during the early summer could have been suppressed, as there may have been less prey around the study areas. In the future, when researching on multi-carnivore landscapes, experiment should start in the late summer and end in the spring to counteract natural wildlife movements and attain more data points. The ideal timing of an experiment may change if attempting to target a specific carnivore species.

Next, I consider the wide diversity of livestock at the participating farms. Each farm in the study owned different domestic animals (llamas, alpacas, ducks, chickens, or a variety of those species). I controlled for the variety of livestock at the study areas by conducting a within-subjects analysis, which compares each farm to itself. However, as researchers complete more RCT NLD experiments, carnivore visit trends could emerge with size of the farm and livestock type. Even though this is a moot point while using a within-subjects analysis, the results of the NLD experiments could be strengthened while also using farms of similar size and a smaller variety of livestock.

Furthermore, geography of study areas and proximity to carnivore habitat may influence visit frequency. While analyzing the data within-subjects to control this variable, the number of carnivore visits to a property could correlate to the distance from suitable habitat(s) (Ripari et al., 2022). For example, one of the farms resides between three cattle ranches and a major road. The landowner assumes these landmarks inadvertently protect their property from wildlife conflict, and my data reflects this sentiment—only one carnivore visited this study area during the experiment. Conversely, some of the study areas border streams in a drought-stricken region (Scasta et al., 2016; Wright & Roy, 2022). Therefore, I hypothesize that carnivores may visit study areas near water sources more often than sites further away. Even though the within-subjects design protects my analysis from this variable, researchers should strive to meet the assumptions for parametric statistical tests, which produce more power than non-parametric tests. Parametric tests require similar variances between variables, meaning researchers should choose to experiment on similar properties if that is an option. Without more research on the relationship between carnivore visits in NLD experiments and proximity to bodies of water, I cannot consider properties closer to water sources as more prone to carnivore visits. I would encourage future research to consider property proximity to water as another variable to consider in their datasets—especially in the drought-stricken regions of the western United States. However, choosiness of which farms to run NLD experiments on is not a regular occurrence, as seen with this study and Fergus (2020).

While there were no major equipment failures, there are many possible difficulties future researchers may encounter. First, solar-powered Foxlights® must receive "full sunlight" to operate. If it is ideal to deploy a light device in a shaded area, replace it with a fully-charged solar device or use battery-powered devices instead of relying on a single device (*Solar Foxlights Instructions*, 2023). Conversely, researchers should not place cameras in the direct sun. Reconyx® states high temperatures (>90º F) can reduce battery life by up to 50%, alter images, and impact animal detection (*HyperFire Instruction Manual*, 2017). The best place for cameras may be under a tree, and not facing east or west. This can be a difficult requirement to meet when monitoring rangeland with motion-activated cameras; it could be beneficial to provide artificial shade in these scenarios.

In summary, I have added to the knowledge of RCT NLD experiments by detailing the experimental methods and observing a lack of conflict in my experiment (Fergus, 2020; Louchouarn & Treves, 2023; Ohrens et al., 2019a). Researchers should continue conducting experiments with a gold-standard, crossover design to meet the best interest of wildlife, livestock, and humans. Claims of success or ineffectiveness while using NLDs can only be verified with the strongest experimental inference possible. Even so, there is still a lacking amount of NLD research using RCT with a crossover design (Khorozyan, 2022). Researchers can create sounder comparisons with more data by using similar methods of experimental design and analysis. Since my study is comparable to Fergus (2020), we can conduct a meta-analysis on our datasets. Both authors want to pursue the possibility to share combined results with NLD researchers.

This may be the first ever RCT-crossover NLD experiment completed in western Colorado (Treves et al., 2016). I expect this research to serve as a guiding document for future NLD work in this region. So long as the research uses the same experimental design and analyzes data within-subjects, results and data between studies are comparable (Mikolajewicz & Komarova, 2019). However, even when researchers combine numerous, similar studies, they may find no treatment effect because a presumed change in behavior could only occur for one species of carnivore, one type of livestock, or some other narrow set of circumstances. Such a result would be informative, but until researchers complete more gold-standard experiments analyzing within-subjects, I cannot be confident with claims of effect or no effect.

