Human-Carnivore Coexistence: The Functional and Perceived Effectiveness of Solar Lights, and Attitudes Toward Jaguars and Pumas in Colombia

By

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Introduction to the dissertation

Across the world, top predators shape ecosystems by influencing the behaviors and population densities of smaller predators and of prey animals; thus their absence can lead to ecological and trophic disruptions (Estes et al., 2011; Ripple et al., 2014). Key terrestrial predators are the big cats: the tiger (*Panthera tigris*), leopard (*Panthera pardus*), jaguar (*Panthera onca*), snow leopard (*Panthera uncia*), puma (*Puma concolor*), cheetah (*Acinonyx jubatus*), and the lion (*Panthera leo*). Big cats face threats such as wildlife trafficking, poaching and retaliatory killing after livestock losses (Morcatty et al., 2020; Treves & Karanth, 2003). Furthermore, because of the growing human population and ever-expanding consumerism, the habitat of these predators, and natural prey is in jeopardy (Ceballos et al., 2015; Khorozyan et al., 2015; Ripple et al., 2014).

Jaguars and pumas are the two big cats in Latin America, inhabiting diverse ecosystems (Nielsen et al., 2015; Quigley et al., 2018). As apex consumers, the removal of jaguars and pumas can degrade ecosystems by allowing populations of herbivores to over-populate habitats and degrade the vegetation community (Estes et al., 2011). Both species inhabit ranchlands and have been reported to attack domestic animals on occasion in Latin America (Amit et al., 2013; Marchini & Macdonald, 2018; Ohrens et al., 2019; Quigley, 2006; Quigley et al., 2015). Predation on domestic animals could cause conflicts with owners who might respond with predator-killing campaigns or political opposition. Many farmers or ranchers around the world resort to killing predators hoping to reduce predation on domestic animals (Treves & Karanth, 2003). In Colombia, both species have been reported to attack on domestic animals at farms (Quigley et al., 2015). Furthermore, previous studies have identified the importance of private lands for puma and jaguar conservation in Colombia (Zárrate-Charry et al. 2018; Boron et al., 2016). Although non-lethal methods are being implemented on farms, to my knowledge, no evaluation of the functional and perceived effectiveness using randomized, controlled trials has been conducted. Given the conservation significance of large predators, non-lethal methods to protect domestic animals deserve more attention as a possible solution to prevent livestock losses. Non-lethal methods of protecting domestic animals have the potential to achieve two important societal goals: protect important native species and safeguard livelihoods of rural human populations. I evaluated the functional and perceived effectiveness of a non-lethal method, Foxlights®, deployed in two different ways, and the possible change in attitudes toward pumas and jaguars after people participated in randomized, controlled trials with crossover design (Crossover RCTs) at farms of Colombia.

In Chapter 1, "Functional Effectiveness of Solar Lights as Deterrents in Preventing Puma and Jaguar Attacks on Domestic Animals in Colombia", I investigate the functional effectiveness of Foxlights®- solar portable lights. Between 2019 and 2021, I conducted three crossover RCTs in 20 farms of San Luis and Cimitarra, testing two types of deployment in 32 herds: mobile and stationary. I did not detect any deterrent effect of Foxlights® in preventing jaguars or pumas from approaching livestock in pastures located in San Luis and Cimitarra.

In Chapter 2, "Longitudinal Analysis of Attitudes Toward Jaguars and Pumas, and Perceived Effectiveness of a Visual Deterrent in Colombia", I report the longitudinal measures of attitudes among participants of crossover RCTs to test the functional effectiveness (FE) of Foxlights. I interviewed participants who voluntarily agreed to participate in the trials before, at the middle and at the end of the experiment. I measured their attitudes toward pumas and jaguars, and the perceived effectiveness (PE) of the non-lethal method. The results suggest an improvement in attitudes toward jaguars and pumas after participation, and a mismatch between the PE among participants and the evaluation of FE in the crossover RCTs. Gender, site and treatment did not predict changes in attitudes.

In Chapter 3, "Examining Wildlife Value Orientations and Attitudes Towards Coexistence with Jaguars and Pumas in Colombia", I explore attitudes toward coexistence with jaguars and pumas, and the protection of both felids among twenty rural owners and managers in San Luis and Cimitarra. Also, I identified 5 wildlife value orientations from narratives of participants from Cimitarra. "Aesthetic" appreciation emerged as the predominant wildlife value orientation. Respondents from San Luis and Cimitarra conveyed their support for coexisting with pumas and jaguars while also advocating for the conservation of both felids. Finally, attitudes toward acceptance of jaguars and pumas showed slight improvement after the crossover RCTs.

The attitudes of domestic animal owners to carnivores and their perceived effectiveness of non-lethal methods are thought to predict their adoption and maintenance of strategies for coexisting with wildlife that can cause problems for people. Mine is the largest study yet conducted to measure PE and FE simultaneously in the same farms among owners participating in a crossover RCT. The narratives shared by Cimitarra respondents contribute to our understanding of PE. These narratives revealed that owners may object to the killing of large felids primarily on aesthetic rather than economic reasons. According to theory, the most successful coexistence strategies should align with their values and with their PE that visual deterrents helped them keep their livestock safe. The discrepancy between FE and PE raises interesting questions about the generalizability of scientific experiments and how people perceive the risks they face in coexisting with large carnivores. Functional effectiveness of non-lethal methods guides the decision of which interventions to implement. However, understanding farmers' perceptions of the effectiveness of non-lethal methods is also crucial for gaining a comprehensive understanding of the barriers and motivations associated with their adoption.

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1. Chapter 1: Functional Effectiveness of solar lights as deterrents in preventing puma and jaguar attacks on domestic animals in Colombia

1.1. Introduction

Many populations of big cats are endangered and declining worldwide due to competition with humans for food and space, often resulting in habitat loss and retaliatory killing (Inskip & Zimmermann, 2009; Ripple et al., 2014; Woodroffe & Ginsberg, 1998). Habitat loss is one of the major threats that big cats face, which also increases encounter rates between big cats and humans, and predation risk (Elbroch & Treves, 2023; Khorozyan & Waltert, 2021; Treves et al., 2016). Worldwide, when predation on domestic animals by carnivores occurs, the main management intervention to address the conflict is the lethal removal of carnivores (Breitenmoser, 1998; Treves & Naughton-Treves, 2005; Zimmermann et al., 2021). However, removing one or more individual carnivores does not guarantee a reduction in conflict, scientific evidence suggests that hunting predators does not decrease livestock predation (Gervasi et al., 2021; Krofel et al., 2011). Instead, the evidence suggests lethal control can increase risks to livestock and can lead to immigrant carnivores filling the vacancy if source populations occur nearby (Cooley et al., 2009; Cooley et al., 2009; Peebles et al., 2013; Santiago-Avila et al., 2018). Nonetheless, non-lethal methods have proved effective in protecting domestic animals (Lennox et al., 2018; Lorand et al., 2022; Moreira-Arce et al., 2018; Treves et al., 2016b, 2019; Van Eeden et al., 2018). For example, Foxlights® have been proved effective to deter pumas from llamas and alpacas in Chile (Ohrens, Bonacic, et al., 2019), painting eye spots on cattle to deter african lions (Radford et al., 2020), the use of fladry flagging to deter wolves (Davidson-Nelson & Gehring, 2010), livestock guarding dogs to deter wolves and coyotes from cattle (Davidson-Nelson & Gehring, 2010), studded leader collars to protect cattle from leopards (Khorozyan et al., 2020), and low-stress handling by "range riders" to protect cattle from pumas, gray wolves, coyotes, grizzly bears, and black bears (Louchouarn & Treves, 2023). However, the effectiveness of many non-lethal, and lethal methods has not been tested using high scientific standards of evidence that minimize research bias (Treves et al., 2019). Researchers have demonstrated that it is feasible to conduct randomized, controlled experiments to test non-lethal methods in field settings (Hall & Fleming, 2021; Khorozyan et al., 2020; Louchouarn & Treves, 2023; Ohrens, Bonacic, et al., 2019). Furthermore, non-lethal methods could promote coexistence between humans and big cats while safeguarding livelihoods (Khorozyan & Waltert, 2021; Treves et al., 2016a, 2019; van Eeden et al., 2018).

In Colombia, jaguar and pumas inhabit private farms, both species range near livestock, and have been reported to prey on livestock. Attacks on domestic animals by jaguars and pumas are rarely reported to the environmental agency but occur on farms. Moreover, when such reports are made to the environmental agencies, they are not always verified due to the challenges of remote areas and limited resources to address such complaints. Consequently, the verified number of attacks to domestic animals as well as the extent of the illegal killing of felids in Colombia is unknown. Retaliatory killing of jaguars and pumas occur mainly on private lands despite national legal protection protection (Ministerio De Medio Ambiente & Desarrollo Sostenible, 2017). Non-lethal methods have been implemented on farms as a strategy to mitigate conflict. Among the non-lethal methods used in Colombia to reduce predation by big cats are deploying electric fences, or switching to creole cattle (e.g San Martinero) or water buffalo, and/or adjusting livestock husbandry practices (Castaño-Uribe et al., 2016; Quigley et al., 2015). However, no statistical evidence is available concerning the effectiveness of non-lethal methods. Furthermore, the effect of time passing, and the lack of a comparison group chosen without selection bias are the main weaknesses in drawing inference using non-randomized before-and-after comparison (BACI). Even without intervention, domestic animals might experience singular predator attacks without any subsequent occurrences (Treves et al., 2019). Therefore, higher scientific standards to evaluate interventions such as randomized, controlled trials (RCTs) are essential to strengthening of inference of functional effectiveness (Christie et al., 2019, 2020; Treves et al., 2019). RCTs are rigorous experiments that avoid bias in treatments, sampling, measurement, and reporting, following the gold standard for predator control (Ioannidis, 2005; Khorozyan, 2020, 2021; Treves et al., 2016a, 2019).

One of the non-lethal methods reported to protect domestic animals from predators is the use of lights (Khorozyan & Waltert, 2021; Linhart et al., 1984; Van Eeden et al., 2018). Among the first studies evaluating the effectiveness of light devices used strobe lights and siren devices in a before-and-after comparison study for reducing coyote predation upon sheep (Linhart, 1984; Linhart et al., 1984, 1992). Researchers have also tested radio-activated guard boxes (RAG) that use signals from radio collars of predators to trigger strobe lights and loud sounds, a method currently used in North America (Breck et al., 2002). Alternatively, findings on a movement-activated guard (MAG) showed effectiveness on reducing consumption of carcasses in a multipredator ecosystem in North America (Shivik et al., 2003). Foxlights® is another well-known device and has been widely commercialized. These devices randomly flash three different colors and patterns that can be seen from 1 Km and operate with a solar panel or a battery. In the first RCT testing the effectiveness of Foxlights®, researchers found lights deterred pumas, but not Andean foxes, from approaching alpacas and llamas in Chile (Ohrens et al., 2019). Although other studies have evaluated Foxlights®, LED flashlights or solar-powered LEDs to deter carnivores and other mammals, those studies lack randomization and control groups (Adams et al., 2021; Lesilau et al., 2018; Naha et al., 2020).

Moving lights that turn on and off unpredictably could indicate human presence. Therefore, I hypothesized that solar-powered Foxlights® placed on domestic animals— hereafter ‘mobile’— and in their sleeping areas— hereafter ‘stationary’— would deter jaguars and pumas from predation on domestic animals. I conducted three RCTs with crossover design on mobile and stationary Foxlights®— hereafter ‘lights’— to test the functional effectiveness of this non-lethal method to protect domestic animals in 20 farms of two municipalities of Colombia: San Luis and Cimitarra. I assessed the hypothesis for each species of big cats and as a group - hereafter — ‘felids’—. This predicts that domestic animals not protected by lights (placebo or control) would be more vulnerable than domestic animals protected by lights (treatment). To our knowledge, this is the first RCTs conducted in Colombia and the first RCTs for jaguars in Latin America.

1.2. Methods

1.2.1. Study sites: San Luis

Located in Antioquia Department in the tropical Andes (Figure 1.1). Armed conflicts took place during the civil war between 1970 to 2003 (García, 2007). After the peace agreement and the decline of armed violence in 2005, farmers returned to their properties (García, 2007). Farmers raise cattle and some crops such as coffee, cane sugar, plantains, and yuca. Transportation is based on horses and donkeys. Furthermore, some farms lack electricity and households rarely enjoy formal education. There are no national parks in or around San Luis. The Río Claro Reserve, is a private reserve located in San Francisco and Sonson municipality, located in Antioquia department. Furthermore, another figure of protection at the regional level “Distrito Regional de Manejo Integrado Bosques, Mármoles y Pantágoras”, covers parts of San Luis, San

Francisco, Sonsón and Puerto Triunfo municipalities. Currently, the government environmental agency is working to declare “La cuchilla la Tebaida”, in San Luis and San Carlos municipality. Throughout history, significant contributors to deforestation in the Andes have included extensive cattle ranching, agricultural activities, and the clearing of land for government-initiated settlement projects (Armenteras et al. 2011; Etter et al. 2006).

I studied 10 farms, range 2-57 ha, mean 18.3 ha with 2-40 animals (cattle, mules, donkeys, horses), mean 10 animals per farm. The distance between farms was 0.244-5 km. The farms have pastures and fragments of humid, premontane and cloud forest with altitude range from 863-1837 meters above sea level (masl). Depending on the owner, the domestic animals sleep in paddocks without supervision or in the paddock next to the house. Only three owners had artisanal enclosures for horses or donkeys. I deployed the lights at the sleeping areas. Farms have 1 to 3 paddocks, and they are surrounded by forest and small-scale crops. Arrangements of the farm and management of domestic animals varied. Domestic animals were 100% pasture-fed.

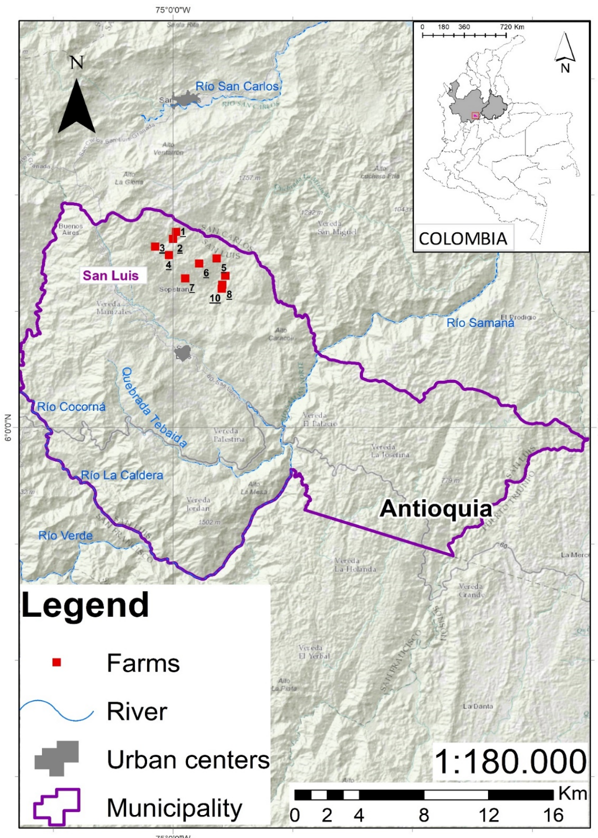

Figure 1.1 *San Luis, Antioquia and the 10 farms I studied.*

Study Sites continued:

1.2.2. Cimitarra

Located in Santander Department in the middle Magdalena valley, situated between the central and eastern Colombia Andes, Cimitarra is characterized by tropical forest and wetland biomes (Boron et al., 2016; Figel et al., 2019; Figure 1.2). The Middle Magdalena Valley stands out as one of the Colombia's regions with the highest degree of degradation and the least protected (Etter at al., 2006; Forero-Medina & Joppa 2010). There are no national parks in Cimitarra. However, Serranía de los Yariguíes National Park is in the same department. The middle Magdalena Valley connects the eastern and western sides of the Andes Mountains. Middle Magdalena valley produces many cattle commercially, and cattle are the main economic activity for owners with small, medium, and large-scale farms (Instituto Colombiano Agropecuario, 2020). I study 10 cattle farms, range 31-3000 ha, mean 910 ha with 18-1380 head of cattle, mean 612 head divided among 1-30 herds per farm. The distance between the farms was 0.755-49 km. The altitude range was 91-205 m asl. Arrangements of the farms and management of domestic animals varied between farms. Domestic animals were 100% pasture-fed. Owners decided how to manage cattle based primarily on the seasonal flood and drought regimes of Carare and San Juan River (Figure 2). The owners use a rotational grazing system, which means the herd went to the next paddock after eating the grass in the previous one. The herds rotate in a group of paddocks varying from 3-7 paddocks per farm. Also, the number of days in one paddock varied from 3-10 days. Usually, the paddocks are fenced or bordered by forested habitats. However, some paddocks are limited by wetlands or rivers instead of fencing.

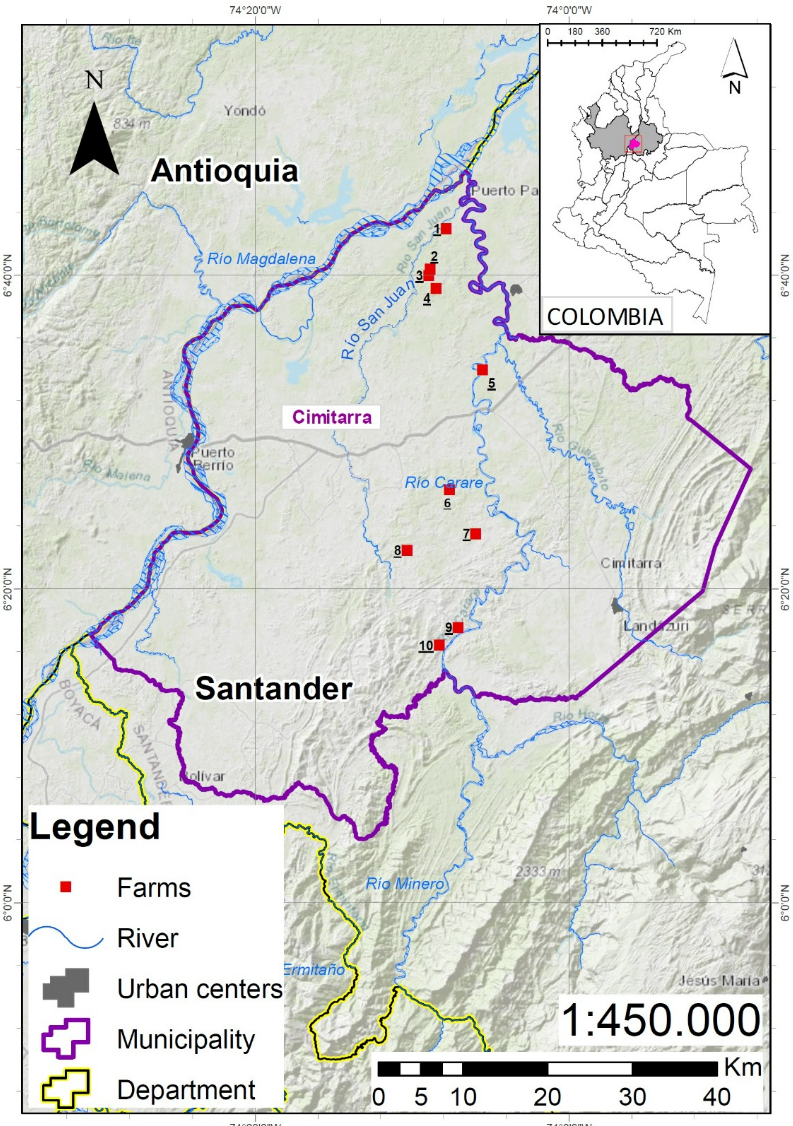

Figure 1.2 *Cimitarra, Santander, Colombia and the 10 farms I studied.*

1.2.3. Verifying livestock attacks

To reduce measurement bias, I approached two third-party entities to verify attacks and identify the type of predator using similar methods– CORNARE in San Luis and The Wildlife Conservation Society in Cimitarra. I chose Cornare because they implemented non-lethal methods on farms that reported attacks in rural area of San Luis. Before my project Cornare attached NiteGuard lights to the back of domestic animals and set up stationary Foxlights and scarecrow. Attaching lights to the back of domestic animals was a farmer's idea in San Luis.. Similarly, WCS has also been developing conservation projects in the Colombian Middle Magdalena. Before the project began, the authors and CORNARE or WCS agreed on field methods for verifying attacks without necropsy. When owners believed an attack had occurred, they contacted the lead author and one of the two organizations responded within 24 hours of the attack. The third parties gathered the GPS location of each attack and examined indirect signs of predation by jaguars and pumas: signs of bites on carcasses, body parts consumed, trails where livestock had been carried or dragged, and carcasses covered by grass or leaves. The lead author corroborated the field data from photos taken by verifiers using hand-held personal cameras. The field verifiers mentioned above had no other role in the experiments.

1.2.4. Participant enrolment and workshops

I recruited participants for one in-person workshop held in a rural part of San Luis and one online workshop conducted in Cimitarra, the latter due to the COVID-19 pandemic. The third parties joined in the invitation extended to rural landowners from San Luis and Cimitarra. Recruitment and workshop attendance was facilitated through a snowball method or word-of-mouth, with owners encouraging their neighbors to attend or participate. I divided the workshop in three sections:1) Introduction to the subject and aim of the workshop 2) Explanation of non-lethal interventions aimed at reducing predation on domestic animals 3) Presentation of my project and explanation of Foxlights as non-lethal method. I explained that the goal of my project was to test the functional effectiveness of Foxlights using randomized controlled trials with a cross over design in farms conditions. I selected 20 farmers from those who voluntarily agreed to implement the method- Foxlights®-on their private properties. The selection criteria was ownership of at least one domestic animal (cows, horses, sheep, or donkeys). Farmers who had experienced loss of domestic animals by jaguars or pumas had the same participation possibility as those who have not.

1.2.5. Experimental Design: Farms and herds

I conducted three randomized controlled trials with crossover design, two in San Luis (6 months and 8 months each) and one in Cimitarra (8 months). I evaluated the effectiveness of Foxlights® as deterrents using a crossover design on 10 herds in San Luis Pilot (hereafter, 'slp'), 10 herds in San Luis experiment (hereafter, 'sle'), and 12 herds on 10 farms in Cimitarra, (hereafter, 'cme'). In crossover design each participant (herd) experience in one phase the treatment and placebo/control condition in a random order separated by a washout period (Jones & Kenward, 2015; Mills et al., 2009). I refer to these three as study site-periods hereafter. The lights are intended as a visual deterrent to keep a target animal away from a specific area. This solar device emits three colors of randomized LED lights, which reportedly can be seen from up to one km away (Foxlights International , 2023). I evaluated the lights for protection of cattle, calves, mules, and horses in San Luis and for cattle and camuro sheep in Cimitarra.

For slp, I recruited 10 farmers, after which one dropped out, and I recruited a replacement. For cme, I had 10 farmers but two of the farmers contributed two herds, so I had 12 replicates in cme. Overall, I studied 32 replicates (defined as herds grazed separately with fenced pastures). I consider it possible that the sites and even the periods affect the results of the experiment, so I tested inter-site and inter-period differences in felid visits before pooling replicates (see definitions of felid visits below).

The average herd size in slp was 7.4 livestock (Sd=9.9, range=2-28, median=2, n=10 replicate herds); sle, 7.7 (Sd =0.5, range=2-28, median=2, n=10); cme was 37.9 (Sd=19.1, range=18-80, median=36, n=12). I evaluated any statistical differences in felid visits associated with herd size before pooling herds.

I categorized cows and horses as large livestock and calves and sheep as small livestock. I analyzed differences in felid visits by livestock size before pooling across replicates. I did not have a sufficient sample size of each breed of livestock (horses, camuro sheep, calves, mules, etc.) to evaluate differences between breeds. I defined two categories for livestock size: Large for cows, mules and horses and large and small when the herd had calves.

1.2.6. Experimental Design: Cameras

I used trail cameras as a monitoring tool to record puma and jaguar presence and behavior responses to the lights (Caravaggi et al., 2017). Camera deployment was close to the Foxlights, to record puma and jaguar approaches in each phase, treatment and placebo/control conditions. Distance from Foxlights to cameras range from 200m to 1 km. Previous studies testing the effectiveness of non-lethal methods used trail cameras to record carnivore presence (Fergus, 2020; Hermanstorfer, 2023; Louchouarn & Treves, 2023; Ohrens et al., 2019).I installed trail cameras (Reconyx HyperFire HC500 and Bushnell TrophyCam HD) in the same rotation paddocks or areas where lights were deployed or in the forest around. I deployed an average of 1-3 cameras per replicate (slp: range 1-3 cameras per replicate, median= 1, sle: range 1-3, median= 2, cme: range 1-5, median= 3) for a total of 9171 camera-days. I recorded camera-days as a 24 h period when a camera was functional. I deployed cameras for an average of 145-404 camera-days per replicate varying by site (slp: 145 camera-days, range 5-308, median=149, sle: 287.1, range 80-464, median=312, cme: 404, range 119-668, median=312). When a replicate had more than one camera, I summed camera-days at that replicate to measure our response variables. I evaluated the effect of the number of cameras before pooling replicates.

When a camera malfunctioned, I replaced it if a replacement was available. Because of thefts and malfunctions, two of our replicates provided no camera data or few photos in one phase (slp herds 5 and 9, sle herd 15). I included these replicates in the first evaluation of treatment effect and then excluded them to evaluate sensitivity of our results to potential measurement bias. To include those three replicates, I rely only on the number of attacks (defined below). Our response variables are (1) approaches by pumas or jaguars to the herd evaluated as detected by cameras and (2) attacks by pumas or jaguars to the herd evaluated. I programmed the cameras to take three photos or videos in a burst with a delay of 60 s between bursts. I never collected more than one burst of three photographs of pumas or jaguars within 24 h of each other at the same camera. Therefore, I defined a set of photos in one day at one camera as a visit. I divided the number of visits per camera-day per replicate, split for pumas and for jaguars or the sum of the two for all felid visits. All reference to visits below is standardized per camera-day per replicate unless mentioned otherwise.

I assume visits were independent. However, in the results I describe four instances of potentially non-independent visits. Also, I documented two attacks without any associated photos, so in those cases, I recorded one visit for each replicate and divided by the camera-days for that replicate as if I had photos. In one case I had a photo and an attack in the same herd during the same hour, so I counted them as a single visit.

1.2.7. Experimental Design: Treatment and control

Among 20 farmers who voluntarily agreed to participate in my research, the landowner chose one herd for the evaluation of Foxlights. I randomly assigned each herd to control or treatment. I made the randomization by study area: San Luis and Cimitarra. The first phase lasted 3-4 months, then the same herd experienced the other condition in the second phase of the same duration, after a wash out period. This period was defined as a time with no condition and I did not analyze the camera data from this period lasting nine days in slp, 63 in sle, and 23 in cme. Farms in sle resumed their prior order in slp for treatment and placebo. In both study areas dry and rainy seasons were covered.

In slp, I deployed mobile lights on the backs of five horses and five cows. The farmer and lead author agreed on which animal I placed the light. I strapped 10 lights onto 10 animals. However, I experienced challenges placing the lights on some of the animals' backs. Four horses tolerated the lights, but 2 horses and 4 cows did not tolerate them. Those 6 animals bit the belts and tried to remove them in various ways, likely due to heat and chafing from the material. Therefore, I changed deployment for subsequent experiments.

In sle, I deployed four mobile lights on horses and 6 stationary at the sleeping area on a stake or tree at a height of 1.4-2.0 m. In cme, I deployed mobile light in 1 replicate on a sheep and stationary in 11 replicates, with an average of three lights (range= 1-6, median=3).

In slp, I turned off the lights for the active placebo control condition. However, I were concerned that two owners might have subverted the experimental design when they were in the control condition and turned the lights back on without notifying either author. This could create treatment bias and obscure the treatment effect. Therefore, I analyzed the data with and without herds 2 and 6. Subsequently, during sle and cme, I removed the lights from the farms during the control condition (passive control). I statistically compared the effects of the two different treatment conditions (mobile versus stationary), passive control versus active placebo control, and the number of lights in treatment conditions before pooling replicates.

In one farm in cme, I deployed stationary lights with cows and calves and a mobile Foxlight with camuro sheep in two paddocks separated by four km. However, I learned later that the camuro sheep were able to move freely in and out of pastures and even into neighboring unfenced forest. Although this farm had verified attacks before our study began, I recorded no attacks during either phase at either replicate (herds 30 and 32). These movements of camuros could potentially cause treatment bias. Therefore, I performed the final analysis with and without these two sheep replicates. (See appendix 3,4 for pictures of mobile vs stationary)

1.2.8. Statistical Analyses

Since I have a small sample, I assessed the normality of my data with Shapiro -Wilk test (Coin, et al., 2008). Based on this outcome, non-parametric tests were used. I report results of these randomized, controlled trials with cross-over design by first analyzing univariate order effects (control then treatment or treatment then control) and potentially confounding effects in univariate non-parametric tests first. I then evaluated treatment effects partitioned by the significance of the latter.

In typical randomized, controlled trials, the measurement of treatment effect involves a straightforward comparison of conditions, e.g., treatment group minus control group. But many confounding variables associated with between-subjects' differences may interfere with our interpretation of a treatment effect or lack of it. One circumvents this in at least three common procedures: with massive sample sizes which I could not achieve. Alternately, researchers screen subjects to select those very similar in known confounding effects which I could not achieve either because I asked farmers to volunteer. Therefore, I relied on the third common procedure which is crossover design for within-subjects analysis. Differences between subjects are reduced or eliminated by within-subjects analysis because each treatment effect on a subject is compared to the control effect on that same subject (Díaz-Uriarte, 2002; Jones & Kenward, 2015; Ohrens et al., 2019). Between-subject variation is a major source of confounding variables in randomized controlled trials that do not use crossover design. Our randomized, controlled, crossover design is stronger than a simple before-and-after comparison of impacts (BACI) without randomization, and stronger than a randomized, controlled trial without crossover because all replicates were exposed to both conditions in random order.

Our random assignment crossover design (treatment or control reversed during the washout period) permits us to analyze treatment effects within subjects (replicate herds). I define treatment effects as a significant difference between lights turned on and deployed versus control (lights turned off or absent) in the same replicate at a threshold significance level of $p = 0.05$. I also scrutinize effect sizes (differences in the frequency of visits by felids) to learn more from the analyses than the frequentist threshold might reveal. Our within-subjects analyses provided more statistical control over potentially confounding variables than would be possible with grouped analyses of treatment versus control. By assigning treatment or control randomly, I reduced the potentially confounding effects of changes between phases 1 and 2. However even with our (relatively large for our field) sample of 32 replicates, I cannot rule out entirely a phase effect, such as seasonal variation in the visitation by felids. Also, pumas and jaguars may have reacted differently to experimental conditions. Therefore, I compared the two felids" visits before pooling them. To compare the number of jaguar visits and puma visits to the same replicate I used the within-subjects non-parametric Wilcoxon signed rank test and Spearman rank correlations (Armitage, 1973).

To evaluate if herd sizes confounded analyses, I used Spearman and Kendall correlations to assess the relationship between herd size and felid visits. I used spearman rank correlations for paired analyses within subjects when both variables are ordinal or the alternative Kendall tau correlation coefficient when there are many ties (e.g., number of lights). For the remaining covariates that did not change within replicates (livestock size, site), I used grouped analysis: Wilcoxon rank sum tests and Kruskal Wallis tests (Armitage, 1973).

To be confident our nuisance variables were not interacting and thereby confounding our interpretation of treatment effects, I ran negative binomial generalized linear mixed models (GLMM). The response variables were the summed visits between phase 1 and 2 per camera day by species. The predictors were study site period (slp,sle,cme), livestock size (large and large and small), herd size and the interactions between those predictors. As random effects I chose the number of Foxlights. GLMM are valuable where the response variable is binary, ordinal, count-based or non-normally distributed (Bono 2021, Stroup et al. 2016).

First, I test study site (slp,sle,cme), livestock size (large and large and small), and herd size for collinearity using spearman rank correlation (Table 1.4) and the variance inflation factor (VIF) (Belsley, 1980). The VIF indicates with a coefficient how the variance is inflated due to data collinearity(Jou et al., 2014; Table 1.5). I calculated the variance inflation factor for each pair of variables. A VIF greater than 10 suggests a presence of data collinearity (O’Brien, 2007). I did not include the number of cameras because jaguar and pumas’ visits are standardized to camera days.

For treatment effect and phase effect, I used the non-parametric version of the Hills-Armitage procedure because our data violated the assumption of normality and constant variance required by ANOVA (Díaz-Uriarte, 2002; Jones & Kenward, 2015). I used sequential Wilcoxon signed-ranks tests to detect a treatment effect independent of phase and then detect a phase effect revealing if felid visits differed between phase 2 and phase 1 regardless of treatment condition. Then I combine the two potential effects in a Wilcoxon signed rank test comparing Phase 2 minus phase 1 to felid visits treatment minus control, which evaluates if treatment effects are equal to or different from phase effects. A similar analysis evaluated the effectiveness of Foxlights® previously (Ohrens et al., 2019).

Deleted: This analysis has been applied with success

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To evaluate the sensitivity of our results to the above-referenced herds that might potentially create measurement bias or treatment bias, I repeated the analysis without seven replicates that might have undermined our design (herds 2,5,6,9,15,30,32). Our sensitivity analyses had n=25 instead of n=32 replicates. As a further test of sensitivity, I examined the same herds across two field seasons (slp and sle). When the herds were the same and had not changed in size, I could ask if (a) treatment effects changed by field season, (b) frequency of felid visits changed within-subjects between seasons. I did not re-randomize replicates so I could not ask if order effects changed between seasons within-subjects.

I refer to p-values as suggestive when they approximate p= 0.05 and significant for p=0.01 following Benjamin et al.,(2018), and to reduce false positive rates(Colquhoun, 2014). Because I am replicating a study by Ohrens et al., (2019), I allow p>0.005 (Benjamin et al., 2018) to guide inference. In accordance with Colquhoun 2014, I conducted an adjustment of significance thresholds for experiments that make multiple comparisons.

1.3. Results

In San Luis (slp and sle) I recorded zero felid attacks among 20 replicates. In cme, I documented 3 felid attacks on domestic animals among 12 replicates. I suspect the attacks were by pumas; one attack was on a calf and two on camuro sheep. One owner (herd 31) allowed her camuro sheep to roam freely within several fenced pastures and beyond farm boundaries. The two camuros were not wearing Foxlights® and died within paddocks used by herds of cattle in the treatment conditions. I record these as attacks even though the cattle I intended to protect escaped harm.

In four cases in San Luis (three in slp: 2019; one in sle:2020), I photographed two jaguars and two puma that could be the same individuals later photographed in a different replicate in the same camera-day. The cameras were separated in distance 1237 m (herd 4-5), 1863 m (herd 1-4), and in two cases 1177 m (herd 1-5), respectively (Table 1.1). Although these visits might be statistically non-independent, they seem behaviorally independent given the distance and time elapsed. Also, visits were divided by camera-days, so the response variables were not the same at each replicate visited on the same day, achieving statistical independence.

Table 1.1 Records that are possibly the same individual of puma o jaguar in San Luis.

Herd	Treatment/Control	Species	Date of report	Hour	RCTs
1	Treatment	Puma concolor	September 2/2019	2:50:00 PM	San Luis Pilot
5	Control	Puma concolor	September 2/2019	3:48:00 PM	San Luis Pilot
5	Control	Puma concolor	September 10/2019	7:03:00 AM	San Luis Pilot
1	Treatment	Puma concolor	September 10/2019	7:52:00 AM	San Luis Pilot
4	Treatment	Panthera onca	November 10/2019	7:08:00 PM	San Luis Pilot
5	Control	Panthera onca	November 10/2019	10:05:00 PM	San Luis Pilot
1	Control	Panthera onca	February 6/2020	9:45:32 PM	San Luis Experiment
4	Control	Panthera onca	February 6/2020	11:20:00 AM	San Luis Experiment

I began addressing potentially confounding effects by comparing covariates that I consider nuisance variables (predator species, size of livestock, herd size, and number of cameras) within and across replicates. I detected pumas approaches in 12 replicates (38%), jaguars in 12 replicates (38%) and I detected both felids in 8 replicates (25%, 5 in San Luis and 3 in Cimitarra) (Table 1.2).

Table 1.2 Records of jaguar and puma approaches, attacks, and both records on 32 herds in San Luis and Cimitarra, Colombia 2019-2021

Approaches, attacks, or both	**Herds approached (n=32)**	**herds approached San Luis Pilot (n=10)**	**herds approached San Luis Experiment (n=10)**	**herds approached Cimitarra (n=12)**	**% herds approached (n=32)**
Puma approach only	12	3	4	5	38%
Jaguar approach only	12	6	3	3	38%
Puma attacks	2	0	0	2	6%
Jaguar attacks	0	0	0	0	0%
Puma attack and photos of approaches	1	0	0	1	3%
Jaguar attack and photos of approaches	0	0	0	0	0%

I detected 0.26 puma visits per 100 camera-days per replicate across all sites (sd 0.39, range 0-1.30, median=0, n=32), and 0.26 jaguar visits per 100 camera-days per replicate (sd 0.43, range 0-2.08, median=0, n=32). All references to visits are standardized by camera-day hereafter.(Appendix 1,2 with pictures of puma and jaguar in each study area).

The data for puma and jaguar visits, for both phases are not normally distributed (Shapiro-Wilk: jaguar $W = 0.63$, $p < 0.0001$, puma: $W = 0.71$, $p < 0.0001$, both felids $W = 0.82$, $p < 0.0001$). Even when I calculated the change in felid visits between phases (phase 2 -phase 1) or between conditions (treatment - control) the distributions were not normal. (jaguar: $w = 0.79$, $p < 0.0001$, puma: $w = 0.81$, $p < 0.0001$, both felids 0.89, $p=0.004$).

I found no significant difference between the change in puma visits and the change in jaguar visits to the same replicate from phase two to phase one (within-subjects non-parametric Wilcoxon signed test V=72, p=0.85) and the two felids' visits suggest a positive correlation within replicates (Spearman= 0.40, p = 0.02, Kendall's Tau= 0.34, p= 0.02). This suggests the two felids follow similar patterns of change in frequency of visits to the same vicinities of herds. Therefore, I tested jaguars and pumas independently and pooled.

Table 1.3 Randomized, controlled trial with crossover design in 32 herds of livestock during May 2019 to December 2021 in Colombia. Independent visits of attacks and approaches by pumas and jaguars.

Replicate herd	Study site-period	Foxlight treatment	Order	Camera days phase 1	Puma visits phase 1	Jaguar visits phase 1	Camera days phase 2	Puma visits phase 2	Jaguar visits phase 2
1	slp	Mobile	AB	73	0	0	102	2	1
3	slp	Mobile	AB	17	0	0	83	0	1
4	slp	Mobile	AB	73	0	0	92	1	1
11	sle	Mobile	AB	227	1	2	237	0	0
12	sle	Stationary	AB	140	0	0	153	0	0
13	sle	Stationary	AB	60	0	1	110	0	0
14	sle	Stationary	AB	106	1	1	115	0	0
21	cme	Stationary	AB	302	0	0	122	0	0
22	cme	Stationary	AB	201	0	0	54	0	0
23	cme	Stationary	AB	280	0	0	125	2	1
24	cme	Stationary	AB	274	4	0	326	0	0
25	cme	Stationary	AB	352	4	0	186	3	0
26	cme	Stationary	AB	62	0	0	57	0	0

7	slp	Mobile	BA	67	0	1	83	0	0
8	slp	Mobile	BA	69	0	0	79	0	0
10	slp	Mobile	BA	147	0	1	171	3	1
16	sle	Mobile	BA	148	1	0	238	0	0
17	sle	Mobile	BA	200	1	0	216	1	0
18	sle	Mobile	BA	90	0	0	27	0	0
19	sle	Stationary	BA	212	0	0	180	0	0
20	sle	Stationary	BA	189	0	0	143	0	0
27	cme	Stationary	BA	345	0	1	160	0	1
28	cme	Stationary	BA	272	1	7	65	0	0
29	cme	Stationary	BA	182	3	0	80	0	0
31	cme	Stationary	BA	378	2	0	290	0	0
Sensitivity analyses (included only to check main results because experimental design was imperfect)									
2*	slp	Mobile	AB	76	0	0	50	0	0
5*	slp	Mobile	AB	73	0	0	0	0	0
6*	slp	Mobile	BA	32	0	0	162	0	1
9*	slp	Mobile	BA	5	0	0	0	0	0
15*	sle	Stationary	AB	2	0	0	78	0	0
30*	cme	Stationary	BA	392	0	0	209	0	0
32*	cme	Mobile	BA	43	0	0	89	0	0

Slp= San Luis pilot, Sle = San Luis Experiment, Cme - Cimitarra Experiment
mobile or stationary refers to the deployment of lights
AB = control then treatment and BA = Treatment then control randomly assigned,
visits in the table have not yet been divided by camera-days per replicate.
**Replicates excluded for sensitivity analyses (and had no puma or jaguar visits reported during the study periods)*

The change of herd size in phase two minus phase 1one, did not correlate to the observed changes in felid visits phase 2 minus phase 1 within replicates (Spearman rank correlation jaguar rho = -0.01 p=0.93, puma rho = -0.17, p= 0.34, both felids rho = -0.16, p = 0.39). Therefore, I pool replicates regardless of herd size.

Change in the number of cameras phase 2 minus phase 1 did not correlate with the change of felid visits within replicates (jaguar rho= -0.12, p=0.52, puma rho = 0.10, p= 0.59, both felids rho = 0.05, p = 0.79). Therefore, I pooled replicates regardless of the number of cameras.

For the remaining potentially confounding covariates that did not change within replicates during our study, I used grouped tests. I compared replicates that contained only large livestock to those that contained large and small. Two replicates contained only small livestock, camuro sheep, but that was insufficient for a robust statistical comparison, so I pooled those two replicates with the replicates that included both large and small livestock (cows and calves). Herds that began with small animals never changed size category e.g., calves where not taken away, and herds that began in the large category did not had young during the study period. I found no difference in the change of felid visits by livestock size (Wilcoxon rank sum test with continuity correction: jaguar W=104, p=0.80, puma W=117, p=0.77, both felids W=120, p=0.70). In case larger herds were more attractive or smaller livestock were more attractive, I tested an interaction term between the two (assigning 0 to replicates with both small and large livestock, 1 to replicates with only large livestock) then multiplied that term against the change in herd size in phase 2 minus phase 1 to test for correlation with change of felid visits (jaguar rho= -0.28, p=0.12, puma rho = -0.06, p= 0.76, both felids rho = -0.21, p = 0.24).I also tested this correlation with the sum of visits in phase 1 and 2 (jaguar rho= 0.19, p=0.29, puma rho = -0.14, p= 0.43, both felids rho = 0.05, p = 0.78). Therefore, livestock size did not confound our analyses, nor did the interaction of livestock size and change in herd size, so I pooled replicates regardless of herd size or livestock size.