Landowner Interviews

To measure the perceived effectiveness of the NLDs (Ohrens et al., 2019b), I conducted landowner interviews throughout the summer (pre-experiment, mid-experiment, post-experiment). I predicted landowners to significantly change their responses in favor of carnivore coexistence values. There were no significant changes in landowner attitudes during the experiment. Even without the data-driven evidence of improved carnivore coexistence values, a perceived effect of the NLDs may be present. No landowners expressed to me that the NLDs were ineffective, nor that they were attracting carnivores rather than repelling them. I interpret NLD success as anti-climactic and paradoxical; when the NLDs display functional effectiveness, ideally, no (or significantly less) carnivore interactions should occur.

Recruiting more landowners (thus, increasing the sample size) may make seemingly subtle changes in attitude more significant. Some landowners disclosed their values could change depending on the day. When using a three-point Likert scale instead of the social science-preferred five-point Likert scale, these small changes appear drastic and apparent (Joshi et al., 2015). Future research utilizing landowner interviews should rely on five-point Likert scales to better approximate nuanced changes. Additionally, a mixed-method examination (interviews, questionnaires, focus groups) with more open-ended questions may yield more interesting results (Browne-Nuñez et al., 2015). Participating landowners may have already held positive carnivore coexistence values, indicating there could have been self-selection bias in my research. Self-selection bias occurs when results are skewed to influence who participates in the study (Treves et al., 2019). In my experiment, it is possible that landowners with pre-existing positive coexistence values were more likely to participate, while those with negative values opted out; a finding that may be reflected in Gil-Fernández et al. (2023). I am not aware of research studying how self-selection bias affects change in attitudes to carnivores.

With self-selection bias potentially influencing the outcome of the interviews, I still observed outcomes worthy of further discussion. First, landowner attitudes toward coyotes declined non-significantly over time. There were no coyote visits in the NLD experiment, or a reported conflict from the landowners. This is an interesting finding because none of the landowners started with the attitude of “dislike”, yet by the post experiment interview, two landowners stated their attitudes changed to the lowest rating category. Perhaps, as time progressed, landowners felt more comfortable with me and were able to answer the interview questions with responses that more closely matched their feelings. Second, I found only a minority of landowners that stated they “disliked” wolves throughout the experiment, a rare finding when comparing my results with some recent surveys where tolerance for wolves declined over years or in relation to changing policies over several months (Browne-Nuñez et al., 2015; Hogberg et al., 2016; Niemiec et al., 2022; Treves et al., 2013). Surveys from Treves et al. (2013) and Hogberg et al. (2016), for example, illustrate Wisconsin resident attitude change regarding gray wolves through many historical events, such as the state's inaugural wolf hunt. My interviews were only separated by a couple of months. Previous research signals there may be a significant decrease in landowner wolf attitudes following a landmark event, such as the Colorado gray wolf reintroduction. When considering the intriguing results of the landowner interviews, my hypothesis is not upheld.

While the landowners in my study did not experience significant attitude changes—thus, signaling a perceived ineffectiveness of NLDs—early research from Colombia shows stronger evidence for positive shifts in coexistence values with a larger sample size (Pineda-Guerrero & Treves, 2023). When asking participants about their attitudes to mountain lions and jaguars (*Panthera onca*), Pineda-Guerrero and Treves (2023) found as much as a 40% positive increase among their respondents. Further, the Colombian landowners exhibited a positive shift in the perceived effectiveness of Foxlights® while the light devices produced no significant changes in carnivore behavior. The conflicting results of these two measures should prompt future researchers to continue the coupled landowner interviews and NLD experiments to better understand landowner carnivore coexistence values.