I found no significant difference between study site-periods in jaguar and puma visits summed across phase 1 and 2 (slp jaguar median = 0.54, slp puma median = 0, sle jaguar median= 0 sle puma median=0 , cme jaguar median = 0.14, cme puma median = 0; Kruskal Wallis df=2, jaguar X^2= 4.7, p= 0.09, puma X^2 = 1.1, p= 0.56, both felids X^2 = 1.6, p = 0.44). However, I found a potential difference in visits (phase 2 minus 1) between study site-periods (jaguar X^2=6.9, p= 0.03, puma X^2 = 1.60, p= 0.44, both felids X^2 =2.54, p = 0.28),omitting the 7 replicates for sensitivity analyses (phase 2 minus 1), increased the significance for jaguars (jaguar X^2=10.16, p= 0.003, puma X^2 = 1.60, p= 0.45, both felids X^2 =4.17, p = 0.12). I interpret this to mean the three-study site-periods showed different patterns of change in jaguar visits over the two phases. Therefore, I treat the study site-periods as separate in the tests of treatment effects and also pooled.

The results of spearman rank correlations and the variance inflation factor for the nuisance variables evaluated by each pair of predictors confirm the variables are not collinear (Table 1.4:1.5).

Table 1.4 Examination for collinearity using spearman rank correlations for predictors: Study site, livestock size and herd size. Values close to 1 represent higher rate of collinearity.

Predictors	Study-Site period	Livestock Size	Herd Size
Study-Site period	1	-0.45	0.64
Livestock Size	-0.45	1	-0.57
Herd Size	0.64	-0.57	1

Table 1.5 Examination for collinearity using variance inflation factor for each pair of predictors. Values close to 1 represent higher rate of collinearity.

VIF Jaguar		
	Categorical Time	
Livestock Size	1.11	**Livestock Size**
Herd Size	2.09	1.52
VIF Puma		
	Categorical Time	
Livestock Size	1.22	**Livestock Size**
Herd Size	1.75	1.41
VIF Felids		
	Categorical Time	
Livestock Size	1.16	**Livestock Size**
Herd Size	1.87	1.45

I ran three Generalized Linear Mixed Model (GLMM) to predict the summed visits in both phases for jaguar (n=32, AIC = 49.7, Loglikelihood= - 16.9, Deviance=33.7 , df=24), puma (AIC=52.9, loglikelihood= - 18.5, Deviance=36.9 df=24) and both felids (AIC=69.9, loglikelihood= - 26.9, Deviance= 53.9 df=24). The distribution of the response variable (Summed visits in both phases for jaguar, puma or both felids) followed a negative binomial distribution and I selected the study site period, livestock size, herd size and interactions as the predictors. The results of our GLMM shows that study site, livestock size, herd size and the interactions between predictors are not statistically significant and did not interact to confound our interpretation of treatment effects for the model of jaguar, puma and both felids.

Table 1.6 Generalized linear mixed model to predict jaguar, puma, or both felids' visits per camera-day as a function of potentially confounding variables measured at the Colombian sites of San Luis during two periods (2019, 2020) and Cimitarra during one period (2021).

Parameter	Jaguar	Puma	Felids
Intercept	-1.13	-2.74	-1.27
Study-Site period	-0.62	0.53	-0.0002
Livestock Size	1.35	1.3	1.31
Herd Size	0.07	0.06	0.07
Study-Site period:Livestock Size	-0.75	-0.66	-0.69
Study Site Period:Herd Size	-0.01	-0.02	-0.01

Note: For each parameter I present the estimates and p-value for that parameter as * p<0.05, ** p<0.01, *** p<0.001.

1.3.1. Effects of variable deployment of lights

Some variables in our deployment of lights might interfere with our evaluation of the simple treatment effect because deployments did not change within replicates (e.g., mobile or stationary lights and number of lights), but these could produce treatment bias and dose effects respectively. For example, if mobile lights are ineffective but stationary ones are effective, our simple evaluation of a treatment effect could result in non-significant results because I combined an ineffective treatment with an effective treatment unknowingly. Therefore, I report the correlations of number of lights to felid visits and the difference between felid visits to herds with mobile lights to those to herds with stationary lights next.

I found no significant difference in the sum of felid visits phase 1 + 2 in replicates with mobile versus stationary lights (removing replicate 2,5,6, 9,15, 30, 32 so n=25, jaguar W = 101, p =0.11, puma W = 81, p = 0.74, both felids W=91.5, p=0.36). Nevertheless, possibly the deployment (mobile or stationary) was only influential when the lights were turned on (treatment condition), so I repeated the test above during the phase of treatment condition only in each replicate (n=25, jaguar W = 99, p = 0.11; puma, W = 80, p = 0.77; both felids W=95, p=0.25). Therefore, the deployment of lights as mobile or stationary did not confound our interpretation of treatment effects below.

1.3.2. Treatment effect of lights

Jaguar visits differed in the three study periods (Kruskal Wallis n=25, df=2, X^2 =11.12, p=0.003). When I analyzed jaguar visits to slp and sle, I found a decrease of jaguar visits from slp to sle (Kruskal Wallis jaguar df=1, jaguar X^2 =8.88, p=0.002). Therefore, I test for treatment effect combining data of slp, sle cme but also excluding sle and then only for slp. I evaluated period effects prior to assessing treatment effects.

1.3.3. Period effects

1.3.3.1. Period effects slp, sle and cme:

Period effects might confound our results of treatment effect. Therefore, I test for period effects in slp, sle and cme. I observed no difference across phases for pumas, jaguars or both felids (n=32, jaguar V=45, p= 0.66, puma V=44, p= 0.94, both felids V=93.5 ,p=0.74), nor when omitting the replicates for sensitivity analysis (n=25, jaguar V=40, p= 0.56, puma V=44, p= 0.94, both felids V=85.5, p=0.68). Our findings about treatment effects for data of slp, sle and cme are not confounded by phase effects.

1.3.4. Phase Effects

1.3.4.1. Phase effects slp and cme:

I observed no difference across phases for pumas, jaguars or both felids in slp and cme (Wilcoxon signed rank test, n=22, jaguar V=18, p= 0.63, puma V=16, p= 0.47, felids V=36.5

,p=0.55), nor when omitting the replicates for sensitivity analysis (n=17, jaguar V=16, p= 0.83, puma V=16, p= 0.47, both felids V=32.5, p=0.63). Our findings about treatment effects for data of slp and cme are not confounded by phase effects.

1.3.4.2. Phase effects slp

I observed no difference across phases for pumas, jaguars or both felids in slp (n=10, jaguar V=7, p=0.52, puma V=0, p=0.18, all felids V=3, p=0.14) nor in our sensitivity analyses (n=6, jaguar V=6, p=0.78, puma V=0, p=0.18, all felids V=2, p=0.17). Our findings about treatment effects in slp are not confounded by phase effects.

1.3.5. Treatment effects

1.3.5.1. Treatment effects for slp, sle and cme:

I found no statistically significant effects of lights to deter jaguar, puma, or all felid visits for the entire dataset (Wilcoxon signed rank test n=32, jaguar V=27, p= 0.36, puma V=31, p= 0.32, both felids V=63, p=0.33). For sensitivity analysis, I repeated the analysis without seven replicates that might have undermined our design, but I found no significant treatment effect (n=25, jaguar V =21, p =0.30, puma V=31, p =0.32, both felids V=53, p=0.27).

When I compared visits in treatment minus control to visits in phase 1 minus phase 2, I found no significant difference for jaguars, pumas or both felids (n=32, jaguar V=5, p=0.58, puma V=6, p=0.40, all felids V=14, p=0.34) or for sensitivity analyses (n=25, jaguar V=2, p=0.36, puma V=6, p=0.40, all felids V=9, p=0.23) nor correlations (rho>0.13 in all six comparisons). Therefore, treatment effects on felid visits were similar in magnitude to phase effects on felid visits.

Despite the lack of significance of treatment effect using a frequentist threshold of $p<0.005$, I note there was a tendency for jaguars to visit herds more often in phase 1 and phase 2. (n=32, sd 0.29, n=27 mean=0.07, sd=0.27). Furthermore, treated herds experienced more felid visits per camera-day (n=32, mean felids in treatment= 0.59, sd 0.93, mean felids in control=0.35, sd=0.66, even without the 7 problematic herds, n=25, mean felids in treatment=0.76, sd=0.99, mean felids in control=0.43, sd=0.73). The absolute number of recorded visits (not per camera days) reveals that pumas visited treated herds 16 times compared to 14 times in control herds. Similarly, jaguars visited treated herds 14 times, whereas they visited control herds only 6 times. (n=25 herds in the sensitivity analyses). This raw data and the frequency per camera-day both suggest a higher risk associated with lights, perhaps from curiosity. Furthermore, the three attacks occurred on treated herds.

1.3.5.2. Treatment effects for slp and cme:

I observed some attraction of jaguar, but not for puma and felids summed to the lights (Wilcoxon signed rank test jaguar V=5, p=0.04, puma V=13, p= 0.28, both felids V=20, p= 0.08). Omitting 7 replicates for sensitivity analyses I found similar results for jaguars and felids but not for pumas (Wilcoxon signed rank test, n=17, jaguar V=2, p=0.02, puma V=13, p=0.28, all felids V=14, p=0.05). These results appear to replicate findings for Andean and red foxes (Ohrens et al. 2019, Hall & Fleming et al. 2021) When I compared felid visits in treatment minus control to felid visits in phase 1 minus phase 2, I found no significant difference (n=22, jaguar V=5, p=0.58, puma V=4, p=0.85, all felids V=10, p=0.55) and for sensitivity analyses (n=17, jaguar V=2, p=0.36, puma V=4, p=0.85, all felids V=6, p=0.40) nor correlations (rho>-0.02 in all six comparisons), from which I conclude treatment effects on felid visits are similar in magnitude to phase effects on felid visits for slp and cme.

The absolute number of recorded visits (not per camera days) reveals that pumas visited treated herds 14 times compared to 11 times in control herds. Similarly, jaguars visited treated herds 14 times, whereas they visited control herds only 2 times. (n=16 herds in the sensitivity analyses).

1.3.5.3. Treatment effects for slp:

I found no deterrent effect of lights to deter jaguars, pumas, or all felid visits in slp (Wilcoxon signed rank test, n=10, jaguar V=2 p=0.09, puma V=2 p= 0.78, both felids V=5 p= 0.29**.** For sensitivity analyses excluding four replicates problem (2,5,6,9) of slp, I found some attraction for jaguars but not for pumas or both felids (Wilcoxon signed rank test, n=7, jaguar V=0, p=0.05, puma V=2, p=0.78, all felids V=3, p=0.28). When I compared felid visits in treatment minus control to felid visits in phase 1 minus phase 2, I found no significant difference (n=10, jaguar V=2, p=0.78, puma V=1, p=1, all felids V=4, p=0.78) and for sensitivity analyses (n=6, jaguar V=0, p=0.37, puma V=1, p=1, all felids V=2, p=1) nor correlations (rho>-0.08 in all six comparisons), from which I conclude treatment effects on felid visits were similar in magnitude to phase effects on felid visits for slp.

The absolute number of recorded visits (not per camera days) reveals that pumas visited treated herds 3 times compared to 0 times in control herds. Similarly, jaguars visited treated herds 5 times, whereas they visited control herds only 1 time (n=6 herds in the sensitivity analyses). This raw data and the frequency per camera-day both suggest a higher risk associated with lights.

1.3.6. Changes over two study site-periods: slp and sle

I observed a decrease in jaguar visits from slp to sle (Kruskal Wallis jaguar df=1, jaguar X^2 =8.88, p=0.002). Jaguars in San Luis changed behavior from attracted to lights in slp to being deterred by them during sle or the experimental methods increased the deterrent effect of the experimental design (regardless of the lights), so jaguars visited less often as the study progressed. Either explanation is consistent with cme and slp showing attraction by jaguars to lights and sle showing deterrence of jaguars. I found no difference in the frequency of visits of pumas and jaguars in San Luis when comparing the same herd in slp and sle in the same treatment condition (Wilcoxon signed rank test, n=8, control condition: jaguar V = 1, p = 0.42, treatment condition: jaguar, V = 15, p = 0.06, control condition: puma, V = 4, p = 0.85, treatment condition: puma, V = 7, p = 0.58). Finally, treatment effects were the same (non-significant) when comparing the herd in slp to that same herd in sle (jaguar V = 0, p = 0.10, puma V = 3, p = 0.58). Therefore, treating replicates in slp and sle as the same subjects (n=6) did not change our main results with n=25.

1.3.7. Treatment effect for deployment type: Mobile vs Stationary

To evaluate if the deployment type has a treatment effect, I repeated the analysis separated by mobile and stationary for the entire experiment and excluding the replicates problem (conditions AB, BA, AC, and CA where A= Control/Placebo B= Stationary C = mobile).I found no significant effect of lights deployed stationary or mobile to deter jaguars, pumas or felids (Kruskal Wallis n=32, df=3, jaguar X^2 =2.3, p= 0.50, puma X^2=2.07 p= 0.55, both felids X^2 =2.94, p= 0.39) or in sensitivity analysis (n=25, df=3, jaguar X^2=3.6, p= 0.30, puma X^2=2.1, p= 0.53, both felids X^2=3.8, p= 0.27).

1.3.8. Dose effect

Finally, the number of lights represents a potential dose effect (more lights might mean more deterrence), so I correlated felid visits during the treatment condition to the number of lights in that replicate (Kendall n=32 jaguar tau = 0.04, p = 0.77, puma tau = 0.24, p = 0.12, both felids tau = 0.20, p = 0.17). Although non-significant, the tendency to a positive correlation needed scrutiny. I placed more lights near the larger herds and pastures of cme, which also experienced more felid visits. However, slp also experienced more visits in treatment condition compared with control with only one light. For sensitivity analysis, I test without replicates that interfered with our design (Kendall n=25, jaguar tau = 0, p = 1, puma tau = 0.22, p = 0.21, both felids tau =0.16, p =0.32). Although results are non-significant, the tendency to a positive correlation needed scrutiny in future research.

1.4. Discussion

I could not detect a deterrent effect of Foxlights® against jaguars or pumas from approaching livestock on pastures in San Luis and Cimitarra, Colombia. Nor did I find the lights attracted either repelled to pastures. The lack of treatment effect of lights did not change when compared to subjects in control conditions without lights (passive control) or with lights turned off (active placebo control). I found no significant difference in effect between stationary lights and mobile ones affixed to the back of a domestic animal. I found no significant difference in effect by the number of lights deployed.

Because of a weak attractive effect for jaguars in the first trial at two of our sites (San Luis and Cimitarra) and a weak deterrent effect on jaguars in the second later trials at San Luis, I do not believe a larger sample of herds would have changed our results. Because of the large sample size relative to most studies in our subfield, it seems unlikely our tests lacked power (25-32 herds depending on which variables I included), especially given our crossover design RCT (Colquhoun 2014; Benjamin et al. 2018; Christie et al. 2019). Namely, our study joins others that find mixed effects or short-term effects only.

Meta-analyses and reviews summarize mixed effects, short-term desired effects, and some counter-productive effects of light deterrents (Treves et al. 2016, 2023; Khorozyan & Waltert, 2021; Moreira-Arce et al., 2018; Van Eeden et al., 2018). While one RCT with crossover design found Foxlights® effective in deterring Chilean pumas from attacking llamas and alpacas they also reported that Andean foxes approached treated herds at higher frequencies (Ohrens et al., 2019). Moreover, an RCT conducted at outdoor piggeries in Australia found Foxlights® ineffective in protecting pigs from red foxes and reported higher rates of approaches and piglet mortality in piggeries fitted with Foxlights® (Hall & Fleming, 2021). That study had corroborating evidence on moonlit conditions to argue that light of any sort raised the risk for piglets. Smaller sample RCTs with crossover design reported no effect of Foxlights® paired with fladry (Fergus et al., 2023). These mixed results suggest habituation to lights, differences between individuals of the same species, or differences between species of predators, as described by (Khorozyan & Waltert, 2021) in the meta-analysis of interventions used to protect livestock from wild cats.

Our results on carnivore approaches and attacks support the hypothesis that pumas and jaguars may have begun as or may have become habituated to lights, a process by which animals become accustomed to repeated stimuli and stop responding to them (Blumstein, 2016). A summarized in the first paragraph of the discussion, jaguars seemed slightly attracted to our treated pastures (with lights) in the first trials in each study site (San Luis pilot, slp, and Cimitarra, cme) but by the time of the second trial in San Luis (sle) 2 months after slp, that attraction became avoidance. Not so for pumas. Both study areas are fragmented landscapes with human activity, so I presume all felids are exposed to various lights at different levels. Presumably few of the pre-existing lights were tri-colored and randomly flashing though. Thus, it is possible that some individual big cats commonly see fluorescent or yellow stationery, steady lights in these areas and do not respond strongly to them. Possibly, jaguars might be curious about the experimental lights, the new object in the environment, which could explain the visits to herds in treatment in the initial stage of our experiment giving way to habituation and avoidance thereafter. Previous controlled experiments testing effectiveness of non-lethal methods have found an increased activity of predators in treatment condition attributing this to the curiosity and intelligence of carnivores (Louchouarn & Treves, 2023). Individuals are likely to vary in curiosity, neophobia, or risk-taking around people, domestic animals, or structures (Bunnefeld et al., 2006; Larrucea et al., 2007). If approaches or curiosity are associated with higher risk of attacks, then deterrents that prompt curiosity or exploratory behavior seem risky.

Whether the lights affected the rate of attacks on livestock is difficult to address given the rarity of such attacks in all studies thus far. I only observed three attacks: on one farm I recorded two attacks on sheep (when I intended to protect cattle in a different pasture) and an attack on a calf in a different farm. In all cases the attacks occurred less than 500m from the deployed lights. The sheep in the former case were able to cross in and out of the cattle pasture and were killed within a treated pasture. This seems equivocal evidence for the deterrent effect of lights. Yet, our results do not provide much support for the use of lights as an effective method for protecting domestic animals from jaguars and pumas in fragmented forests. Therefore, I conclude that caution should be used in promoting lights as a deterrent for carnivores in human-inhabited areas of North and South America. Caution is warranted.

A cautious approach to deploying lights and measuring their effects in approaches by wildlife seems wise. I recommend more study of the relationship between approaches and attacks. Approaches by themselves are not problematic as our study and many others demonstrate frequent visits by predators without ensuing attacks (Chavez & Gese, 2006; Louchouarn & Treves, 2023). Larger samples will be needed to evaluate if approaches correlate strongly to attacks, a gap in knowledge across our subfield. Also, I call for more behavioral research on predators around livestock to tailor non-lethal methods of deterrence for the benefit of all.

A number of studies have measured effects of lights (Hall & Fleming, 2021; Koehler et al., 1990; Naha et al., 2020; Stone et al., 2017), yet ours is the first study to our knowledge that measured the effects of doses of treatment (number of lights) in addition to the first test of mobile lights. Mobile lights were initially proposed by the owners themselves in the San Luis study area. Some livestock individuals did not tolerate the attachments, so I switched those to stationary deployments. From a practical perspective, the mountain pastures in which our study livestock were released could be large, visually obstructed by trees within pastures, or topographically complex. All these attributes might reduce the effect of a single stationary lights. That constraint reduced our sample of mobile lights and power of statistical tests, limiting our ability to discriminate differences between mobile and stationary lights (sensitivity analysis n=25, mobile=10, stationary=15). Nevertheless, I recommend further research rather than a premature judgment that mobile lights are as effective as stationery. The conditions I describe are common worldwide in livestock grazing areas. Setting aside the ethical and sociopolitical question of whether livestock should be grazed in wild habitats of large carnivores, discovering an effective mobile deterrent would benefit many people, wild animals, and domestic animals. Therefore, I recommend further RCTs of mobile deterrents.

1.5. Limitations

In San Luis, trials on neighboring herds were not far enough apart for me to be confident that multiple individual pumas and individual jaguars were exposed to both treated and control herds. Furthermore, spatial spillover effects are a limitation in the RCT in San Luis due to proximity of farms. Conceivably one individual might have excluded conspecifics or heterospecific from two or more herds. The area covered in San Luis was 1851.43 ha which is not as extensive as one might expect for the home range of pumas and jaguars. I photographed at least two individuals of puma and jaguar in Slp and Sle. The number could be higher given not all carnivores will be captured by the same cameras. Unfortunately, confirming whether it is the same or a different individual is challenging due to factors such as animal side photographed, blurred photographs, and the inherent difficulty in identifying puma individuals. For future projects I recommend that the units evaluated are separated to cover the home ranges of different individual predators, as did our experiment in Cimitarra.

Another limitation was the lack of active placebo control conditions in sle and cme. Our goal was to conduct the experiments with a consistent placebo condition; lights installed but turned off. However, I was concerned that two owners in slp might have subverted the experimental design when they were in the placebo control condition and turned the lights back on. I decided to remove the lights in sle, and cme to avoid the latter treatment bias. The problematic farms were removed for sensitivity analyses. I recommend active placebos for future RCTs.

Also, on one farm I recorded two attacks on sheep when I intended to protect cattle. This suggests the felids were hunting around our treated pastures even if they did not approach the intended subject of our interventions. Because the sheep were moving in and out of the cattle pastures, the safety of the cattle and calves may have been enhanced by the presence of the sheep as alternative prey for felids. Due to the importance of cattle production in Magdalena Medio Valley, further predator control experiments could test if mixing paddocks with cattle and sheep could reduce cattle loss, the main economic activity in the region. This is a variation on supplemental (diversionary) feeding for bears (Garshelis et al., 2017), and restoring prey (Treves et al., 2009). Both are strategies rarely if ever used for livestock protection.