I hypothesize the differences in response results between Pineda-Guerrero and Treves (2023) and this study may correspond to the sample size of participating landowners, but cultural differences may also affect the interview outcomes. Colombia is one of the most biodiverse countries in the world, ranking sixth in mammal biodiversity—most of which resides in the Northern Andean Mountains (Bedoya-Durán et al., 2021). As forest habitat loss continues—and with it, habitat fragmentation and human disturbance of wildlife—local non-governmental organizations began forming small (<100 ha), privately-protected conservation areas, which do not provide a significant impact on forest mammalian species, likely due to the lack of connectivity between protected areas (Bedoya-Durán et al., 2021). Also, a recent study from Costa Rica demonstrates a unique duality among ranchers in their attitudes toward jaguars and mountain lions, illustrating what carnivore coexistence in Latin America could look like. Most of the surveyed ranchers believed big cat-livestock coexistence cannot occur without conflict (66%), big cats are dangerous to people (63.3%), and that the felids cause economic losses (66.1%). At the same time, ranchers recognized the importance of big cats to the forests (90.6%), asserted felid attacks can be prevented (72.7%), and felt if livestock losses from felids were few, then they can be tolerated (77.3%) (Gil-Fernández et al., 2023). The structure of the community-led, private-protected conservation areas and high rancher carnivore tolerance from Gil-Fernández et al. (2023) and Pineda-Guerrero and Treves (2023) demonstrate some evidence for cultural differences around attitudes to carnivores between Latin America and the United States.

Additionally, when I compared the landowner interviews to the community survey, most of the post-hoc analyses found no significant differences between the two sampled groups. I may have observed slightly diverged attitudes because of varying levels of wildlife experience between the landowners and community members. However, a post-hoc Wilcoxon ranked-sum test found landowners felt significantly different about lethal methods compared to their community neighbors. Given their proximity to the experiment all summer, perhaps their perspective shifted due to increased exposure to NLDs. Once again, this could reflect self-selection biases; landowners pre-experiment openness to exploring NLDs may influence the outcomes of post-hoc comparisons and could be unrepresentative of the community. Also, sample size differences among the two groups meant I had low power to discriminate landowners (n=5) from the community members (n=280). These findings continue to support the call for larger, longer experiments paired with longitudinal interviews.

Prior to finding the landowners I partnered with for this experiment, I struggled to locate interested participants. Private landowners are an important part of this study, as researchers rely on them to measure the functional and perceived effects of carnivore coexistence. I attribute the struggle to find livestock owners to the avenues in which I sought them. At the beginning of the experiment, I consulted with several local government agencies and non-profit organizations to connect with livestock owners. The groups declined to assist me in the landowner search on the grounds of value judgement disagreement or privacy concerns—even though our Institutional Review Board protocols state participants remain confidential through the research process and beyond. This required alternative means to locate livestock partners through private, personal networks instead. Therefore, while future researchers may attempt to partner with state and county agencies, they may find more success through personal contacts. Thus, I recommend the two-pronged recruitment approach described above.

Another reason for the widespread landowner hesitancy could relate to a sociological concept called the outsider-insider doctrine. Researchers may exhibit different characteristics than the communities in which they work (i.e., a new person to the region requesting to speak with landowners who encountered problems with carnivores in the past), preventing access to "insider" knowledge. In this scenario, the "insider" knowledge exists as the contact—a role played by government agencies and non-profit organizations—between private landowners with interest to participate in NLD experiments, and the researcher (Cruikshank, 1990; Merton, 1972). These concerns provide reasoning to empower the local communities which may encounter carnivore-livestock conflict to improve region-wide carnivore coexistence values.

Colorado Wolf Reintroduction

Given the impending wolf reintroduction via Proposition 114 (Prop. 114) and my own ex, coexistence research on the western slope is crucial to Colorado communities and its progress. Prop. 114 was a citizen-initiated ballot measure intended to require Colorado Parks and Wildlife (CPW) to plan, reintroduce, and manage gray wolves in western Colorado by the end of 2023. It required CPW to use the best available science, hold statewide hearings to include all opinions and stakeholders, track the opinions of Colorado citizens, and reintroduce the wolves by the end of 2023 (Wildlife- General Provisions, 2020). The ballot measure passed by a slim 50.9% to 49.1% during the 2020 election and is now known as State Statute 33-2-105.8 (Niemiec et al., 2022). Previous human dimensions of wildlife surveys demonstrated majority support for reintroducing wolves, followed by a swift change in public sentiment in a short time frame (Ditmer et al., 2022; Niemiec et al., 2022). The quick, significant decline in apparent coexistence values further prompts the need for NLD research to measure the functional and perceived effects through coupled experiments and surveys (Ohrens et al., 2019b). I believe Colorado wildlife professionals should continue to build a culture of coexistence through NLD experiments for the wolf reintroduction to succeed.

My study is not the first carnivore coexistence research on this landscape. Gray wolves resided in Colorado until humans extirpated them in the 1940s. After a citizen found a dead gray wolf on the side of a highway in the 1990s, researchers collaborated with the United States Fish and Wildlife Service (USFWS) to evaluate the possibility of restoring population connectivity to gray wolves in the western U.S. One researcher identified seven potential wolf recovery areas within Colorado, evaluating 11 different habitat characteristics (Bennett, 1994). Of the seven recovery areas, the Grand Mesa-Uncompahgre-Gunnison National Forest received the highest rating; both Montrose and Ouray Counties are within the National Forest boundaries (Bennett, 1994). Furthermore, a human dimensions of wildlife survey based around the attitudes and social tolerance for gray wolves took place in the same year, finding Colorado residents supported reintroducing gray wolves (Manfredo et al., 1994). These two studies together demonstrate the logical and necessary need for continued carnivore coexistence research in this region. However, the research is almost 30 years old and much has changed in that time, including Coloradan's perspectives on wildlife values (Manfredo et al., 2018). Manfredo et al. (2018) found mutualists (a wildlife value orientation classification where individuals believe wildlife are part of the human social network, and that wildlife and humans should coexist) as the highest wildlife value classification in the state at 35% of respondents. While the high density of mutualists in the state could reflect promising outcomes for gray wolf reintroduction, it's important to note Colorado is one of two western states (n=19) where the percent of mutualists declined since 2004 (-2.9% rate of change in Colorado, -3.7% rate of change in Hawaii). All other western states experienced increases in the proportion of mutualists within the state (Manfredo et al., 2018). The wildlife values of Colorado residents and how values may influence actions will be a factor in the success or failure of the Colorado wolf reintroduction.

To best plan for a successful reintroduction, a complete review to the extent of Bennett (1994) should take place again, similar to the report WildEarth Guardians submitted in 2022 (WildEarth Guardians, 2022). This review could connect with both better than gold-standard NLD research and community coexistence surveys to create the best avenue for carnivore coexistence possible. Following a different research plan could lead to a reintroduction without community support, given the missing measurement of functional and perceived effects of NLDs and carnivore coexistence. Diminished social tolerance for carnivores such as wolves could lead to an increase in illegal killings (Browne-Nuñez et al., 2015; Treves & Bruskotter, 2014), even though the United States' preserved nature—which includes the stabilized populations of carnivores—falls into the public trust; meaning, U.S. common laws require the federal government to preserve natural assets for future generations (Treves et al., 2017).

<u>Conclusion</u>

In this study, I set out to run a better than gold-standard (randomized, controlled trial with a crossover design) NLD experiment and assess carnivore coexistence values on the Colorado western slope. Throughout my research, I addressed the challenges of NLD experiments and championed the better than gold-standard research methods as transparent, robust protocols for future studies. While I do not draw any inferences from the research, my work could be a baseline for others to reproduce given its rigid, transparent design and enactment. I call for similarly designed, longer experiments with larger sample sizes, and for researchers to conduct meta-analyses with the current and future data. More completed meta-analyses can lead to stronger statistical power; however, systematic reviews require researchers to rely on similar experimental methods.