1.5.1. Experimental evidence

Our findings highlight the importance of randomized, controlled experiments to test the effectiveness of methods to protect livestock from predators. Such trials might prevent the misallocation of funds to ineffective treatments and thereby improve conservation efforts for big cats. The effectiveness of non-lethal methods is often inferred from before-and-after comparisons. However, I suspect a non-randomized before-and-after comparison in our study area would have produced misleading results (Christie et al. 2019). For example, if I had not randomized treatment, the above-referenced switch from attraction to deterrence of jaguars in San Luis might have been misinterpreted as a desired effect of lights. In general, domestic animals may be attacked only once without a repeat incident, even without any intervention and therefore intervening after an attack can led to a mistaken inference that the intervention was effective (Tompa 1983; Treves & Naughton-Treves 2005; Treves et al., 2019). In our study, 14 farms reported attacks by felids in the past and four reported recent felid attacks in the last three months before the RCTs. During our RCTs, no further attacks were recorded on two of the four farms that had recently reported attacks. Therefore, I confirm concerns that inferences drawn from before-and-after comparisons without randomization are liable to mislead without careful control of background variables such as correlations between number of livestock lost in time t and interventions in time t+1. Such correlations are common when owners react to the loss of a domestic animal by intervening then assume subsequent events relate only to their actions not to the vagaries of animal behavior, environmental variables, chance, and human behaviors. I further emphasize the importance of randomization to reduce research bias.

1.6. Conclusions and Recommendations

I could not detect a deterrent effect of lights against jaguars or pumas from approaching livestock on pastures in San Luis and Cimitarra, Colombia. Therefore, I recommend the adoption of predator control methods by governments and property owners, whether lethal or non-lethal, must be based on the strongest scientific evidence available. Here I recommend randomized, controlled trials, with crossover design whenever possible, to evaluate proposed methods. I also recommend several novel approaches to non-lethal deterrents such as mobile lights, deterrents that reduce novelty yet deter carnivores, vulnerable less expensive animals placed with less vulnerable more expensive animals and addressing inter-individual variation in both humans and carnivores when designing experiments and reporting their conclusions. Non-lethal methods represent an opportunity to promote coexistence with jaguars and pumas and protect the livelihood of rural communities that rely on agriculture and animal husbandry, especially when considering that predator-killing campaigns have caused historic eradication of large carnivores (Breitenmoser, 1998; Chapron et al., 2014; Ripple et al., 2014).

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1.8. Appendices

1.8.1. **Appendix 1.** Individuals of jaguar and puma recorded in our randomized controlled trial with crossover design in San Luis.

1.8.2. Appendix 2. Individual of puma and jaguar recorded in our randomized controlled trial with crossover design in Cimitarra.

1.8.3. Appendix 3. Mobile Foxlights deployed on the animal's back in San Luis with the owner.

1.8.4. Appendix 4. Stationary light deployed in paddocks of one farm in Cimitarra.

2. Chapter 2: Longitudinal Analysis of Attitudes Toward Jaguars and Pumas, and Perceived Effectiveness of a Visual Deterrent in Colombia

2.1. Introduction

Human-wildlife conflict (HWC) encompasses the challenges that arise when the presence or behavior of wildlife represents real or perceived risks to human interests such as property, recreation, and human safety (IUCN SSC HWCTF, 2020; Treves, 2008). These conflicts lead to tensions among different groups of individuals and adverse effects on both human and wildlife populations (IUCN SSC HWCTF, 2020). Real or perceived human-carnivore conflict frequently results in the mortality of carnivores and reinforces negative attitudes toward these predators (Miller et al., 2016). The most common response of affected human communities is to kill problem wildlife as a form of retaliation or to prevent further issues (Inskip & Zimmermann, 2009; Treves & Karanth, 2003). Addressing HWC is essential for both the conservation of carnivore species and the well-being of human communities. Governments worldwide invest significant logistical efforts and financial resources implementing interventions to address human-carnivore conflict (Oliveira et al., 2021). For example, interventions to reduce attacks by carnivores encompass a range of strategies such as non-lethal and lethal methods (Breitenmoser et al., 2009; Eklund et al., 2017; Lorand et al., 2022; McManus et al., 2015; Moreira-Arce et al., 2018; Treves & Naughton-Treves, 2005; Van Eeden et al., 2018). I use the term intervention as "The action of intervening, or interfering in any affair, so as to affect its course or issue", www.oed.com, and defined as the types of methods used to mitigate HWC (Treves et al., 2009). Scientific evidence has demonstrated that a variety of interventions have the potential to facilitate coexistence between humans and carnivores (Inskip & Zimmermann, 2009; McManus et al., 2015; Treves et al., 2009). Previous research on voluntary conservation programs found that the perceived effectiveness significantly mediates the prediction of adoption intention (Zhang & Khachatryan 2023). In the field of human-carnivore conflict, evaluations of functional and perceived effectiveness of interventions rarely have been evaluated using unbiased and rigorous scientific criteria (Ohrens, Santiago-Ávila, et al., 2019).

The functional effectiveness (FE) of an intervention in HWC measures whether the method reduces future attacks on domestic animals by wildlife (Ohrens et al., 2019; Treves et al., 2016). By contrast, the perceived effectiveness (PE) measures the human perception of reduction in damages of an intervention (Ohrens et al., 2019; Treves et al., 2016). PE, which is dependent on individual perceptions, is altered by personal experience, cognition, identity, bias, and psychological elements that shape human appraisal (Finucane et al., 2000; Kellert, 1985; Ohrens et al., 2019). As an example, to illustrate the integrative framework of FE and PE proposed by Ohrens et al. 2019, PE can differ from FE, an intervention can be perceived as ineffective, but scientific measurements reveal it is effective.

Researchers have suggested that the implementation of non-lethal methods could increase farmers' tolerance toward carnivores (Ohrens et al., 2019; Rust et al., 2013; Treves et al., 2009). However, there is a lack of research reporting changes in individuals' attitudes concerning interventions, although different types of interventions are being implemented worldwide. Attitudinal data provide information about the individual levels of support and knowledge relevant to a project (Heberlein, 1989). Most research has used cross-sectional data and few studies have developed longitudinal studies by interviewing respondents more than once. A longitudinal study of attitudes in randomized controlled trials would elucidate if attitudes toward carnivores and the intervention changed after participation. These data are relevant to detect changes in attitudes, behavior and to elucidate whether interventions effectively alter attitudes.

Henderson and colleagues studied attitudes toward deer damage before and after the reduction of 50% of deer population (Henderson et al., 2000). Residents of treated areas perceived the reduction of deer at their backyards after the intervention. Subsequent cross-sectional research evaluated attitudes toward cheetahs in Namibia and the satisfaction of participants after implementing livestock guarding dogs; recipients reported a decline in losses after the acquisition of dogs and satisfaction after participation (Marker et al., 2003, 2005). Other cross-sectional studies in Tanzania have estimated the perceived effectiveness of mitigation methods to protect livestock from predators. Respondents were asked to rate how effective they thought potential mitigation methods (e.g., guard dogs, herders, traditional bomas, fortified bomas) were in preventing livestock losses among a variety of methods, even if they used or not the method. 98% of the 293 respondents scored fortified bomas as very effective. However, most respondents did not use this type of enclosure (Mkonyi et al., 2017). Nevertheless, cross-sectional evidence of Livestock Guardian Dogs (LGDs) in United States suggests that attitudes did not improve towards wolves or grizzly bears among 50 pastoralists familiar with LGDs (Kinka & Young, 2019). These findings suggest that attitudes of pastoralists to carnivores are shaped by factors extending beyond the pragmatic and financial challenges these species present to the ranching sector (Kinka & Young, 2019). Kinka and Young sampled respondents who had some unspecified experience with LGDs and those respondents' colleagues and neighbors through a snowball method, who might not have had such experience. Recent longitudinal research conducted by Volski and colleagues (2021) evaluated the functional effectiveness of Foxlights and interviewed 11 sheep and cattle ranchers in Northern California both prior to and after dissemination of the results from the functional effectiveness of Foxlights. The study showed participants believed lights are functional or possessed the potential to be effective, although researchers had shared the limit effectiveness of lights (Volski et al., 2021). The functional effectiveness included control groups but lack of randomization. The unique evidence evaluating change in attitudes in RCT to my knowledge, was a study conducted in western Colorado, the functional effectiveness of fladry and Foxlights revealed no treatment effect and no shift in the attitudes of participants (Hermanstorfer, 2023).

Here, I report on longitudinal measures of attitudes among participants in a field experiment evaluating the functional effectiveness (FE) of a non-lethal method — Foxlights®- hereafter lights —intended to protect the participants 'domestic animals. I measured the attitudes of managers and owners of 20 farms of San Luis and Cimitarra, Colombia. I investigated whether participation in randomized controlled trials with crossover design changed self-reported attitudes to jaguars and pumas. I hypothesized that participation in predator control experiments would improve attitudes toward pumas and jaguars. Additionally, as each participant randomly experienced treatment in one phase and the control or placebo in the next phase, I hypothesized that participants who experienced the treatment condition in their first phase would show more improvement in their attitudes toward pumas and jaguars compared to participants who experienced the control condition.

Because I report individual changes in PEs, the relationship between PE, FE, and phase of randomized controlled trials with crossover design (RCTs) and compare PEs of individuals in control or treatment conditions, this is the first study of its kind. Therefore, I propose new hypotheses about PE and FE, discuss cross-sectional data collected at one time point and longitudinal data, and call for replication studies.

2.2. Methods

2.2.1. Study area

2.2.1.1. San Luis municipality

San Luis municipality is in Antioquia department, within the Cordillera Central, the highest of the three branches of Colombian Andes. I studied 10 farms in rural areas, (range= 2-57 ha, mean=18.3 ha) with 2-40 domestic animals (mean=10 domestic animals (cattle, mules, donkeys, horses)). Farms have 0-30 ha of forest (mean=9.5 ha), and between 1 and 27 ha of pastures (mean=8.8 ha). Some owners have small crops of coffee, sugar cane, plantains and yuca. During the civil war, all participants abandoned their properties, and they returned years later (García, 2007). I interviewed women (n=4) and men (n=6) landowners. Landowners in San Luis oversee farms. Participants also varied in age (range 30-65 years old, mean = 49.5 years old) and education level (n=3 elementary level, n=7 primary and pre-school level). Among the 10 farms, 6 participants reported past attacks by pumas or jaguars (range 1-3), and 4 farms were never attacked. Eight out of 10 farms contain patches of tropical rainforest.

2.2.1.2. Cimitarra municipality

Located in Santander department of Colombia in the Magdalena Medio Valley, between the central and eastern Colombia Andes. I studied 10 cattle farms of rural area of Cimitarra, (range=31-3000 ha, mean=910.3 ha) with 18-1380 animals (mean 612 domestic animals: cattle, horses, sheep). Farms have 2-100 ha of forest (mean=293.1 ha), and 2-2000 ha of pastures (mean=617.2 ha). Cattle production is the primary income for farms in Cimitarra (n=10). I interviewed women (n=3) and men (n=7), landowners (n=5) and livestock managers (n=5). Their age ranges from 32-64 years old (mean=45 years old). When comparing to the San Luis municipality, the Cimitarra municipality respondents reported higher education levels (university n=3, bachelor n=4, elementary n=3). Among the 10 farms, 8 reported attacks by pumas or jaguars (range 1-3), and 2 farms never had an attack in the past. Livestock production is the main economic activity for owners of small, medium, and large-scale farms of Cimitarra (Instituto Colombiano Agropecuario, 2020). All farms remain patches of tropical rainforest, the habitat of pumas and jaguars. While landowners in San Luis have low incomes, those in Cimitarra have medium and high incomes.

2.2.2. Sampling

Between 2019 and 2021, I conducted a longitudinal study to evaluate the change in attitudes toward lights and toward wild jaguars and pumas. I completed three interviews of landowners, or livestock managers, at the 20 farms on which I conducted randomized, controlled trials with crossover design (crossover RCT) to evaluate the functional effectiveness of portable solar lights as a non-lethal method (Chapter 1). I conducted two crossover RCTs in two phases each at San Luis, and one in Cimitarra (Table 2.1). In 2020, a field assistant, Sergio Gonzalez, was hired to complete the experiment in San Luis due to travel restrictions under the pandemic. In 2021 I received a waiver for international travel under COVID-19 restrictions from the UW-Madison International Safety & Security Department. I recruited participants for in-person workshops in San Luis and online workshops in Cimitarra (See Chapter 1). I interviewed participants who voluntarily agreed to participate in our trials before, at the middle and at the end of the experiment.

Table 2.1 Interviews and location of crossover RCTs in San Luis and Cimitarra

Year	Location of RCTs	Length	Interviews
2019	San Luis Pilot	6 Months	Pre-experiment
2020	San Luis Experiment	8 Months	Midway and post-experiment
2021	Cimitarra Experiment	8 Months	Pre-experiment - Midway – post-experiment

In San Luis Alexandra Pineda conducted in-person and phone interviews (n=20) with support of Sergio Gonzalez (n=10). Alexandra administered in-person interviews at farms of Cimitarra (n=30). I performed the study with informed consent from all participants and approved protocol 2016-1071-CR003 from The Institutional Review Board at the University of Wisconsin-Madison. I prepared interviews in English and Spanish for the review board.

2.2.3. Interviews

2.2.3.1. Change in attitudes and perceived effectiveness of lights.

I developed an interview designed to compare respondents' attitudes towards lights, jaguars, and pumas. The interview has sections of socio-demographic information, farm description, livestock management, perceived losses, knowledge of species (Identification of tracks and signs to recognize an attack), perception of conflict, perceived effectiveness of lights, and attitudes toward pumas and jaguars (Appendix 1). I adapted questions from other surveys of large carnivores, and I asked new questions(Hogberg et al., 2016; Ohrens et al., 2019; Treves et al., 2013). I conducted interviews in Spanish.

Respondents were asked the same questions at both study sites three times. To assess the change in attitudes toward lights, I asked respondents: 1. Do you think lights are effective for livestock protection? 2. Is your livestock safer with the use of lights? To assess the change in attitudes toward felids and coexistence, I asked respondents: 3. How much do you like or dislike jaguars? 4. How much do you like or dislike pumas? 5. Can people and jaguars coexist, meaning, can they live in the same place? 6. Can people and pumas coexist, meaning, can they live in the same place? I asked respondents to choose one option on an ordinal scale and assigned a corresponding score for quantitative analysis. I measured questions 1, 2, 5 and 6 on a 3-point scale (‘no ’(-1), ‘unsure ’(0), ‘yes’(1), and question 3,4 on a 5-point scale (‘like very much’(5), ’like somewhat’(4), ‘neutral’(3), dislike somewhat’(2), dislike very much ’(1).

2.2.3.2. Perception of human-felid conflict and toward the government environmental agency

I asked participants their perception of conflict before the experiment with the question: “Has the conflict involving jaguars and pumas increased, decreased, or remained stable over the past five years?“ and the end: “During the time of the experiment the conflict involving jaguars and pumas increased, decreased, or remained stable?” .

I also asked respondents their perception toward the government environmental agency with a question only asked before the RCT: “Do you believe the corporation is effectively and promptly addressing the complaints related to the attacks of jaguars and pumas in the area?”.

Sample size was 20 for all tests, except when I compared the change in attitudes by treatment and control for Cimitarra, where the participants experienced only one of each condition (n=10).

2.2.4. Statistical analysis

Each participant's response was coded into numerical categories for analysis in R version 4.3.1. I determined the individual change values of participants by subtracting their responses after the experiment from those before the experiment, following a previous study on changes in attitudes toward wolves (Hogberg et al., 2016). I used the Wilcoxon signed-rank test to detect changes in attitudes.

I used Kruskal-Wallis tests to compare change in attitudes by treatment or control for Cimitarra where the participants experienced only one of each condition (n=10). To compare if change in attitudes differed by gender or site, I ran Kruskal-Wallis tests for questions two, three and four, (n=20). Furthermore, I analyzed the relationship between change in attitudes, and puma and jaguar visits per farm using Kendall-Tau correlation test (n=20), which corrects for ties between ranks. Data of puma and jaguar visits per farm are results from chapter 1 from the RCTs. Finally, I analyzed the relationship between change in attitudes, and number of lights per farm using the Kendall-Tau correlation test for Cimitarra (n=10). I refer to p-values as suggestive when they approximate p= 0.05 and significant for p=0.01 following (Benjamin et al. 2018) and to reduce false positive rates (Colquhoun 2014). Because I am replicating a study by Hermanstorfer (2023), I allow p>0.005 (Benjamin et al. 2018) to guide inference. In accordance with Colquhoun 2014, I conducted an adjustment of significance thresholds for experiments that make multiple comparisons.

2.3. Results

2.3.1. Did participation affect attitudes?

Overall, results suggest that participation in a predator control experiment shifted participants to more positive attitudes towards jaguars and pumas. When I asked, "Do you think lights are effective for livestock protection?" before the experiment, 14 participants responded ‘yes’, five chose ‘maybe’, and one chose ‘no’. After the experiment, 19 participants chose ‘yes’, and 1 chose‘ maybe’, representing one negative change in attitude by one rank for one participant, no change in attitude for 13 participants, and positive changes for six participants, by one rank (n=5) or two ranks (n=1), which suggests a small change in attitudes toward lights (Wilcoxon signed rank test n=20, V = 3.5, p = 0.07, Figure 2.1).

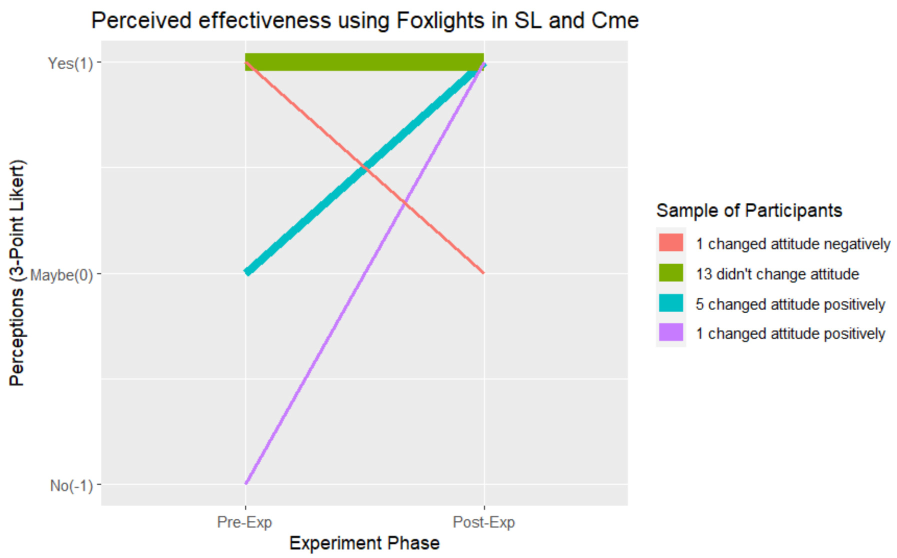


Figure 2.1 Change in attitude to the question (Do you think lights are effective for livestock protection?) before and midway through the experiment among 20 participants of San Luis (SL) and Cimitarra (Cme).

When asked "Is your livestock safer with the use of lights?" before the experiment, 12 participants responded 'yes', four chose 'unsure', and four chose 'no'. After the experiment, 19 participants chose 'yes', and 1 chose 'no', representing no change in attitude for 13 participants, and positive changes for 7 participants, by one rank (n=4) or two ranks (n=3), which indicates a probable change in attitudes (n=20, V = 0, p = 0.01, Figure 2.2), suggesting improved their attitudes toward lights at the end of the experiment.

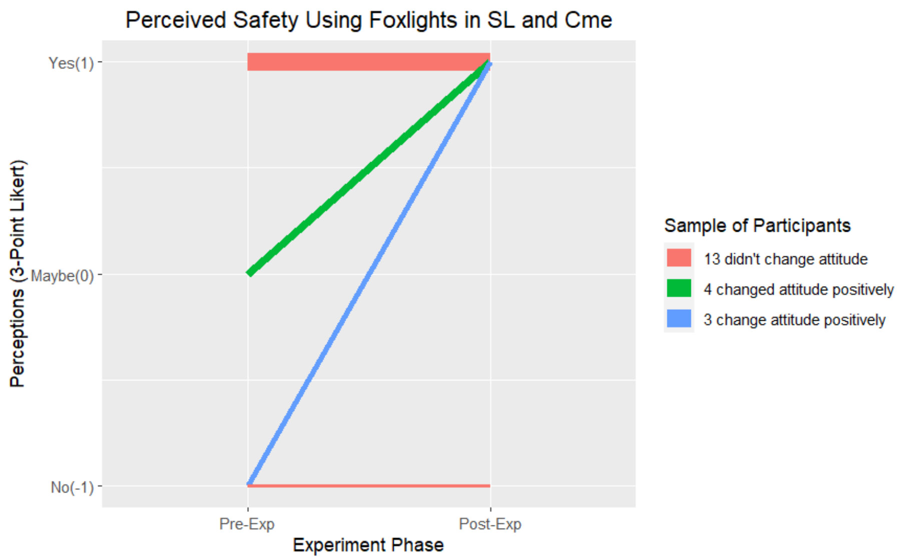


Figure 2.2 Change in attitude to the question (Is your livestock safer with the use of lights?) before and after the experiment among 20 participants of San Luis (SL) and Cimitarra (Cme).

When asked "How much do you like or dislike jaguars?" before the experiment, 1 participant responded, 'Like very much', eight chose 'like somewhat', eight chose 'neutral', and three chose 'dislike somewhat'. After the experiment, 18 participants chose 'like somewhat', one chose 'neutral', and 1 chose 'dislike somewhat', representing a negative changed for one participant, no change in attitude for 10 participants, and positive changes for nine participants, by one rank (n=7) or two ranks (n=2), which indicates a probable change in attitudes to jaguars (n=20, V = 4.5, p = 0.01; Figure 2.3).