Through participating landowner surveys, I observed no significant changes from the beginning of the experiment to the end. However, there is a strong likelihood the sample involves self-selection bias as the private landowners indicated their support for NLDs and carnivore coexistence values throughout the research. I struggled to find landowners more representative of the community attitudes, meaning an increased sample size for future research may be beneficial to evaluating less biased results. I can further conclude with increases in perceived effectiveness from another study in the absence of functional effectiveness (Pineda-Guerrero & Treves, 2023).

I feel this research is important for the success of the Colorado gray wolf reintroduction in 2023. By leading this NLD experiment and concluding non-inferential findings, I lay the groundwork for prospective research in this field. Future researchers should note needed areas of improvement for this work, especially as recent studies show an increase of public interest into non-lethal methods in the United States (Liu & Sharp, 2018; Slagle et al., 2017; Stone et al., 2017). More research will require more funding and ideological support from government agencies and non-profit organizations. I urge interested parties to ask me questions about my research methods to better the quality of science conducted in carnivore coexistence.

Lastly, I believe the efforts put forth by the state of Colorado to educate western slope communities are too low to establish appropriate carnivore coexistence values. I urge the Colorado state government to allocate more resources to the western slope to prepare for gray wolf reintroduction, such as NLD workshops, community meetings, and assets for district wildlife managers. I also encourage district wildlife managers to continue the complex work around gray wolves on the Colorado western slope. Support and preparedness can go a long way when coexisting with wildlife. I believe it is of greater service to the public to utilize all possible avenues of coexistence during wolf reintroduction, especially with NLDs.

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Appendices

<u>Appendix A: Landowner Recruitment Script</u>

Arm 1 recruitment script 1

We are residents of Colorado and researchers from the University of Wisconsin-Madison conducting a study of attitudes to coyotes, black bears, and gray wolves in Montrose County, Colorado. We are interested in learning about your community's views and would like to invite you to participate in an experiment with predator deterrent methods.

If you agree to collaborate with us, we will partner with you to experimentally test a non-lethal deterrent against wild carnivores such as coyotes, cougars, or bears. We will provide you with non-lethal deterrent methods such as Foxlights® or fladry (hanging flags presenting a visual obstacle or deterrent) to use to project your property. The experiment would last up to 4 months on your property and include our team visiting occasionally to install and maintain the non-lethal methods, trail cameras to detect wildlife approaches, and update you on status and next steps. In our initial meeting, we will explain every step before you sign up for the project.

If you might be interested to participate and would be willing to hear about our research study, please email …. or call…. to let our project team know and to get a full description. You are under no obligation by contacting us and can hang up or quit at any time. Your identity will be kept entirely confidential within our project team as required by University of Wisconsin policies for protection of Human Subjects.

We do not know your name or address. We asked a county or municipal animal control officer to share this document with you. There will be NO follow-up communications from us if you decline our invitation. You must be 18 years or older to participate.

Thanks in advance!

Appendix B: Landowner Interviews Instrument and Simple Data

Arm A Landowner Questionnaire (N=5 for all questions)

Before experiment

Demographics and attributes

Age **(M=69 years, +/- 9)**. Gender **(3 F, 2 M).** Years of residence in Montrose County, CO **(M=30.2 years, +/- 17.6)**. Total Property Size **(124.8 acres, +/- 148.8)** Experimental Property Size **(1.46 acres, +/- 1.71)**

Property threatened or damaged **(4/5 farmers previous damages to livestock or crops)**. By what **(2/5 Mountain lions, 2/5 black bears, 2/5 foxes, 2/5 coyotes)**

How do you protect the threatened or damaged property from wildlife now? Please list any tools, strategies, etc. you may use to protect your property from wildlife.

3/5 Fences
3/5 Husbandry management
2/5 Guard animals
2/5 Deterrent methods
1/5 Firearm

How do you protect property not threatened or damaged by wildlife?

3/5 Fences
3/5 Husbandry management
2/5 Guard animals
2/5 Deterrent methods

Attitudes and Intentions

Describe your feelings towards:

Coyotes Dislike Neutral **(40%)** Like **(60%)**
Black bears Dislike Neutral **(20%)** Like **(80%)**
Gray wolves Dislike **(20%)** Neutral **(40%)** Like **(40%)**
Cougars Dislike Neutral **(40%)** Like **(60%)**
Please list ANY other wildlife you Dislike or Like in relation to your property:

Dislike: deer, porcupine, raccoon, insects, voles, beavers,
Like: Turkey, fox, quail, pheasants, hawks, eagles, bobcats, elk, deer
Deer **(20% Dislike, 20% Like)**
Raccoon **(40% Dislike)**
Turkey **(40% Like)**

Describe your feelings towards:

Effective, safe, non-lethal methods for protecting property(s) Dislike Neutral Like **(100%)**
Effective, safe, lethal methods for protecting property(s) Dislike **(20%)** Neutral **(20%)** Like **(60%)**

Does effectiveness in reducing future threats to property make a difference to you?
Yes **(100%)** Not Sure No

Do you plan to protect your property with the experimental methods we will test, if they prove effective?
Yes **(80%)** Not Sure **(20%)** No

<u>Midway through the experiment</u>
Property threatened or damaged **(1/5 Garden, 1/5 feels threatened by nearby coyotes, foxes, and raptors)** By what **(1/5 Deer)**

How do you protect the threatened or damaged property from wildlife now? Please list any tools, strategies, etc. you may use to protect your property from wildlife.

3/5 Fences (+0%)
3/5 Husbandry management (+0%)
3/5 Guard animals (+20%)
3/5 Deterrent methods (+20%)
1/5 Firearm (+0%)
2/5 Experimental Methods (+40%)

How do you protect property not threatened or damaged by wildlife?

3/5 Fences (+0%)
3/5 Husbandry management (+0%)
2/5 Guard animals (+0%)
2/5 Deterrent methods (+0%)
1/5 Experimental methods (+20%)

<u>Attitudes and Intentions</u>
Describe your feelings towards:
Coyotes Dislike **(20%, +20%)** Neutral **(20%, -20%)** Like **(60%, +0%)**
Black bears Dislike Neutral **(20%, +0%)** Like **(80%, +0%)**
Gray wolves Dislike **(20%, +0%)** Neutral **(40%, +0%)** Like **(40%, +0%)**
Cougars Dislike **(20%, +20%)** Neutral **(20%, -20%)** Like **(60%, +0%)**
Please list ANY other wildlife you Dislike or Like in relation to your property:

Dislike: Raccoon, porcupine, beaver, groundhogs, insects, mice
Like: Foxes, Bees
Deer **(20% Dislike, -20%; 20% Like, -20%)**
Raccoon **(40% Dislike, +0%)**

Turkey **(0% Like, -40%)**
Insects **(40% Dislike, +40%)**

Describe your feelings towards:
Effective, safe, non-lethal methods for protecting property(s) Dislike Neutral Like **(100%, +0%)**
Effective, safe, lethal methods for protecting property(s) Dislike **(40%, +20%)** Neutral **(60%, +40%)** Like **(0%, -60%)**

Does effectiveness in reducing future threats to property influence your choice of method?
Yes **(100%, +0%)** Not Sure No

Do you plan to protect your property with the experimental methods we will test, if they prove effective?
Yes **(100%, +20%)** Not Sure **(0%, -20%)** No

After the end of the experiment
*Percentages formatted as follows (%Change from midpoint, %Change from beginning) *
Property threatened or damaged **(1/5 Apple tree)**. By what **(1/5 Black bear)**

How do you protect the threatened or damaged property from wildlife now? Please list any tools, strategies, etc. you may use to protect your property from wildlife.