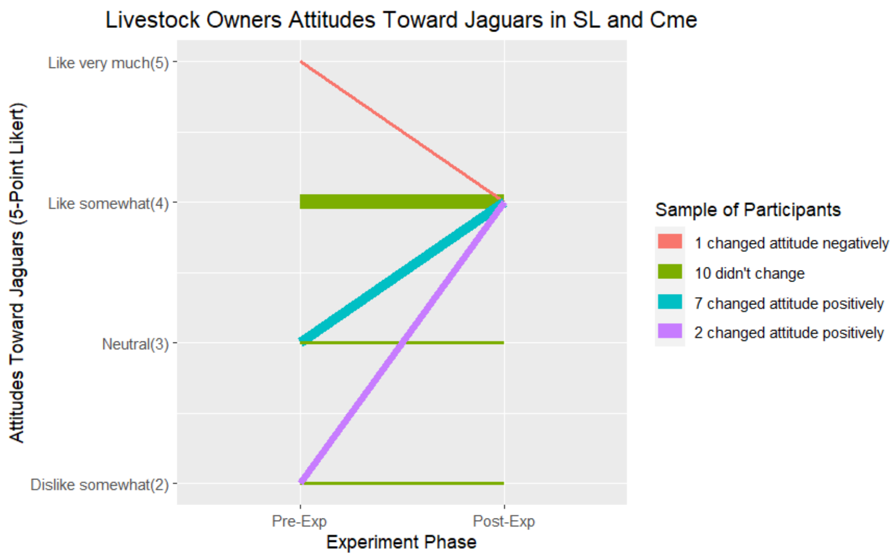


Figure 2.3 Change in attitude to the question (How much do you like or dislike jaguars?) before and after the experiment among 20 participants of San Luis (SL) and Cimitarra (Cme).

When asked "How much do you like or dislike pumas?" before the experiment, 1 participant responded 'like very much', seven chose 'like somewhat', nine chose 'neutral', and three chose 'dislike somewhat'. After the experiment, 16 participants chose 'like somewhat', three chose 'neutral', and 3 chose 'dislike somewhat', representing a negative changed for three participants, no change in attitude for 7 participants, and positive changes for 10 participants, by one rank (n=8) or two ranks (n=2), which suggests a possible change in attitudes (n=20, V = 18, p= 0.04; Figure 2.4).

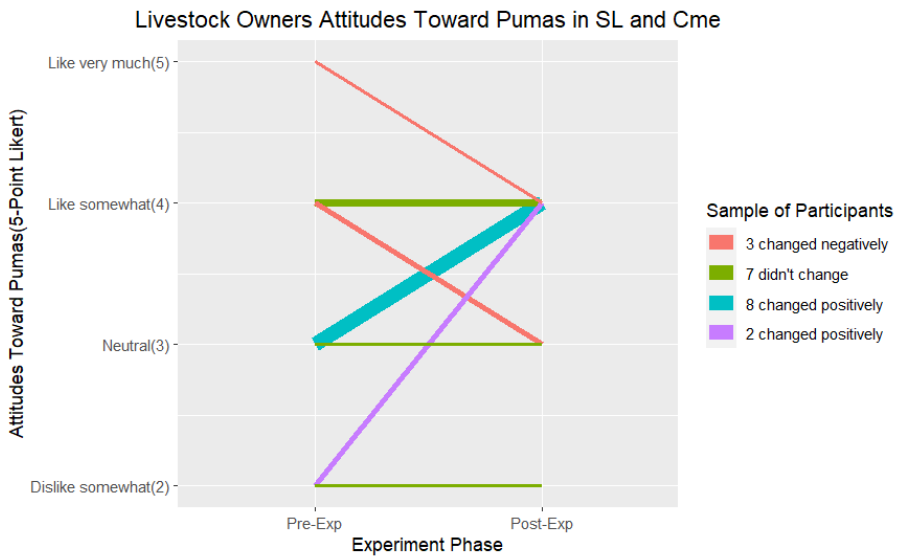


Figure 2.4 Change in attitude to the question (How much do you like or dislike pumas?) before and after the experiment among 20 participants of San Luis (SL) and Cimitarra (Cme).

When asked " Can people and jaguars coexist? and **can people and pumas coexist?** meaning, can they live in the same place?" For both questions before the experiment, 18 participants responded 'yes', one chose 'unsure', and 1 chose 'no'. After the experiment, 20 participants chose 'yes', representing no change in attitude for 18 participants, and positive changes for two participants, by one rank (n=1) or two ranks (n=1), which suggests a positive change in attitudes (n=20, V = 0, p= 0.37; Figure 2.5), because people with negative or neutral attitudes toward coexistence with jaguars or pumas shifted to a more positive attitude at the end of the experiment.

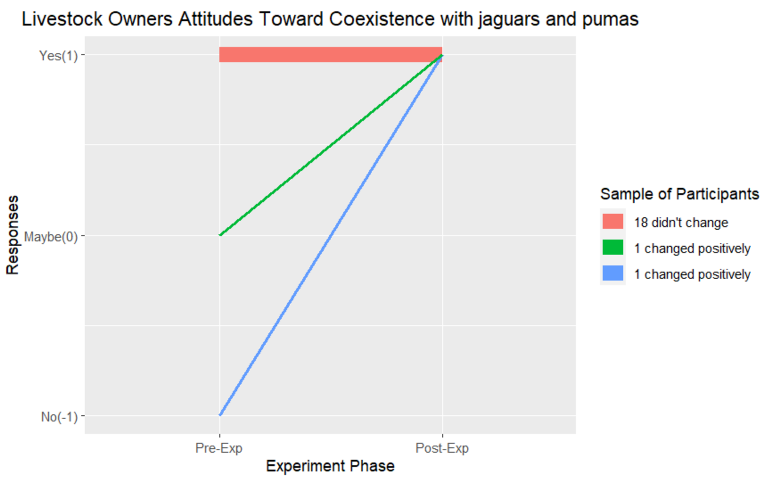


Figure 2.5 Change in attitude to the question (Can people and jaguars coexist? and can people and pumas coexist? meaning, meaning, can they live in the same place?) before and after the experiment among 20 participants of San Luis (SL) and Cimitarra (Cme).

2.3.2. Did the farmers who received placebo change attitudes more, less, or the same as those who received treatment conditions (lights turned on)?

For a subset of 10 participants from Cimitarra, I asked the same question before and midway through the experiment, at which time each had experienced only one condition. Results suggest that participants in the control condition changed to more positive attitudes than those in the treatment group.

When asked "Do you think lights are effective for livestock protection?", among five participants assigned to the control condition, one chose 'yes', and 4 chose 'unsure' at the start of the experiment '; then midway through, five chose 'yes '(meaning the four unsure participants changed positively). Among five participants assigned to the treatment condition, five chose 'yes', and one chose 'no' before the start; then midway through, four chose 'yes 'and one chose 'unsure '(representing a positive change by one rank). Hence, one participant changed negatively by one rank, four did not change, and five changed positively by one (n=4), and two (n=2) ranks respectively (Figure 2.6a). In a grouped comparison of treatment to control condition, changes were not predicted by treatment or control conditions (Kruskal-Wallis n=10, chi-squared= 1.7, df = 1, p = 0.18).

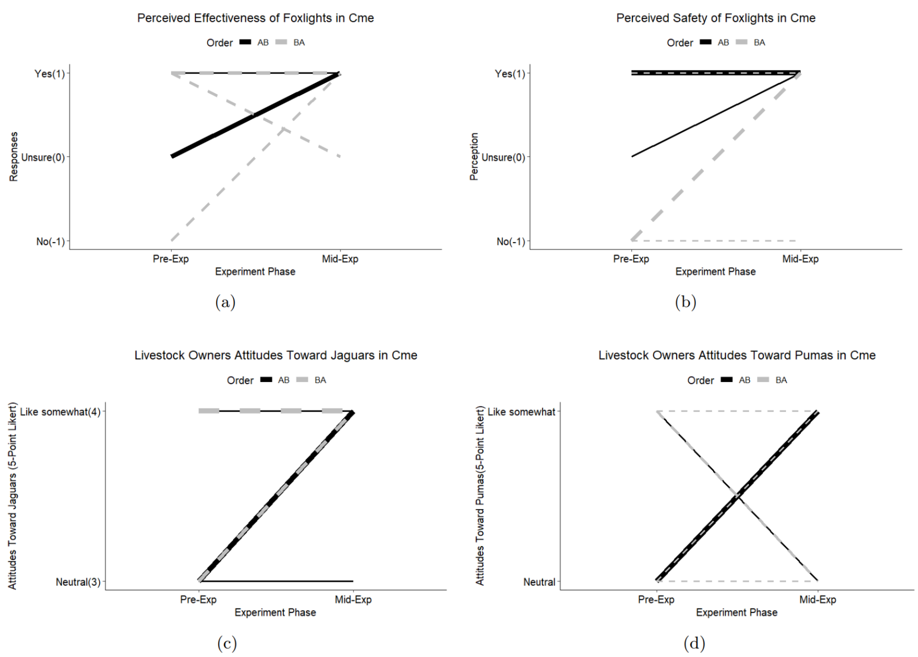
When asked “Is your livestock safer with the use of lights?”, among five participants assigned to the control condition, four chose ‘yes’, and one chose ‘unsure’ before the start of the experiment; then midway through, five chose ‘yes ’(meaning the one ‘unsure ’participant changed positively). Among five participants assigned to the treatment condition, four chose ‘no’, and 1 chose ‘yes’ at the start; then midway through, four chose ‘yes ’and four chose ‘no ’ (representing a positive change for 3 participants by two ranks). Hence, one participant changed negatively by two ranks, four did not change, five changed positively by one rank (n=4), and two ranks (n=1) respectively (Figure 2.6b). In a grouped comparison of treatment to control condition, changes were not predicted by treatment or control conditions (n=10, chi-squared= 1.7, df = 1, p = 0.18).

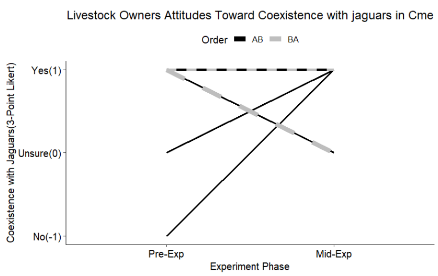
When asked “How much do you like or dislike jaguars?”, among 5 participants assigned to the control condition, one chose ‘like somewhat’, and four chose ‘neutral’ at the start; then midway through, four chose ‘like somewhat ’(meaning the four ‘neutral ’participants changed positively). Among five participants assigned to the treatment condition, three chose ‘like somewhat’, and two chose ‘neutral’ before the start; then midway through, five chose ‘like somewhat ’(representing a positive change for 2 participants by one rank). Hence, five participants did not change, and five participants changed positively by one rank (Figure 2.6c). In a grouped comparison of treatment to control condition, changes were not predicted by treatment or control conditions (n=10, chi-squared= 0.36, df = 1, p = 0.54).

When asked “How much do you like or dislike pumas?”, among five participants assigned to the control condition t, one chose ‘like somewhat’, and 4 chose ‘neutral ’before the start; then midway through, four chose ‘like somewhat’, and 1 chose ‘neutral ’(meaning the three ‘neutral ’participants changed positively). Among five participants assigned to the treatment condition, four chose ‘like somewhat’, and one chose ‘neutral’ at the start; then midway through, two chose ‘like somewhat’, and three chose ‘neutral ’(representing a negative change for one participant by one rank). Hence, three participants changed positively by one rank, no change in attitude for two participants, and five participants changed positively by one rank (Figure 2.6d). In a grouped comparison of treatment to control condition, changes were not predicted by treatment or control conditions (n=10, chi-squared= 2.1, df = 1, p = 0.14).

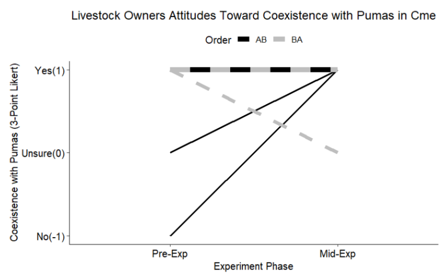
When asked “Can people and jaguars coexist, meaning, can they live in the same place?”, among five participants assigned to the control condition, three chose 'yes', 1 chose 'unsure’, and one chose ‘no’ before the start; then midway through, four chose ‘yes’, and one ‘unsure ’ (meaning a positive change). Among five participants assigned to the treatment condition, five chose ‘yes’ before the start; then midway through, two chose ‘yes ’and three chose ‘unsure ’ representing a negative change by one rank for three participants). Hence, four participants changed negatively by one rank, four did not change, and two change positively by one rank (n=1) or two ranks (n=1) respectively (Figure 2.6e). In a grouped comparison of treatment to control condition, changes were more positive for control conditions (n=10, chi-squared= 3.5, df = 1, p = 0.06).

When asked “Can people and pumas coexist, meaning, can they live in the same place?”, among 5 participants assigned to the control condition, three chose 'yes', 1 chose 'unsure’, and 1 chose ‘no’ before the start; then midway through, five chose ‘yes ’(meaning 2 participants changed positively). Among five participants assigned to the treatment condition, five chose ‘yes’ before the start; then midway through, two chose ‘yes ’and three chose ‘unsure ’ representing a negative change by one rank for three participants. Hence, two participants changed negatively by one rank, six did not change, and two change positively by one rank (n=1) or two ranks (n=1) respectively (Figure 2.6f). In a grouped comparison, changes were more positive for control conditions (n=10, chi-squared= 3.5, df = 1, p = 0.06).





(e)



(f)

Figure 2.6 Changes in Attitudes to Control or Treatment Conditions among 10 Participants in Cimitarra

Note: Order 'AB' denotes a random assignment of participants who initially started in the control condition, while 'BA' denotes those who began in treatment condition among 10 participants from Cimitarra (Cme). (a) Change in attitude to the question (Do you think lights are effective for livestock protection?) before and midway of the experiment. (b) Change in attitude to the question (Is your livestock safer with the use of lights?) (c) Change in attitude to the question (How much do you like or dislike jaguars?) before and midway of the experiment among 10 participants from Cimitarra (Cme) (d) Change in attitude to the question (How much do you like or dislike pumas?) before and midway of the experiment among 10 participants from Cimitarra (Cme). (e) Change in attitude to the question (Can people and jaguars coexist, meaning, can they live in the same place?) before and midway of the experiment among 10 participants from Cimitarra (Cme). (f) Change in attitude to the question **(**Can people and pumas coexist, meaning, can they live in the same place?) before and midway of the experiment among 10 participants from Cimitarra (Cme).

2.3.3. Attitudes by gender

I found gender was not a predictor of change in attitudes of participants from Cimitarra and San Luis.

To compare whether attitudes differed by gender, I analyzed the attitudes toward lights, jaguars and pumas before and after the experiment. Responding to "Is your livestock safer with the use of lights?" before the experiment, five women chose 'yes', one chose 'unsure', and one chose 'no'.; after the experiment, seven chose ‘yes’, (therefore five did not change one changed positively by one rank and one by two ranks, respectively (Figure 13). Among 13 men asked the same question, before the experiment seven chose 'yes', three chose 'unsure', and three chose 'no'; after the experiment, 12 chose 'yes', and one chose ‘no’, therefore eight men did not change attitudes, three changed positively by one rank, and two changed positively by two ranks, respectively (Figure 7a). Gender did not predict change (n=20, chi-squared= 0.1, df = 1, p = 0.70).

Responding to “How much do you like or dislike jaguars?” before the experiment, 4 women chose 'like somewhat', two chose 'neutral', and one chose 'dislike somewhat'; after the experiment, seven chose 'like somewhat’, therefore four did not change, two changed positively by one rank and one by two ranks, respectively (Figure 7b). Among 13 men asked the same question, before the experiment 1 responded 'like very much', four chose 'like somewhat', six chose ‘neutral’, and two chose ‘dislike somewhat’; after the experiment, eleven chose 'like somewhat', one chose ‘neutral’, and one chose ‘dislike somewhat’, therefore one changed negatively by one rank, six men did not change attitudes, five changed positively by one rank, and one changed positively by two ranks, respectively (Figure 14). Gender did not predict change (n=20, chi-squared = 0.3, df = 1, p = 0.86).

Responding to "How much do you like or dislike pumas? " before the experiment, four women chose 'like somewhat', two chose 'neutral', and 1 chose 'dislike somewhat'; after the experiment, five chose 'like somewhat’, therefore two changed negatively by one rank, two did not change, two changed positively by one rank and two by two ranks, respectively (Figure 15). Among 13 men asked the same question, before the experiment one responded 'like very much', three chose 'like somewhat', seven chose ‘neutral’, and two chose ‘dislike somewhat’; after the experiment, 11 chose 'like somewhat', one chose ‘neutral’, and one chose ‘dislike somewhat ’ (therefore one changed negatively by one rank, five men did not change attitudes, six changed positively by one rank, and 1 changed positively by two ranks, Figure 7c). Gender did not predict change (n=20, chi-squared = 0.3, df = 1, p = 0.55).

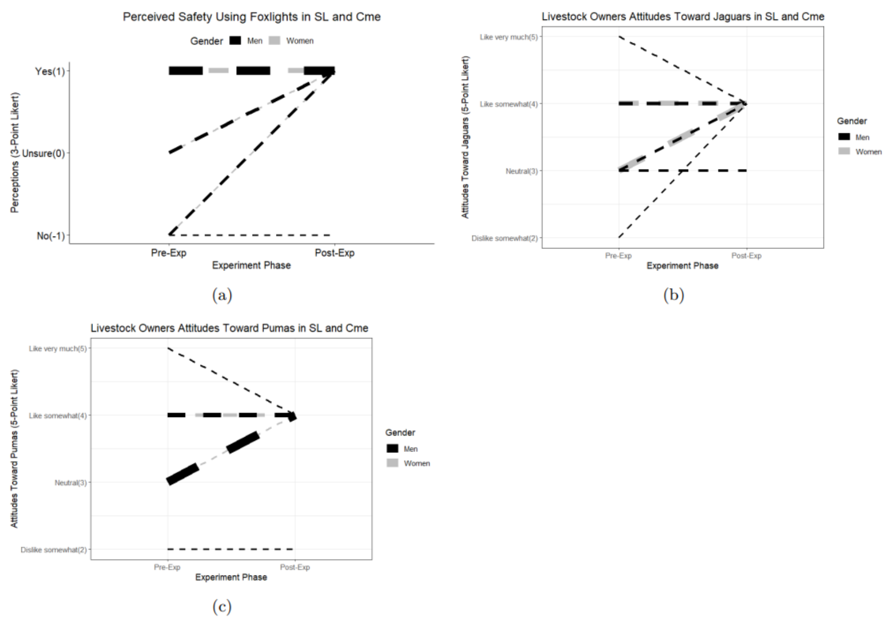


Figure 2.7 Change in attitude by gender among 20 participants of San Luis and Cimitarra (a) Change in attitude to the question “Is your livestock safer with the use of lights?” (b) Change in attitude to the question “How much do you like or dislike jaguars?” (c) Change in attitude to the question " How much do you like or dislike pumas? "

2.3.4. Attitudes by Site

To compare whether attitudes differed by study site, I analyzed the attitudes toward lights, and jaguars and pumas before and after the experiment. The results suggest that site did not predict change in attitudes of participants.

I compared change in attitudes to the question (“Is your livestock safer with the use of lights?”) between our two study sites. Among 10 participants from San Luis asked this question before the experiment, seven chose ‘yes ’and three chose ‘unsure’; after the experiment, 10 chose ‘yes’, therefore seven did not change attitudes and three improved by one rank, respectively (Figure 8a). Among 10 participants from Cimitarra before the experiment, five chose ‘yes’, one chose unsure, and four chose 'no'; after the experiment, nine chose 'yes 'and one chose 'no', therefore, six did not change attitudes, one changed positively by one rank and three by two ranks, respectively (Figure 16). Sites did not predict change of attitudes (n=20, chi-squared = 0.7, df = 1, p = 0.39).

I compared change in attitudes to the question **(**"How much do you like or dislike jaguars?"**)** between our two study sites. Among 10 participants from San Luis asked this question before the experiment, one chose 'like very much', four 'like somewhat', two chose 'neutral', and 3 chose 'dislike somewhat'; after the experiment, nine chose 'like somewhat', and one chose 'dislike somewhat', therefore one changed negatively by one rank, five did not change attitudes, two improved by one rank, and two by two ranks, respectively (Figure 17). Among 10 participants from Cimitarra before the experiment, 4 chose 'like somewhat', and six chose 'neutral'; after the experiment, nine chose 'like somewhat 'and one chose 'neutral', therefore, five did not change attitudes, five changed positively by one rank, respectively (Figure 8b). Sites did not differ significantly in change of attitudes (n=20, chi-squared = 0.04, df = 1, p = 0.83).

I compared change in attitudes to the question (**"**How much do you like or dislike pumas?") between our two study sites. Among 10 participants from San Luis asked this question before the experiment, one chose 'like very much', three 'like somewhat', three chose 'neutral', and three chose 'dislike somewhat'; after the experiment, eight chose 'like somewhat', one chose 'neutral', and one chose 'like somewhat', (therefore one changed negatively by one rank, five did not change attitudes, two improved attitudes by one rank, and two by two ranks, respectively (Figure 18). Among 10 participants from Cimitarra before the experiment, four chose 'like somewhat', and six chose 'neutral'; after the experiment, eight chose 'like somewhat 'and two chose 'neutral ', therefore, two changed negatively by one rank, two did not change attitudes, and six changed positively by one rank**,** respectively (Figure 8c**).** Sites did not differ significantly in change of attitudes (n=20, chi-squared = 0, df = 1, p = 1).

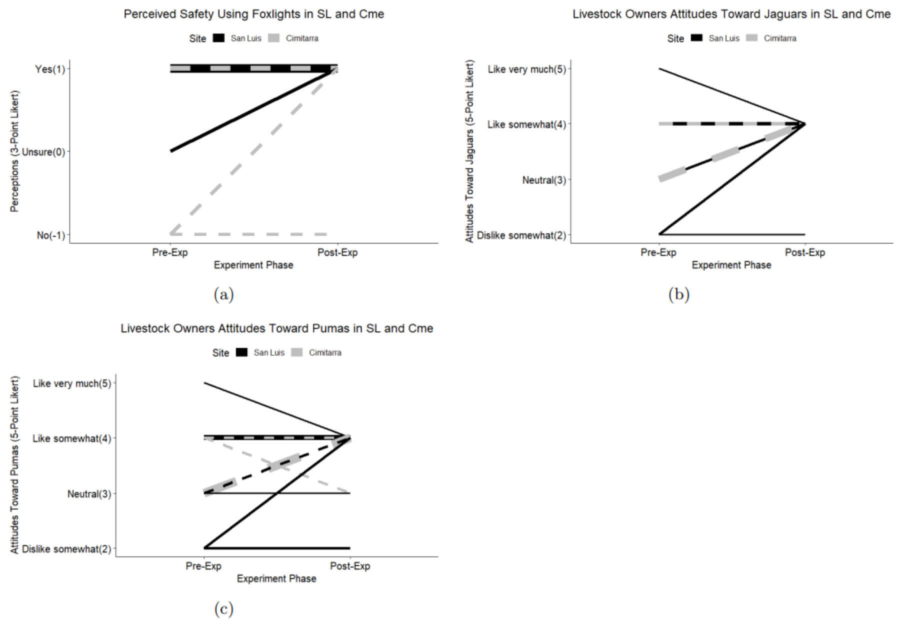


Figure 2.8 Change in attitude by site among 20 participants of San Luis and Cimitarra (a) Change in attitude to the question “Is your livestock safer with the use of lights?” (b) Change in attitude to the question “How much do you like or dislike jaguars?” (c) Change in attitude to the question " How much do you like or dislike pumas? "

2.3.5. Did the attitudes change to felid visits?

I used Kendall correlations to evaluate the relationship between the puma and jaguar visits per farm and any change in attitudes. To the question (“Do you think lights are effective for livestock protection?”) I did not find any relationship between total jaguar visits per farm and the change in response (jaguar: Kendall tau = 0.22, p= 0.21, puma tau = 0.31, p= 0.10), nor for the question (“Is your livestock safer with the use of lights?”) (jaguar: tau = 0.07, p= 0.96, puma:l tau = = 0.10, p= 0.59). Either for the question (“How much do you like or dislike jaguars? How much do you like or dislike pumas?") (jaguar: tau = 0.12, p= 0.49, puma: l tau = 0.25, p= 0.17).

I found a possible relationship between puma's visits and the change in attitudes of coexistence with pumas ("Can people and pumas coexist? Live in the same place?") but not for jaguars ("Can people and jaguars coexist, meaning, can they live in the same place?") (jaguar: l tau = 0.25, p= 0.18, puma: tau = 0.46, p= 0.02). This suggests those owners who experienced more visits by pumas changed to more positive attitudes toward coexistence with pumas than those owners with fewer visits.

In every case, correlations were positive, suggesting a tendency to change toward positive attitudes to coexistence, to lights, and to the felids as the number of visits increased among farms.

2.3.6. Did the attitudes change to number of lights?

I used Kendall correlations to evaluate the relationship between the number of lights set up in farms of Cimitarra and the change of responses. I did not detect any relationship (tau = -0.08, p= 0.76, tau= 0, p=1tau= -0.42, p=0.15, tau= 0, p=1). However, to the question ("Can people and jaguars coexist? meaning, can they live in the same place?", **"**Can people and pumas coexist? meaning. Can they live in the same place?", I found a suggestive relationship, owners with more lights changed to more positive attitudes toward coexistence of jaguars and pumas (jaguar: Tau= 0.59, p=0.04, puma: Tau= 0.59, p=0.04).

Although most correlations were not statistically significant, there was a tendency to positive correlations, suggesting owners who had more lights tend to change attitudes positively toward livestock safety.

2.3.7. Perception of human-felid conflict and toward the government environmental agency

Among 20 participants, 14 believed the conflict with jaguars and pumas has increased in the last five years, five perceived it as equal, and one perceived it as decreasing. After the experiment, 19 participants believed the conflict with felids decreased, and one thought it was the same. I refrained from conducting any statistical tests due to the divergence between the initial and final questions pertaining to the perception of conflict with jaguars and pumas. Nevertheless, I have included the raw data for reference. Fourteen trial participants conveyed their discontent regarding the government's performance in mitigating human-carnivore conflicts.

2.4. Discussion

After randomized controlled trials with crossover design (crossover RCTs) aimed at evaluating the use of lights as deterrents against predators, 20 owners or managers of livestock changed to more positive attitudes than they reported prior to the crossover RCTs. My results suggest that participation possibly changed attitudes towards felids, coexistence with big cats, and lights as deterrents. Contrary to my results, previous research has showed how attitudes toward wolves among survey respondents from Wisconsin, USA did not appear to improve after implementing compensation programs and the state’s inaugural wolf hunt (Naughton-Treves et al. 2003; Hogberg et al., 2016; Treves et al., 2013). Also, recent research evaluating change in attitudes toward carnivores (coyotes, black bears, mountain lions, and red foxes) in relation to interventions found attitudes of participants remained relatively stable, where two out of five owners changed to more negative attitudes towards carnivores, and three out of five showed stable attitudes (Hermanstorfer, 2023). Collectively, these studies raise the question of whether interventions that protect domestic animals can influence attitudes toward carnivores over time.

Additional longitudinal studies are warranted to measure the impact of interventions on potential shifts in attitudes in the long term. Furthermore, I found no evidence to support the hypothesis that participants during treatment condition changed more than those on placebo or control condition. Indeed, the converse was more likely as those who began in the control condition changed more positively than those who began in the treatment condition. Nor did the number of lights appear to correlate to changes in attitudes. Therefore, I propose the hypothesis that participation was sufficient to shift attitudes and perceived effectiveness (PE). I also propose that midway through the experiment those participants who had begun with the placebo or control condition wanted to ensure their turn would come to use the treatment and therefore responded more positively than those who were facing the placebo or control condition next.

Furthermore, I found a mismatch between the perceived effectiveness of participants and the evaluation of functional effectiveness of Foxlights in the crossover RCTs. In chapter 1 I showed no clear effect of lights in deterring pumas or jaguars from protected livestock. Indeed, I found a tendency for lights to initially attract jaguars and perhaps later deter them from one site. Therefore, I propose another hypothesis. After participants in the treatment condition who observe more or equivalent rates of visits by felids will not improve attitudes to felids, lights, or coexistence, whereas participants in the control condition will express more positive changes in attitudes regardless of felid visits. The latter would represent a case where PE correlates to FE but the control condition prompts improvements in attitude as participants express interest in testing the treatment for themselves. Alternatively, if I recall all participants complained of felid attacks prior to the study but few experienced any during the study, then I might conclude that at worst the treatment and control conditions were equally effective functionally because of the presence of researchers, cameras, equipment, etc. In that case, the alternative hypothesis is that

PE does not correlate closely to FE because the participants did not perceive an improvement in safety of their livestock. In other words, their perceived past conflict did not match the perceived current conflict that was lower than in the past. Future research should quantify perceived conflict in the past, during and after the experiment on the same scale so the hypotheses can be disentangled.

In 2021, Volski and collaborators measured FE and PE of Foxlights among cattle producers in Northern California. The experimental design of FE included control and treatment groups but lacked randomization, potentially biasing the evaluation of functional effectiveness and undermining strong inference (Volski et al., 2021). They interviewed participants before and after sharing the inferred FE results. The FE revealed weak evidence for reducing coyote activity with Foxlights. They also interviewed participants that were part of the evaluation but also other interviewees using a network sampling technique. After the researchers shared the results respondents believed Foxlights work or potentially work. Although I conducted a different experimental design (Crossover RCT) where I interviewed participants after completing the trial and measured attitudes quantitatively, I found similar results. While lights did not deter pumas and jaguars from livestock pastures under field conditions, participants perceived the interventions were effective. Despite the limited sample size, the initial findings seem to indicate that people are open to finding ways to coexist with large felids and are hopeful that these methods can yield positive results. My study suggests that individuals in these areas may be willing to adopt non-lethal strategies for safeguarding their herds on farms, driven by their personal experiences and beliefs. Addressing incongruence between PE and FE will require experts in science communication, rural outreach, and perhaps trusted messengers among the recipients of interventions.

Ranchers worldwide view predators as a threat to their herds, and some even resort to employing lethal methods to eliminate the risk and safeguard their livestock (Zimmermann et al., 2021). The general perception of livestock owners worldwide is that lethal mitigation strategies are more effective than non-lethal strategies (Scasta et al., 2017).For example, ranchers in Wyoming did not perceive lethal mitigation strategies and non-lethal strategies to be equivalent; they deemed lethal methods as more effective (Scasta et al., 2017).Previous research has found users of guardian dogs perceive this intervention as highly effective tool, but not as a replacement or reduction in the requirement for lethal management (Kinka & Young, 2019). By contrast, the scientific evidence indicates that implementing lethal methods can heighten the risks of predation on livestock and potentially result in immigrant carnivores occupying the vacated territory if there are source populations in proximity (Cooley, Wielgus, Koehler, Robinson, et al., 2009; Elbroch & Treves, 2023; Santiago-Avila et al., 2018). Indeed, years of evidence suggest that even in the rare cases in which locally killing carnivores is effective, lethal interventions start an annual cycle of killing, recolonization by new carnivores, and more killing. We should expect PE to differ from FE. Our evaluation of FE and PE highlights the need for both attitudinal data and RCT evaluations of both PE and FE. Although our results have limitations such as the sample size, the field of human-carnivore conflict need more research to compare PE to FE under different conditions, including replication of our findings that participation in experiments improved attitudes to wild carnivores and coexisting with them.

When livestock owners report jaguar or puma attacks to the government environmental agencies in Colombia the agents do not always visit the farm to verify the attacks. That may be generating a conflict between the farmers and the government environmental agency. Such bad feelings could be expressed against the felids when the hostility is mainly to the agency. For example, 14 participants of our trial expressed their dissatisfaction about the lack of support from the government to mitigate human-carnivore conflict. During the participant recruitment process, I made it clear that the primary objective was to measure FE of Foxlights. Participation in our experiment was voluntary without monetary incentives. Although our sample size is small, the results suggest livestock owners are willing to participate in measuring the FE of non-lethal methods. In other words, they have an interest in finding ways to coexist with jaguars and pumas.

My results suggest that participants with negative or neutral attitudes toward jaguars and pumas shifted to more positive attitudes at the end of the experiment, at least in the short term. However, research evaluating the long-term impact of attitudes is also required to understand if attitudes remain stable or only changed positively initially because participants perceived the domestic animal would be safe. A potential explanation for the observed shift towards more positive attitudes could be attributed to participants feeling acknowledged and somewhat empowered to mitigate livestock losses. Also, the good relationship built throughout the project could facilitate confidence in the method used in the short term even if its actual FE was negligible or even attracted felids. Understanding human attitudes toward carnivores, towards non-lethal methods, towards research, and the differences between PE and FE is relevant to conservation, animal welfare, and protection of property. Scholars have proposed that adopting non-lethal methods may enhance farmers' tolerance of carnivores (Ohrens et al., 2019; Rust et al., 2013; Treves et al., 2009). I propose the hypothesis that involving livestock owners in experiments or conservation projects would promote coexistence and improve attitudes.

2.5. Limitations

One limitation of my research could be the confirmation bias of respondents. Another limitation of my study is the small sample size. The strict requirement for respondents to have participated in the crossover design RCT (as explained in Chapter 1) restricted my capacity to include a larger number of interviewees due to the logistical constraints associated with the field experiment involving Foxlights® and associated trail cameras. Consequently, I recommend that future researchers increase the sample size to enhance both the statistical power and the inferences drawn. Furthermore, recruitment and workshop attendance were facilitated through a snowball method or word-of-mouth, with owners encouraging their neighbors to attend or participate. This may introduce potential bias because word-of-mouth and snowball methods tend to bring together participants with similar attitudes and mindsets (Treves et al. in press).

2.6. Conclusion and recommendations

I tentatively found decoupling of PE from FE, at least in the short term. The three cognitive processes that may influence PE and the decision to implement an intervention are the uncertainty about FE, possible sides effects (e.g. social norms), and the ability to implement the intervention (Ohrens et al. 2019). Therefore, respondents likely felt capable of implementing the intervention, and it is probable that there are no prevailing social norms against using lights in San Luis and Cimitarra. Moreover, they reported no side effects during the use of lights on farms. The fact that there were few or no attacks while using the lights may have also influenced their PE. All 20 respondents kept the lights after the experiment concluded.

Furthermore, attitudes toward jaguars and pumas improved at the end of the crossover RCT. Results suggest people with negative or neutral attitudes toward coexistence with jaguars and pumas shifted to a more positive attitude at the end of the experiment. Additionally, participants perceived decreased in conflict and felt more protected from jaguars and pumas.

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3. Chapter 3: Examining Wildlife Value Orientations and Attitudes Towards Coexistence with Jaguars and Pumas in Colombia

3.1. Introduction

Values form the basis upon which an individual's attitudes and norms are established (Fulton et al., 1996). Values are culturally constructed, often formed in early life, and tied to one's identity (Vaske & Manfredo, 2012). Value orientations are characteristic of an individual's hierarchical belief structure that reflect an expression of basic values (Manfredo et al., 2003). A wildlife value orientation represents patterns of "basic beliefs that give personal meaning of right and wrong and an ideal life to one's more basic values in relation to wildlife" (Teel et al., 2007, p. 300). Values guide behaviors, attitudes, and experiences with respect to wildlife (Fulton et al., 1996; Teel et al., 2007; Zinn & Pierce, 2002). In turn, attitudes are defined as the positive or negative evaluation of an object (Vaske & Manfredo, 2012). While it is believed that value orientations guide attitudes, attitudes are thought to have a direct impact on behavior (Vaske & Manfredo, 2012). The concept of Wildlife Value Orientation (hereafter, 'WVOs') has been developed within the cognitive hierarchy, known as the value-attitude-behavior framework (Homer & Kahle, 1988).

The categorization of WVOs vary among scholars. For example, Fulton et al., (1996) identify *a protection vs. use orientation* and *a wildlife appreciation* orientation. Later research identified two predominant wildlife value orientations: mutualism and materialism (Manfredo et al., 2003, 2021; Teel et al., 2007). Mutualists tend to believe that wildlife are like kin, deserve compassionate care and ought not to be hunted (Teel et al., 2007). Conversely, people categorized as materialists believe that wildlife is meant to serve human interests and is a resource to be managed (Dayer et al., 2007; Teel et al., 2007).

Previous research has found significant differences in WVOs. For example, residents of rural areas tended to have a higher orientation toward domination (a WVO associated with materialistic views) than their urban counterparts (Teel and Manfredo et al., 2009, Jacobs 2007). WVOs also varied between different states of the U.S. (Manfredo et al., 2021), and social identity groups (Liordos et al., 2023). Also, the evidence suggests that WVOs vary according to demographics (Jacobs et al., 2022). For example, in both the Netherlands and the United States, men exhibited a greater inclination toward domination/materialist WVOs compared to women (Jacobs, 2007; Vaske et al., 2011). Younger respondents showed a stronger inclination toward mutualism than older respondents (Manfredo et al., 2009; Vaske et al.2012). Mutualism tends to be highest among urban residents with high education levels (Jacobs, 2007; Manfredo et al., 2009; Teel et al., 2007). One explanation for the mutualist-urban correlation is that people in cities tend to encounter animals as pets and/or as subjects of wildlife documentaries on television and social media (Manfredo et al 2009).

WVOs have also been used to explain variation in attitudes toward certain wildlife species, including large carnivores (Manfredo et al., 2009; Zinn et al., 1998). Several studies have examined individuals' attitudes toward carnivore populations and their preferences concerning carnivore management (Bruskotter et al., 2015; Naughton-Treves et al., 2003; Treves et al., 2009; Treves & Martin, 2011). Previous research also suggests a higher preference for non-lethal predator methods among urban residents compared to rural residents (Manfredo et al., 1998; Stanger et al., 2022; Zinn et al., 1998). The evidence suggests most urban and suburban residents view lethal predator control methods as inappropriate (Stanger et al., 2022). Related to this present study, many of these studies revealed the popularity of non-lethal methods to mitigate conflict with carnivores, particularly among people inclined to have mutualist WVOs (Manfredo et al., 2020; Stanger et al., 2022).

Most research on WVOs and attitudes toward non-lethal approaches to mitigate carnivores has been conducted in N. America and Europe, leaving a gap in human dimensions research, particularly for species in South America. Existing research in South America has primarily concentrated on identifying human attitudes toward jaguars and pumas, but with limited attention to non-lethal interventions and WVOs (Amit & Jacobson, 2017a; Conforti & Cascelli de Azevedo, 2003; Engel et al., 2016, 2017; Guerisoli et al., 2017, 2020; Marchini & Macdonald, 2012, 2018, 2019; Ohrens et al., 2016; Zimmermann et al., 2021). For example, findings in Pantanal and Amazonia revealed that livestock loss is not the only predictor of ranchers' intentions to kill jaguars (Marchini & Macdonald, 2012); this behavior can also be influenced by peer group pressures, fear, and personal and social motivations, as observed in Brazil, Costa Rica and Bolivia (Amit & Jacobson, 2017b; Marchini & Macdonald, 2012, 2018). Research on pumas in Argentina found that people had negative attitudes that were not strongly associated with predations (Nanni et al., 2021). A better understanding of attitudes by livestock owners and toward interventions to mitigate conflict could improve conservation management strategies (Leflore et al., 2020; Treves et al., 2013).

To fill this knowledge gap, the purpose of this chapter is to explore attitudes and underlying WVOs toward coexistence with jaguars and pumas, and the protection of both felids among twenty rural owners and managers in San Luis and Cimitarra, Colombia. Additionally, I draw inference about WVOs based on the stories provided by ten respondents from Cimitarra in relation to these animals. Finally, I explored possible changes in attitudes toward both felids by surveying a subset of respondents from Cimitarra (n=10) before and after a randomized controlled trial with cross over design (Crossover RCT), to test the functional effectiveness of Foxlights®.

3.2. Methods

Between 2019 and 2021, I conducted crossover RCTs to test the functional effectiveness of Foxlights (hereafter, lights) in rural farms. This study took place in San Luis and Cimitarra, Colombia, two localities with jaguar and puma distribution but with contrasting socioeconomic characteristics (See Methods section in Chapter 2). I interviewed each participant three times during the trials while I tested the functional effectiveness of lights.

I recruited respondents for in-person workshops held in the rural area of San Luis and for online workshops with respondents from Cimitarra, due to the COVID-19 pandemic. I selected 20 farmers, 10 in San Luis and 10 in Cimitarra among those who voluntarily agreed to implement the solar lights in their private properties. I selected individuals who owned at least two domestic animals (cows, horses, sheep, or donkeys). Farmers who had experienced loss of domestic animals by jaguars or pumas had the same likelihood to be accepted into the study as those who has not without experienced attacks. See maps for locations of study sites (Chapter 1).

After respondents joined the crossover RCT, I randomly assigned each farm to control/placebo or treatment condition. The first phase of the crossover RCT lasted 3-4 months, then the same farm experienced the other condition in the second phase for the same length. I conducted two crossover RCTs in San Luis, and one in Cimitarra, each trial of two phases (Table 3.1).

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Table 3.1 Interviews and location of crossover RCTs in San Luis and Cimitarra

Year	Location of RCTs	Length	Interviews	Total interviews
2019	San Luis Pilot	6 Months	Pre-experiment	30
2020	San Luis Experiment	8 Months	Midway and post-experiment	
2021	Cimitarra Experiment	8 Months	Pre-experiment - Midway – post-experiment	30

In San Luis, with assistance from Sergio Gonzalez, we conducted in-person and phone interviews. In Cimitarra, I administered in-person interviews. We performed the study with informed consent from all respondents, and under the approved protocol 2016-1071-CR003 from the Institutional Review Board at the University of Wisconsin—Madison. We conducted a total of 60 interviews in Spanish.

3.2.1. Human-felid Coexistence and Conservation in San Luis and Cimitarra

I asked open-ended questions to all 20 respondents about the feasibility of human coexistence with large felids (jaguars and pumas) as follows:

Q1 "Can people and jaguars coexist? Why or why not?

Q2"Can people and pumas coexist? Why or why not?

Q3"Should humans protect jaguars and pumas in the area? Why or why not?".

I asked the questions once, prior to initiating the crossover RCTs at farms. I transcribed the respondents' answers in Spanish and categorized them into codes. Codes were established after a thorough review of the responses, with the aim of categorizing the data for qualitative analysis. I coded the open-ended responses about the feasibility of coexisting with large felids into seven distinct codes and open answers about felid protection into 8 codes (Table 3.2). A second observer (L. Naughton) categorized all responses independently and we later tested for interobserver reliability. If the second observer and I disagreed on the categorized response, it was discarded from the analysis. Although the questions about coexistence with jaguars and pumas (question 1 and 2) were posed separately, the answers were pooled due to the similarity in the answers. If the response to the first and second questions concerning the coexistence of jaguar and puma was classified with the same code I only tallied once. I then tallied how many times a coded was recorded (total: 46). Answers were translated to English after codification.