2/5 Fences (-20%, -20%)
4/5 Husbandry management (+20%, +20%)
4/5 Guard animals (+20%, +40%)
1/5 Deterrent methods (-40%, -20%)
0/5 Firearm (-20%, -20%)
1/5 Experimental Methods (+0%, +20%)
2/5 Personal Vigilance (+40%, +40%)
1/5 Cameras (+20%, +20%)

How do you protect property not threatened or damaged by wildlife?

2/5 Fences (-20%, -20%)
1/5 Husbandry management (-40%, -40%)
3/5 Guard animals (+20%, +20%)
1/5 Deterrent methods (-20%, -20%)
1/5 Experimental methods (+0%, +20%)
1/5 Personal Vigilance (+20%, +20%)

Attitudes and Intentions

Describe your feelings towards:
Coyotes Dislike **(40%, +20%, +40%)** Neutral **(20%, +0%, -20%)** Like **(40%, -20%, -20%)**
Black bears Dislike Neutral **(20%, +0%, +0%)** Like **(80%, +0%, +0%)**
Gray wolves Dislike **(20%, +0%, +0%)** Neutral **(60%, +20%, +20%)** Like **(20%, -20%, -20%)**
Cougars Dislike **(40%, +20%, +40%)** Neutral **(20%, 0%, -20%)** Like **(40%, -20%, -20%)**
Please list ANY other wildlife you Dislike or Like in relation to your property:

Dislike: Porcupine, Raccoon2, Deer, Skunk, Fox **Raccoon, porcupine, beaver, groundhogs, insects, mice**
Like: Fox, Feral Cat, Turkey, elk, deer **Foxes, Bees**
Deer (20% Dislike, -20%; 20% Like, -20%)
Raccoon (40% Dislike, +0%, +0%)
Turkey (0% Like, -40%)
Insects (40% Dislike, +40%)

Describe your feelings towards:
Effective, safe, non-lethal methods for protecting property(s) Dislike Neutral Like **(100%, +0%, +0%)**
Effective, safe, lethal methods for protecting property(s) Dislike **(60%, +20%, +40%)** Neutral **(20%, -40%, +0%)** Like **(20%, +20%, -40%)**

Does effectiveness in reducing future threats to property influence your choice of method?
Yes **(100%, +0%, +0%)** Not Sure No

Is the non-lethal method that you helped us to evaluate currently in use and maintained to protect your property?
Yes **(80%, -20%, +0%)** Not Sure **(20%, +20%, +0%)** No

How can we improve our research?

3/5 Conduct experiment in the fall/winter
1/5 Economic benefits for farmers to have increased biodiversity
1/5 Management implications are hard with fladry, especially on large areas of land

Did you learn anything?

Yes 80% No 20%

Would you participate again?

Yes 100%

Appendix C: Montrose Community Survey Instrument and Simple Data

Arm B Montrose Community Survey

Screening Questions
Are you 18 years of age or older? (N=281) Yes **(281, 100%)** No
Are you a resident of Montrose County, Colorado? (N=281) Yes **(280, 99.6%)** No **(1, 0.4%)**

Attitudes and Intentions
Describe your feelings towards (N=280):
Coyotes Dislike **(56, 20%)** Neutral **(115, 41.1%)** Like **(109, 38.9%)**
Black bears Dislike **(24, 8.6%)** Neutral **(80, 28.6%)** Like **(176, 62.9%)**
Gray wolves Dislike **(127, 45.4%)** Neutral **(53, 18.9%)** Like **(100, 35.7%)**
Cougars/Mountain Lions Dislike **(50, 17.9%)** Neutral **(103, 36.8%)** Like **(127, 45.4%)**
Deer Dislike **(7, 2.5%)** Neutral **(28, 10%)** Like **(245, 87.5%)**
Elk Dislike Neutral **(21, 7.5%)** Like **(259, 92.5%)**
Other wildlife you like or dislike on public lands (optional)
149/280 (53.2%) of respondents submitted an answer for this question.

Describe your feelings towards (N=280):
Effective, safe, non-lethal methods for protecting property(s) Dislike **(39, 13.9%)** Neutral **(80, 28.6%)** Like **(161, 57.5%)**
Effective, safe, lethal methods for protecting property(s) Dislike **(106, 37.9%)** Neutral **(67, 23.9%)** Like **(107, 38.2%)**

Do you have any comments about views you shared with us? (optional)
106/280 (37.9%) of respondents submitted an answer for this question.

Randomly presented statement
Alternative A: Native wildlife provide benefits to many people for recreation, viewing, spiritual appreciation.
Alternative B: Native wildlife sometimes damage property such as feeders, garbage bins, crops or ornamental plants, domestic animals such as pets and livestock.
Alternative C: Native wildlife that survive year-round in Montrose County have physiological and ecological adaptations to our harsh winters.

Do you believe Montrose County should host all native wildlife populations? (N=277, non-response= 3, 1.1%)
Yes **(169, 60.1%)** No **(67, 23.8%)** Not sure **(41, 14.6%)**

Do you support Colorado Proposition 114, the Gray Wolf Reintroduction Initiative, which was on the ballot in Colorado as an initiated state statute on November 3, 2020? (N=277, non-response= 3, 1.1%)

A **"yes"** vote supported requiring the Colorado Parks and Wildlife Commission to create a plan to reintroduce and manage gray wolves on designated lands west of the continental divide by the end of 2023.
A **"no"** vote opposed creating a plan to reintroduce and manage gray wolves on designated lands west of the continental divide by the end of 2023.

Yes **(88, 31.8%)** No **(155, 56.0%)** Not sure **(34, 12.3%)**

Do you have any comments about views you shared with us? (optional)
130/280 (46.4%) of respondents submitted an answer for this question.

Appendix D: Unit Cost Calculations for Fladry

Calculations for Rope cost per meter (multiplied by 2 for account for top and bottom rope:

$$\left(\frac{\$69.92}{1{,}000\ ft\ of\ rope} \times \frac{1\ ft}{0.3048\ m}\right) \times 2 = \frac{\$0.456}{meter}$$

Calculations for fladry flag cost per meter:

$$\frac{\$28}{500\ ft\ of\ construction\ tape} \times \frac{1\ ft}{30.48\ cm} \times \frac{50\ cm}{1\ flag} \times \frac{1\ flag}{7\ in} \times \frac{1\ in}{0.0254\ m} = \frac{\$0.517}{meter}$$

Calculations for staple cost per meter (assuming no stapler malfunctions):

$$\frac{\$4.34}{2\ boxes\ of\ staples} \times \frac{1\ box}{5{,}000\ staples} \times \frac{3\ staples}{1\ flag} \times \frac{1\ flag}{7\ in} \times \frac{1\ in}{0.0254\ m} = \frac{\$0.007}{meter}$$

Calculations for 11-inch cable ties per meter (approximation):

$$\frac{\$45.35}{1\ pack\ of\ cable\ ties} \times \frac{1\ pack}{500\ ties} \times \frac{1\ tie}{2\ m} = \frac{\$0.045}{meter}$$

Calculations for 8-inch cable ties per meter (approximation):

$$\frac{\$32.58}{1\ pack\ of\ cable\ ties} \times \frac{1\ pack}{100\ ties} \times \frac{1\ tie}{2\ m} = \frac{\$0.163}{meter}$$

Summation of materials to reach cost of fladry per meter:

$$0.456 + 0.517 + 0.007 + 0.045 = \frac{\$1.03}{meter}$$

OR

$$0.456 + 0.517 + 0.007 + 0.163 = \frac{\$1.14}{meter}$$

I predict the true estimation falls within the range of \$1.03/meter and \$1.14/meter.

Appendix E: Non-Lethal Deterrent Camera Data

Public access online spreadsheet available at the following link:

https://docs.google.com/spreadsheets/d/1rSYW3LIL-

iGNwGevJAggqp24NAwpjZ0yjGQU_qQxGlM/edit?usp=sharing