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3.2.2. Wildlife Value Orientations and attitudes toward felids among cimitarra respondents

I also asked a subset of respondents from Cimitarra (n=10) to tell me a happy and sad story related somehow to large felids as an alternative technique to reveal underlying WVOs cross-culturally (as Dayer et al., 2007; Teel & Manfredo, 2010). Qualitative techniques such as story collection reveal more in-depth understanding of human thoughts (Martinez-Ebers, 1997; McCoy et al., 2016).Specifically, I asked:

Q4"Can you tell me a happy story about a jaguar or puma that you have experienced, heard about, or saw on television?"

Q5"Can you tell me a sad story about a jaguar or puma that you have experienced, heard about, or saw on television?"

I then categorized the respondents' stories into WVOs using the typology of Dayer et al., 2007; Teel & Manfredo 2010. Each answer was categorized into one to three WVOs. Interpretation and categorization were made in Spanish to avoid missing information with the translation. Among 10 respondents, six expressed both positive and negative stories, whereas four mentioned only one of the two stories, resulting in a compilation of 16 stories categorized into five WVO, mentioned 22 times. Four responses did not express a WVO and could not be classified. The second observer independently categorized all responses, and we excluded Wildlife Value Orientations (WVO) in cases of disagreement.

Furthermore, I measured attitudes and acceptance of jaguars and pumas based on questions of forced-choice responses before and after the experiment, only to respondents of Cimitarra, n=10 (Manfredo et al., 1998; Naughton-Treves et al., 2003; Zimmermann et al., 2021). I asked:

Q6"In your opinion, what should be done with the jaguar population?"

Q7"In your opinion, what should be done with the puma population?"

Response options for questions six and seven include: allowed to grow, stay the same, reduced or eliminated.

WVO1."Seeing jaguars at your farm makes you happy"

WVO2."Seeing pumas at your farm makes you happy"

1. "If I'm walking and I see a jaguar I get scared"
2. "If I'm walking and I see a puma I get scared"

Response options for questions 1-2-include: agree, neutral and disagree.

3. "A jaguar passes by your farm; you see the animal or its tracks"
4. "A puma passes by your farm; you see the animal or its tracks"
5. "A jaguar attacks domestic animal"
6. "A puma attacks domestic animal"

Response options for questions 3-6 include: try to scare it, nothing should be done, must be captured and relocated, must be hunted, and not sure (Table 3.2; Appendix 1).

In this chapter, I integrated qualitative social research methods, including in-person interviews and story collection (Dayer et al., 2007; Herrman et al., 2013), alongside quantitative analysis to identify changes in attitudes following the crossover RCT with information of questions made to participants.

Table 3.2 Categorization of open-ended responses of participants of San Luis and Cimitarra to codes (n=20) to codes, and categorization of stories from respondents of Cimitarra (n=10).

Questions	Codes	Example of answer	Frequencies
1. Categorized responses to the question: "Can people and jaguars coexist? Why or why not? 2. "Can people and pumas coexist? Why or why not?	Coexistence is conditional on no damage or attack	"Because if they [jaguars and pumas] respect our animals, we respect them"	10
	Coexistence is possible because favored by local environment	"Because we [humans and felids] both live here, this is the good area for them, the mountain area"	5
	Coexistence is possible	"We [humans and felids] can share spaces"	4
	Coexistence is beneficial	"They [jaguars and pumas] balance ecosystems"	2
	Wild felids should be allowed to live.	"They [jaguars and pumas] also have the right to live"	2
	Coexistence depends on landowners not resorting to killing felids	"It depends on whether the owner orders them to be killed or not"	2
	Coexistence is not possible due to attacks on livestock	"It is 'very complicated' because of livestock attacks"	1
3. Categorized responses to the question: "Should humans protect jaguars and pumas in the area? Why or why not?"	Yes, but only if paid	"If [the government] give money to protect [jaguars and pumas], I could take care of them, after all, they live here"	4
	Yes, due to ecosystem benefit	"That animal is needed to control capybaras"	4
	Yes, because they deserve to live.	"Because he [pumas] also lives here, just like me"	4
	Don't know	"I don't know"	3

	Yes, because they are beautiful	“Because those animals are very cute”	2
	Yes, because it is the law (the government orders it).	“Because Cornare [Government environmental agency] says they are important”	1
	It depends on the landowner’s decision.	“Because the boss says not to kill them”	1
	Only if there are no attacks on livestock.	“If they didn't do so much damages than maybe”	1
4. WVOs emerging from stories “Can you tell me a happy story about a jaguar or puma that you have lived, heard about, or seen on television?” 5. WVOs emerging from stories “Can you tell me a sad story about a jaguar or puma that you have lived, heard about, or seen on television?”	Aesthetic	“When I see them [pumas] and jaguar in National Geographic documentaries I get excited, they are so beautiful.”	8
	Concern for livelihood	"When I heard a cow scream in pain because it was being attacked by felines, the next day I found it dead, and a part of it had been eaten; I knew it had been the jaguar."	4
	Concern for human safety	"I saw a jaguar, and I got very scared, especially because of the children."	4
	Mutualism	"When you hear rumors that they're killing jaguars in the area, it makes me sad."	3
	Concern for suffering of domestic animals	"When a puma killed a sheep that I really loved, I found it dead the next day."	3

3.2.3. Statistical Analyses

I ranked and summed a multi-item scale of questions 8 to 11, with negative attitudes receiving a lower score than positive attitudes. The total score from the multi-item scale range from 8 to 14 for questions before the experiment and from 10-17 after experiment. To measure individual changes, I calculated the difference between the multi-item scale responses before and after the experiment. To evaluate if there were changes in attitudes, I conducted a one-sample Wilcoxon test for the difference of the multi-item scale ('after' minus 'before'). Then I repeated the previous step and split the questions by jaguars and pumas. In accordance with (Colquhoun, 2014), I conducted an adjustment of significance thresholds for experiments that make multiple comparisons. I applied the false discovery rate controlling procedure for three hypotheses with a threshold of 0.005 (Benjamin et al., 2018). Finally, I tested whether attitudes toward jaguars differed from pumas using a paired Wilcoxon test. I conducted the analysis in R studio, version 4.3.1.

3.3. Analysis and Results

3.3.1. Sample characteristics

Among 20 respondents, I interviewed seven women and 13 men (San Luis women n= 4, Cimitarra women n=3, San Luis men n=6, Cimitarra men n=7). In contrast to all 10 in San Luis being resident landowners, the respondents from Cimitarra included managers (n=5) and landowners (n=5). The managers in Cimitarra also reside on farms, while the landowners primarily live in the city but make monthly visits during which time they stay on their farms. In San Luis respondents encompassed a range of ages from 30 to 65 years and in Cimitarra from 32 to 64 years old (average San Luis 49.5 years, Cimitarra: 45 years). Education levels in San Luis were as follows: three respondents had completed elementary education, while seven had attended only one or two years of primary schooling or preschool. Respondents from the municipality of Cimitarra displayed higher levels of education compared to those from San Luis municipality. Three respondents held university degrees, four had bachelor's degrees, and three had completed elementary education.

3.3.2. Human-felid coexistence and conservation in San Luis and Cimitarra

I classified answers for or against coexistence between wild felids and humans into seven codes, in order from the most-to-least frequently mentioned: coexistence conditional on no damage or attack, coexistence favored by local environment, coexistence possible, coexistence beneficial, moral argument to allow jaguars/pumas to live, coexistence depends on landowner, coexistence not possible or very difficult due to attacks. Six answers were categorized in more than one code (e.g, There is room for both [Felids and humans] if they do not disturb was categorized into “Coexistence is possible” and “Coexistence is conditional on no damage or attack”) (Table 3.3).

Table 3.3 Frequency per code and by study area

Code	San Luis	Cimitarra
Coexistence is conditional on no damage or attack	7	3
Coexistence is possible because favored by local environment	3	2
Coexistence is possible	1	3
Coexistence is beneficial	0	1
Wild felids should be allowed to live.	0	2
Coexistence depends on landowners not resorting to killing felids	0	2
Coexistence is not possible due to attacks on livestock	0	1

I classified answers for or against felid' protection into eight codes. Listed in order of the most-to-least frequently mentioned they are: yes, but only if paid; yes, due to ecosystem benefit; yes, because they deserve to live; don't know; yes, because they are beautiful; yes because it is the law; it depends on the landowners' decision; only if there are no attacks on livestock.

3.3.3. Wildlife value orientations and attitudes toward felids among Cimitarra respondents

Each story conveyed by respondents of Cimitarra was categorized into one to three WVO (following Dayer et al., 2007). Among 16 stories I identified five distinct WVOs (Figure 3.1). Among 16 stories, *aesthetics* was the most frequently WVO mentioned and the least mentioned was *concern for the suffering of domestic animals*. Seven stories referred to real life encounters, three from television, and four stories had been relayed to the respondent by someone else. Five stories portrayed the emotion of fear.

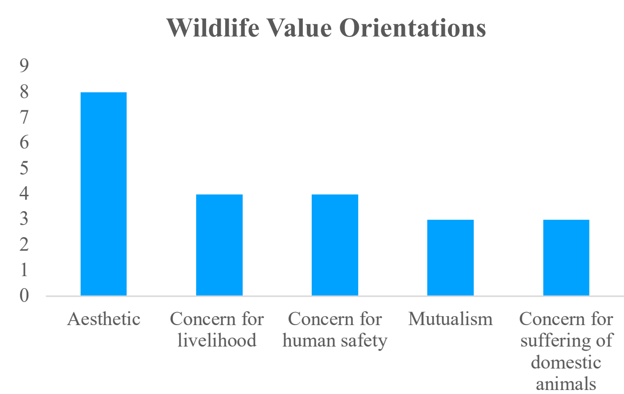

Figure 3.1 Wildlife value orientations of respondents from happy and sad stories.

In the stories that mentioned the aesthetic value of wildlife, respondents emphasized fear at the same time highlighting the beauty of jaguars and pumas. In other words, respondents' stories suggested that they hold more than one WVO. For example, respondents stated:

"*When I see them (pumas and jaguar) in National Geographic documentaries I get excited, they are so beautiful.*"[1] (Translated from Spanish)

"*My husband once told me that he saw a big cat pass by, I don't know which one it was, it occurred when the sun was already going down, and as soon as he saw it, he just turned to look at it, they looked at each other and each one went on with his own business.*"[2] (Translated from Spanish)

"*One day I was gathering the cows and a puma was in a pasture a little further ahead, the cows were in an uproar, you could tell they were afraid of that animal. I had never encountered it (puma), you hear that they are around, but I had never seen it and you feel a rush in your body when you see it, it is between joy and fear.*"[3] (Translated from Spanish).

While none of the Wilcoxon tests showed statistical significance, the changes are suggestive because attitudes improved after the experiment for all participants except, possibly four respondents, who chose to capture and translocate pumas that approached their farms or in case of an attack after the crossover RCT.

The 10 respondents of Cimitarra varied in their response to "In your opinion, what should be done with the jaguar population? ". Before the experiment, one participant responded, 'allowed to grow', and nine chose 'keep to the current number'. After the experiment, five respondents chose 'allowed to grow' and five chose 'keep to the current number', representing a positive change in attitude by one rank for four respondents, no change in attitude for six

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[1] "Cuando veo pumas y jaguares en los documentales de Natgeo, yo me emociono, ellos son muy bellos"
[2] "Mi esposo alguna vez me contó que vió pasar un felino grande, no sé cuál era, eso fue cuando ya estaba cayendo el sol, y que apenas lo vió solo lo volteo a mirar y salió corriendo, se encontraron se miraron y cada uno siguió en lo suyo"
[3] "Un día estaba recogiendo las vacas y un puma estaba en un potrero un poco más adelante, las vacas estaban alborotadas se notaba que tenían miedo de ese animal. Yo nunca me lo había encontrado, uno si escucha que ellos andan por ahí pero nunca lo había visto y uno siente un corrientazo en el cuerpo cuando lo ve, es entre alegría y miedo"

respondents, (n=10 respondents, median change =0, range of change =0 to 1) (Figure 3.2a). Although the median change for 10 respondents was zero, changes did not occur by chance. For example, zero respondents became more negative and four out of ten became more positive.

For pumas, changes in attitudes were less noticeable in response to "In your opinion, what should be done with the puma population? ". Before the experiment, ten respondents chose ‘keep to the current number’. After the experiment, two respondents chose ‘allowed to grow’, and eight chose ‘keep to the current number', representing no change in attitude for eight respondents, and positive changes by one rank for two respondents, (n=10, median change =0, range of change =0 to 1) (Figure 3.2b). Although the median change for 10 respondents was zero, changes did not occur by chance. For example, zero respondents became more negative, and two out of ten became more positive. Furthermore, two respondents that did not change in the past question changed to positive attitude toward population of pumas.

Attitudes to jaguars became slightly more positive in response to "Seeing jaguars at your farm makes you happy" (Figure 3.2c). Before the experiment, four respondents agreed with the statement and six chose 'neutral'. After the experiment, seven respondents agreed and three chose ' neutral ', representing no change in attitudes for seven respondents, and positive changes by one rank for three respondents, (n=10, median change =0, range of change =0 to +1).

Attitudes to pumas became slightly more positive in response to, "Seeing pumas at your farm makes you happy". Before the experiment, one participant responded 'agree', nine chose 'neutral'. After the experiment, four respondents chose 'agree', and six chose 'neutral', representing no change in attitude for six respondents, and positive changes by one rank for three respondents, (n=10, median change =0, range of change =0-1; Figure 3.2d). Zero respondents became more negative, and three improved their attitudes. Two respondents that changed positively in the previous question changed their attitude in this question.

Like the previous question, attitudes changed positively for three respondents. in response to "If I'm walking and I see a jaguar I get scared". Before the experiment, five participants responded ‘agree', and five chose 'neutral'. After the experiment, eight respondents chose 'agree', and two chose 'neutral', representing no change in attitude for seven respondents, and positive changes by one rank for three respondents (n=10, median change =0, range of change 0 to 1; Figure 3.2e). One respondent that improved their attitude in two previous questions also improved in this question.

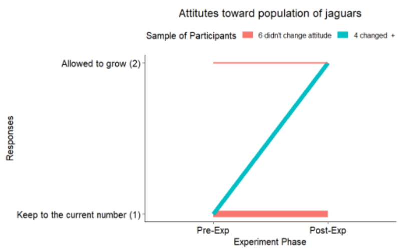
Contrary to the previous questions, attitudes did not change in response to, "If I’m walking and I see a puma I get scared". Before the experiment, nine respondents responded 'agree', one chose 'neutral'. After the experiment, nine respondents chose 'agree', and one chose 'neutral', representing no change in attitude (n=10, median change =0, range of change =0-0; Figure 3.2f).

Attitudes toward jaguars became slightly more tolerant in response to “A jaguar passes by your farm; you see the animal or its tracks”. Before the experiment, two respondents responded, ‘Try to scare it ‘, eight chose ‘nothing should be done’. After the experiment, ten respondents chose ‘nothing should be done ‘, representing no change in attitude for six respondents, and four respondents changed their attitudes from ‘try to scare it’ to ‘nothing should be done’, which represents a positive change by one rank, (n=10, median change =0, range of change = -1 to 0; Figure 3.2g). The same two respondents who responded more positively to the question about the puma population chose noninvasive management in this question after the experiment.

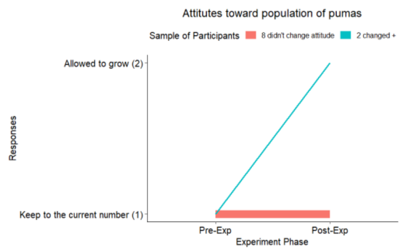
Respondents varied in responses to “A puma passes by your farm; you see the animal or its tracks”. Before the experiment, seven respondents responded, ‘try to scare it', three chose 'nothing should be done'. After the experiment, seven respondents chose 'try to scare it', one ‘nothing should be done', and two 'must be captured and relocated', representing no change in attitude for four respondents, positive change by one rank for three respondents, and negative change by two ranks for three respondents. Two respondents changed from a non-invasive method ‘try to scare it to ‘nothing should be done’, which represents a positive change in attitudes (n=10, median change =0, range of change = -3 to +1; Figure 3.2h). When the same question was asked with jaguars, the respondents did not choose the option of relocating the animal, but with pumas, two respondents chose this option. The two respondents that chose the option of translocation did not improve their attitude towards pumas.

When I asked what should be done if "A jaguar attacks a domestic animal" before the experiment, six respondents responded, 'Try to scare it', two chose 'Nothing should be done', and two chose 'Must be captured and relocated'. After the experiment, ten respondents chose 'Nothing should be done', representing no change in attitude for six respondents, and positive change by one rank (n=2) and two ranks (n=2), (n=10, median change =0, range of change =0 to 3) (Figure 3.2i).

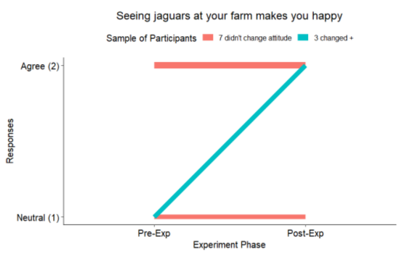
When I asked what should be done if "A puma attacks a domestic animal" before the experiment, seven respondents responded, 'Try to scare it', and three chose 'must be captured and relocated'. After the experiment, eight respondents chose 'Try to scare it', and two chose 'Must be captured and relocated', representing no change in attitude for five respondents, positive change by one rank for three respondents, and negative change by one rank for two respondents, (n=10, median change =0, range of change =-3 to 3; Figure 3.2j).


Attitutes toward population of jaguars
Sample of Participants
6 didn't change attitude
4 changed +
Allowed to grow (2)
Keep to the current number (1)
Responses
Pre-Exp
Post-Exp
Experiment Phase

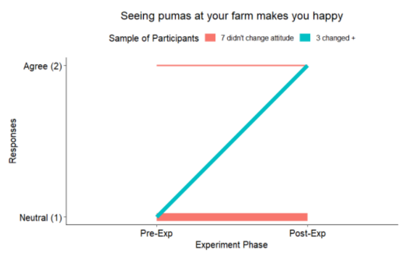
(a)


Attitutes toward population of pumas
Sample of Participants
8 didn't change attitude
2 changed +
Allowed to grow (2)
Keep to the current number (1)
Responses
Pre-Exp
Post-Exp
Experiment Phase

(b)


Seeing jaguars at your farm makes you happy
Sample of Participants
7 didn't change attitude
3 changed +
Agree (2)
Neutral (1)
Responses
Pre-Exp
Post-Exp
Experiment Phase

(c)


Seeing pumas at your farm makes you happy
Sample of Participants
7 didn't change attitude
3 changed +
Agree (2)
Neutral (1)
Responses
Pre-Exp
Post-Exp
Experiment Phase

(d)

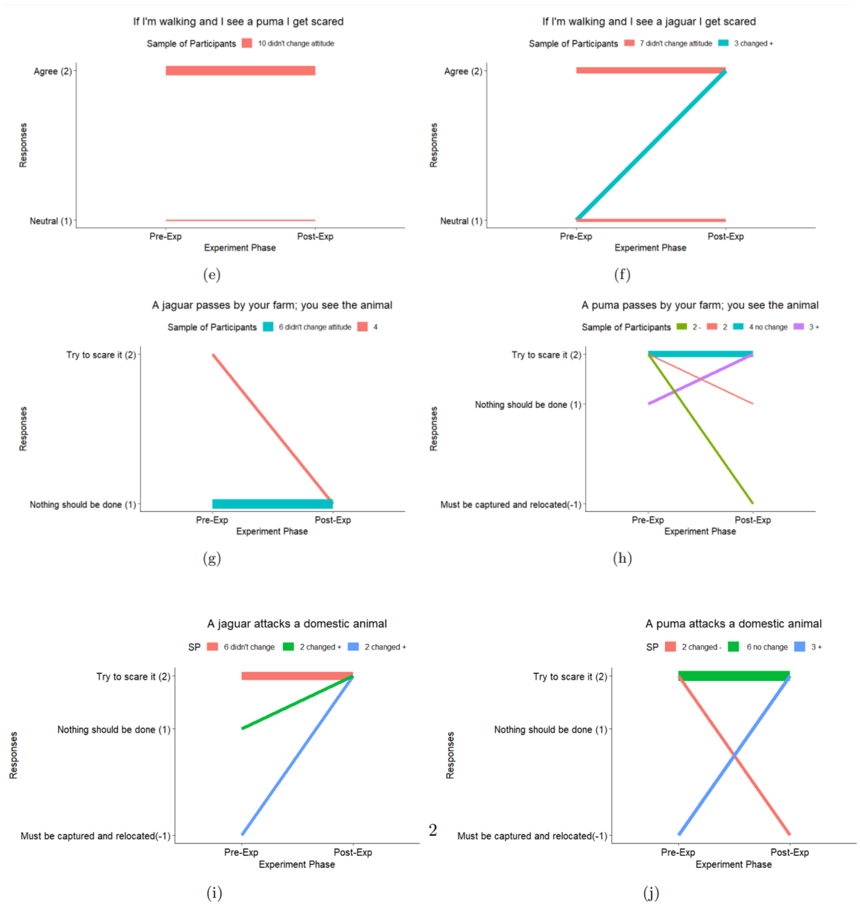


Figure 3.2 Comparison of attitudes of 10 respondents from Cimitarra before and after the crossover RCT. Width of the line represents the number of respondents.

The multi-item scale did not reveal any change in attitudes after participation in the randomized controlled experiment (Wilcoxon signed rank test V=41.5, p=0.16 nor when we separated the felids: (jaguar V=41.5, p=0.16; puma V=22, p=0.60). Additionally, when I tested whether attitudes toward jaguars and pumas differed, there were no differences (V=23, p=0.14). I chose one question with the most significant change: "In your opinion the population of jaguars should be?", but I did not detect change in attitudes (Wilcoxon signed rank test n=10, V =0, p = 0.07).

3.4. Discussion

Respondents from San Luis and Cimitarra expressed their support for coexisting with pumas and jaguars while also advocating for the conservation of both felids. However, when asked why, 50% of respondents (San Luis=7, Cimitarra=3) answered in favor of coexistence, with the condition that there are no instances of damage or attacks, the most prevalent response. Three of those ten respondents, all of whom were from San Luis, gave this answer despite reporting that they had never experienced any attacks on their domestic animals by jaguars or pumas. This finding suggests that the perception of risk may influence respondents' attitudes toward coexistence. However, according to results of chapter 2, respondents receiving the placebo control changed more than those receiving the treatment. Participation seemed to raise tolerance or at least the expectation of receiving the treatment did. This suggests perceived risk is also easily manipulated by the expectation of receiving help no matter how ineffective that help might be.

The perception of risk associated with large carnivores has been proposed as a factor influencing human acceptance (Kellert, 1985; Wilson et al.,1997). People's perceptions of risks are influenced by the cultural context in which they live (Douglas, 1992), and the specific characteristics of the risk or threat itself (Slovic, 1987). The uneven distribution of risks and benefits between rural and urban residents may provide an explanation for why urban populations consistently exhibit higher levels of tolerance toward carnivores than their rural counterparts (Bruskotter et al., 2017; Williams et al., 1973). A study conducted in rural area of

Africa found local perceptions of risk varied by gender or group identity and the discrepancy between perceived risk did not correspond to monitored frequency of damage by wildlife (Naughton-Treves 1997). Scientific evidence suggests that perceived threat is not the main factor influencing tolerance toward predators (Hogberg et al., 2016; Marchini & Macdonald, 2012; Treves & Bruskotter, 2014).

Whatever their perceived risk, all 20 respondents supported the protection of felids in the area. When I asked why? The three most common and equally prevalent answers were: yes, but only if paid; yes, due to ecosystem benefit; and yes, because they deserve to live, n=4 for each. Similar to previous responses about coexistence, these answers are favorable but conditional. Respondents' answers also highlighted how non-lethal methods could promote coexistence between humans and felids. To prevent felid attacks, non-lethal methods offer an opportunity to safeguard domestic animals and de-escalate potential conflicts. Respondents also supported coexistence, arguing "Because both [humans and felids] live here, this is the good area for them, the mountain area". I classified this type of answer as "Coexistence is possible because it is favored by local environment". In all, 25% of respondents (San Luis=3, Cimitarra=2) supported coexistence between humans and felids recognizing the fact that their farms have forest and wetlands, habitat for jaguars and pumas. Empathy in their answers also suggests mutualist WVOs, as well as responses such as "We can share spaces" expressed for 20% respondents (San Luis=1, Cimitarra=3). Contradictory responses have also been reported in other studies. In Brazil, jaguars were often admired for their beauty, yet their response to the statement about protection was often answered: "yes, but not on my ranch" (Zimmermann et al., 2005). The equal distribution of intrinsic values, ecosystem benefits, and payments of respondents who explained why they supported protection felids, raise interesting issues of respondents' rationales.

The four respondents from San Luis that affirmed this statement. "if [the government] gives money to protect [jaguars and pumas], I could take care of them, after all, they live here". This response was categorized as "yes, but only if paid". A plausible rationale behind requests for compensation in exchange for jaguar and puma protection efforts may be related to a government program called BanCO2. BanCO2 pays landowners for the preservation of standing forest at properties. Economic incentives are extended to landowners, encompassing rural communities, indigenous groups, and Afro communities residing in strategically important regions, as a means of acknowledging their contribution to carbon footprint mitigation through voluntary agreements aimed at protection or restauration of Colombian ecosystems (BanCO2, 2023). Two of the four respondents who expressed a desire for monetary incentives, all from San Luis, had previously received such payments, as revealed during interviews. This response of low-income farmers in San Luis is likely because subsistence farmers have unequal capacities to cope with wildlife losses, as previously demonstrated (Naugthon-Treves 1997). Moreover, the perception of risk is probably higher among San Luis farmers. Compensation is often focus on carnivores in wealthy countries of Europe and United States (Naughton-Treves et al., 2003; Swenson & Andrén, 2005; Treves et al., 2009). However, research on compensation apparently did not improve individual tolerance toward wolves in Wisconsin, and bear hunters who were compensated were more likely to approve lethal control (Naughton-Treves et al., 2003). Also, REDD+ projects within jaguar distribution in Latin America don't necessarily have the desired benefits for jaguar conservation because of a mismatch between project goals and outcomes (Hyde et al., 2022). Programs with conservation goals such as compensation or REDD+ require rigorous monitoring of potential changes in participants' attitudes and ecological outcomes. In the subfield of tolerance for predatory wildlife, Treves & Bruskotter (2014) proposed that values other than economics, such as peer group pressures and identity politics, seemed to predict tolerance for predators more than payments or losses of income (Marchini & Macdonald 2012).

I identified five distinct Wildlife Value Orientation (WVO) related to jaguars and pumas from narratives of 10 respondents from Cimitarra. Aesthetic appreciation emerged as the predominant WVO, followed by concern for livelihood and mutualism. Similarly, other studies have reported aesthetic WVO in local narratives concerning pumas, jaguars, and jackals (Drouilly et al., 2021; Herrman et al., 2013; Zimmermann et al., 2005). Perceiving carnivores (jackals) as beautiful increased the average marginal probability of a farmer tolerating them (Drouilly et al., 2021). One study found the public is also more likely to support the protection of aesthetically pleasing species (Liordos et al., 2021). While research on WVOs in Latin America remains scarce, ongoing research at Colorado State University has identified mutualism as a predominant WVO in South America (Manfredo et al., 2023). Respondents from Cimitarra with higher education level and income revealed mutualism among their WVO.

In my study, the second and third most frequently mentioned WVOs were concern for livelihood and mutualism. Consistent with these results, previous research conducted in Uganda and Kenya also found concern for livelihood as a predominant WVO (Naughton-Treves et al. in prep). Understanding the spatial distribution of values is crucial as it can aid in discerning how public responses to wildlife management actions vary across the landscape (Dietsch et al. 2016).

When I asked the 10 respondents of Cimitarra about their preferred management strategies in the hypothetical scenarios, such as observing jaguars or pumas passing the farm, or in the event of an attack on domestic animals, 100% of respondents agreed on the use of non-lethal methods rather than lethal methods, both before and after the experiment. Our results are consistent with previous research measuring WVO and the acceptability of different management actions (Dietsch et al., 2016; Manfredo et al., 2016). Respondents in Cimitarra showed a preference leaning more toward mutualism WVO and favored non-lethal methods. Although none of the statistical tests for hypothetical scenarios reached significance, the results suggest a slight improvement in attitudes for a subset of 10 participants after their participation in the crossover RCT. Before the RCT, most of respondent's attitudes were neutral or positive regarding the different scenarios (e.g., seeing a felid, livestock attack) with jaguars and pumas. Those respondents kept their positive attitude after the RCT. However, more importantly, those respondents with neutral and negative attitudes before the RCT improved their attitude. Before the RCT, two participants did express that jaguars should be captured and relocated in situations where they attacked domestic animals. For pumas, three respondents selected the same option, including the same two individuals from the jaguar scenario and an additional participant. However, after the RCT, these same respondents changed in favor of attempt to scare the felids away.

No respondents from Cimitarra chose to eliminate the jaguar or puma populations, neither before nor after the RCT. This indicates acceptance towards these felids and is in alignment with the WVO results. When I asked about jaguar and puma population, respondents improved their acceptance of jaguars and slightly toward pumas. Before the RCT, nine respondents chose to maintain the jaguar population at its current number, while ten selected the same option for pumas. However, after their participation, among the nine respondents, four improved their attitude and chose to allow the population of jaguars to grow, and two chose to allow the puma population to increase. Therefore, the results of attitudes toward jaguars and pumas in this chapter and results of Chapter 2, I concluded that participation in the experiment was a worthwhile intervention by itself. It would be informative to measure WVOs before and after an experiment to learn which ones respond to participation. Contrary to my findings, which indicate slightly more tolerance toward population of jaguars and pumas, a cross-sectional study involving 80 ranchers from Orinoquia, Colombia, in response to a similar question, revealed a preference for reducing or eliminating both jaguars and pumas (Hyde et al., 2023). Additionally, Zimmerman et al. (2021) posed a similar question about the jaguar population in seventeen areas with human-jaguar conflicts in seven Central and South American countries, uncovering a wide range of both favorable and unfavorable attitudes toward the desired jaguar population. The two previous studies did not measure the attitudes of the same respondents in relation to an intervention, making direct comparisons inappropriate. Therefore, I call for further research into attitudes regarding intervention strategies. Zimmermann and colleagues (2021) advocate for avoiding broad generalizations and conducting localized studies that enable decision-making tailored to address each unique conflict scenario. My study adds to that recommendation by encouraging researchers to ask respondents if they have participated in a collaborative research study or been involved in an experimental trial or similar. I also recommend researchers ask respondents if outside actors helped them with prevention of livestock losses. Such variables may be essential to understanding different attitudes across small spatial scales.

Studies on changes in attitudes toward carnivores after an intervention (e.g., policy change, non-lethal method implementation, compensation paid) have not detected a favorable shift in human attitudes, either by longitudinal measures of changes in the same individuals before and after the intervention or by correlations that compare recipients to non-recipients (Browne-Nuñez et al., 2015; Hermanstorfer, 2023; Hogberg et al., 2016; Lischka et al., 2019;

Naughton-Treves et al., 2003; Treves et al. 2013). Evidence on change in human attitudes (longitudinal studies) using repeated measures before and after change in policy for wolf-killing in US suggests tolerance declined or did not change (Browne-Nuñez et al., 2015; Hogberg et al., 2016). Similar results found tolerance toward bears did not improve after the distribution of bear-resistant garbage bins (Lischka et al., 2019). A randomized trial with a pseudo-control that evaluated an informational intervention succeeded in raising tolerance for Ohio black bears by presenting responders with information on the benefits of bears (Slagle et al. 2013). However, my results, evaluating changes in attitudes after participation in a controlled experiment, suggest a slight increase in acceptance toward jaguars and pumas, as well as a preference for non-lethal methods.

The hypothetical scenarios, narratives and WVOs reveal fear for human and animal safety, but also appreciation for beauty of jaguars and pumas. I found both species of felids evoked strong emotions, both positive and negative. After the experiment, 80% of respondents expressed fear when encountering jaguars, and 90% expressed fear when encountering pumas. Fear of both felids seems to be rooted in people's minds. Prior research findings indicate that exposure to human-bear conflicts may not significantly influence one's tolerance toward bears, but the cognitive and emotional consequences of such encounters can have an impact (Lischka et al., 2019). This has also been evaluated in the experiences and emotional responses of farming communities living with Asian Elephants (de Silva et al., 2023). Therefore, further research can explore whether education campaigns, as a method to mitigate human-carnivore conflict, can lead to changes in attitudes and emotions toward jaguars and pumas.

Further research in Colombia and worldwide would help to explain WVOs, how they change, are initially established, and what effect interventions might have on them.

Understanding of wildlife value orientation will help improve the effectiveness of conservation strategies that depend on public support.

3.5. Limitations

Participation in the crossover trial was voluntary. It is conceivable that managers and landowners who already held favorable attitudes toward jaguars and pumas were more inclined to participate, while those with less positive attitudes may have chosen not to take part. Additionally, a significant portion of the interviews were conducted in person on farms, potentially creating a scenario in which respondents felt pressured to respond positively to the questions due to my presence. Nevertheless, the findings of Wildlife Value Orientations (WVOs) and attitudes toward both felids revealed a spectrum of attitudes among respondents, encompassing positive, negative and in some cases contradictory attitudes toward jaguars and pumas.

Another limitation that constrains the inferences is the small sample size. My stringent requirement that respondents also be participants in the crossover design RCT (chapter 1) limited my ability to interview more respondents by the constraints on the field experiment with Foxlights® and associated trail cameras. Therefore, my results are appropriately viewed as preliminary and suggestive, despite being the largest sample of quantitative (chap 2 and 3) and qualitative (chap 3) attitudes and WVOs among participants before-and-after an experimental trial of a non-lethal intervention for human-carnivore conflicts. Accordingly, I have suggested numerous novel hypotheses, which future researchers may test and refine.

A limitation of my study beyond its small sample size is the inclusion of respondents with different socioeconomic backgrounds. Some respondents were managers and other owners living away from the farm. The latter status presumably correlates to more urban, wealthier, more educated backgrounds or lifestyles, none of which I measured. Tolerance toward wildlife is closely linked to changes in social conditions, including increased income, education, and urbanization (Bruskotter et al., 2017; Teel & Manfredo, 2010). Research has shown that urban residents often display mutualistic wildlife value orientations and prefer non-lethal methods (Liordos et al., 2021; Manfredo et al., 2009, Treves et al. 2009). The urban residency could potentially explain my findings, as half of my sample resided in urban areas but make frequent visits to their farms.

3.6. Conclusions and Recommendations

Respondents from San Luis and Cimitarra support coexistence among humans, jaguars, and pumas while also advocating for the conservation of both felids. However, out of the 20 participants, 10 express supports for coexistence, contingent upon no domestic animal attacks by felids. Non-lethal methods to protect domestic animals could promote coexistence while safeguarding human livelihoods.

Results showed that respondents in Cimitarra value jaguars and pumas for aesthetic reasons, and exhibit both concern for livelihood and mutualism in their WVOs. The stories uncovered that owners might oppose the elimination of big cats primarily due to their preferences rather than financial concerns. In accordance with the theory, the most effective strategies for coexistence should be in harmony with their values and with their belief that visual deterrents are effective in safeguarding their livestock. The WVO and attitudes of livestock owners, both those willing and unwilling to implement non-lethal interventions, need further exploration.

I identified five WVOs that leaned towards a mutualist orientation rather than a doministic one, among Cimitarra respondents using the methodology outlined by Dayer et al. (2007). Future research on WVOs can test hypothesis about WVOs after participation in RCTs, testing quantitative hypothesis about change in WVOs or if they are not affected by participation. WVOs of stakeholders and institutions need examination and how divergent values among these groups influence their capacity to collaborate and promote coexistence between humans and wildlife.

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3.8. Appendices

3.8.1. Appendix 1. Questions asked to respondents in San Luis and Cimitarra.

1. Can people and jaguars coexist?
   Yes__ No__ Why or why not?

2. Can people and pumas coexist?
   Yes__ No__ Why or why not?

3. Should humans protect jaguars and pumas in the area?
   Yes__ No__ Why or why not?

3.8.2. Appendix 2. Questions asked to respondents in Cimitarra.

4. Can you tell me a happy story about a jaguar or puma that you have experienced, heard about, or saw on television?

5. Can you tell me a sad story about a jaguar or puma that you have experienced, heard about, or saw on television?

6. In your opinion, what should be done with the jaguar population?

   Allowed to grow__ stay the same__ reduced__ eliminated__

7. In your opinion, what should be done with the puma population?

   Allowed to grow__ stay the same__ reduced__ eliminated__

8. Seeing jaguars at your farm makes you happy.

   Agree__ neutral __disagree__

9. Seeing pumas at your farm makes you happy.

   Agree__ neutral __disagree__

10. If I'm walking and I see a jaguar I get scared.

    Agree__ neutral __disagree__

11. If I'm walking and I see a puma I get scared.

    Agree__ neutral __disagree__

12. A jaguar passes by your farm; you see the animal or its tracks.

Try to scare it__ nothing should be done__ must be captured and relocated__ must be __and not sure__

13. A puma passes by your farm; you see the animal or its tracks.

Try to scare it__ nothing should be done__ must be captured and relocated__ must be hunted__and not sure__

14. A jaguar attacks domestic animal

Try to scare it__ nothing should be done__ must be captured and relocated__ must be hunted__and not sure__

15. A puma attacks domestic animal

Try to scare it__ nothing should be done__ must be captured and relocated__ must be hunted__and not sure__

4. Final Recommendations

The importance of scientific information is often forgotten when seeking solutions to environmental problems. Our persistent quest for quick, short-term fixes to complex environmental challenges causes us to overlook the critical role that science plays in comprehending and solving problems. Promoting coexistence between big cats and humans requires interdisciplinary research and reliable inferences.

Here are a series of recommendations that I hope can guide future research. I encourage future researchers to share the experience of field experiments with transparency as I did in Chapter 1 and our research group did in Treves et al. 2024 in press. No matter how thoroughly we plan a study, every project will face logistical challenges, particularly when we are trying to evaluate ideas never tested before. For example, further testing of mobile lights is warranted through long-term experiments to assess habituation over time. I suggest evaluating the comfort level of the animal with the belt to be used before attaching the light. It is feasible that in colder temperatures, the material may produce less friction.

I also encourage future researchers to continue addressing the current gaps in understanding the functional effectiveness of methods that are being implemented in farms in Colombia and worldwide. Properties in closer proximity to suitable carnivore habitats may have a higher number of carnivore visits compared to farms further away. In my study, farms with direct access to rivers, wetlands, and forests recorded more jaguar and puma visits compared to those not directly accessible, results consistent with prior experiments (Fergus et al. 2023). Individual differences of farms raise the hypothesis that some livestock may experience deterrent effects and others attractive or no effect. Detecting approaches of visits of carnivores to test

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functional effectiveness by itself may be an inadequate measure of risk of predation. Actual injuries or deaths of domestic animals may be the only useful measure of the effectiveness of deterrents. Some farms may face a greater risk of felid attacks regardless of the number of approaches. Among 20 farms, 2 farms reported loss of domestic animals before, during, and after the experiment. Hot spots of risk may obscure the effectiveness of deterrent methods because many farms experience near-zero risk regardless of beign in treatment or placebo conditions.

I also have concerns about the assumptions that are made in our field about the losses of domestic animals. Future research evaluating the functional effectiveness of methods should consider incorporating molecular analysis to determine the species or even individual involved in the attacks. Uncertainty about losses (which individuals, which species, species, and whether scavenging an already dead livestock or actual predation) can all introduce uncertainty into measures of risk and evaluations of the effectiveness of deterrents. I partially countered the potential measurement bias by including a third party from the government agency and Wildlife Conservation Society to verify that attacks occurred. However, identifying predators of attacks on domestic animals by signs on carcasses can introduce measurement bias because not all attacks exhibit clear signs. For example, I did not record puma presence in one farm where one attack was verified as a possible attack by puma based on parts consumed and the marks on the carcass. It's conceivable that the attack might have been carried out by a puma, but it's equally plausible that an error occurred during the identification process. This uncertainty stems from the absence of a systematic method for necropsy, records of that procedure, or molecular analysis, which could introduce a significant margin of error. Including molecular analyses, if funds are available, can increase accuracy and decrease research bias.

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Several methods are already in use by Colombian farmers. For example, research electric fences are currently implemented on farms in Colombia. We do not have RCTs to evaluate the effective design and doubts have recently been raised about their assumed unievrsal effectiveness of electric fences (Khorozyan 2022). We also need to evaluate mixing cattle and sheep in paddocks to reduce cattle losses or recovery prey. This intervention might be the second most supported by my participants, as the results of the WVO indicate concern for the lives of their domestic animals. Although the suggestion of adding sheep to cattle paddocks has ethical dimensions of sheep welfare beyond our scope here, this intervention is a novel suggestion in the literature to our knowledge. More often, researchers recommend raising less-vulnerable livestock, rather than adding one or more vulnerable livestock to protect more valuable, less vulnerable ones.Combining several methods of deterrence on a single farm seems common in my experience of Colombian farms. Researchers agree that combining interventions could increase effectiveness (Moreira et al. 2018; Shivik 2006). We will have to adapt scientific methods to evaluate multiple deterrents simultaneously; crossover RCTs with their within-subjects analyses provide opportunities for such complex designs (Fergus et al. 2023).

Evaluating the functional effectiveness of methods with randomized, controlled trials is feasible. However, achieving large samples, given the time-intensive nature of projects undertaken by governments and NGOs, could pose a challenge to advancing the field of functional effectiveness of methods to prevent attacks by carnivores. I encourage to conduct collaborative projects to increase sample sizes and strengthen the inferences about the functional effectiveness of predator control.

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My results suggest that participants' attitudes toward pumas and jaguars improved after the intervention. An intriguing question is whether all interventions enhance attitudes toward carnivores and for how long the change in attitudes will persist. Future studies can measure changes in attitudes in relation to educational programs, non-lethal methods, compensation initiatives, etc. Furthermore, assessing perceived and functional effectiveness is needed for obtaining a comprehensive understanding of the limitations and potential user benefits when deciding whether to adopt a specific intervention.

Interdisciplinary research is essential to experiments with non-lethal methods because we need information on what methods work with specific species, within which landscapes. under what sociopolitical conditions of acceptability, and if owners adopt or maintain methods for economic, aesthetic, or other reasons. My work adds to others suggesting economic reasons are secondary to other value-based reasons. Aesthetic values are one type of non-economic valuation and I encourage further work to understand and quantify the WVOs identified in this sample of Colombian farmers. I predict interventions to improve attitudes or foster coexistence should consider both aesthetic reasons and the perceived effectiveness of methods. Once we are aware of WVOs among domestic animal owners and their perceived effectiveness about the non-lethal methods then we can also imagine other non-lethal methods they might implement at their farms. Given the three actors in predator-livestock-owner interactions all have overlapping but distinct interests, researchers in our field would benefit from deppening understanding of all the actors.

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