Low-Stress Livestock Handling Protects Cattle in a Five-Predator Habitat

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Abstract

Given the ecological importance of top predators, societies are turning to non-lethal methods for coexistence. Coexistence is challenging when livestock are released within wild predator habitats, even when people supervise or use lethal methods. We report a randomized, controlled design to evaluate low-stress livestock handling (L-SLH), a form of range riding, to deter grizzly (brown) bears, gray wolves, cougars, black bears, and coyotes in Southwestern Alberta. The treatment condition was supervision by two newly hired and trained range riders and an L-SLH practicing range rider. This treatment was compared against a baseline pseudo-control condition of the single experienced range rider working alone. Cattle experienced zero injuries or deaths in either condition. We infer that inexperienced range riders trained and supervised by an experienced rider did not raise or lower the risk to cattle. Also, predators did not shift to the cattle herds protected by fewer range riders. Pending experimental evaluation of other designs, we recommend use of L-SLH.

Introduction

Given the important role of top predators in the function and diversity of ecosystems, societies and governments are prioritizing co-existence [1]. Human-induced mortality in large carnivores is the dominant cause of mortality across the world. It has resulted in ecosystem degradation [2] and extinctions of large carnivore populations or entire species. Successful predator conservation depends on converting competition over land and resources from lethal to non-lethal [1,3-6]. Conflicts with bears and wolves in North America have heightened importance given the protected status of these populations in some jurisdictions and the societal support for free-ranging livestock grazing on public lands. As predators have recolonized their historic ranges and encountered often unsupervised free-ranging livestock, the result is conflict that can either spark a renewal of eradication campaigns against top predators or innovative coexistence strategies.

Regardless of where or why livestock are raised, predator control to reduce conflict with free ranging livestock is costly, either because of the scale of the operations, a high rate of livestock losses, the control methods being used, or, more often, all of the above [7]. In the United States, agriculture and related industries contribute 1.1 trillion US dollars to the national gross domestic product (GDP), and the highest value livestock sector is cattle production [8]. In Canada, cattle production alone contributes more than 5 billion Canadian dollars to Canada's GDP and tens of thousands of jobs for the province of Alberta [9]. Lee et al. [9] found that more than 60% of Alberta's beef owners claimed to have lost animals to carnivores. When calculated against market value during the study period (2011-2013), these authors estimated that the losses valued more than 2 million CAD per year. Methods to reduce conflict include education and attractant mitigation programs (e.g., BearSafe program; [10]) and non-lethal and lethal predator control (e.g., relocations, aversive conditioning and targeted trapping and killing; [11-13]). However, many of the methods used to deter large carnivores have never, to our knowledge, been experimentally tested, therefore their use assumes effectiveness [5].

Livestock owners often perceive that non-lethal methods of predator deterrence are not as effective as lethal methods [14]. However, recent independent research has led some experts to argue that killing predators worsens conflicts. Although there is agreement that predation vanishes when no predators exist, the quantitative relationships between predatory threats to people or property and key environmental variables, such as domestic and wild species ecologies, remain murky. Reviews examining predator removal show that removal efforts are rarely successful, even when efforts are directed at a specific individual predator blamed for property damages [15-20]. e.g., cougars in Washington state, USA [21], wolves in Michigan, USA [22] and in Spain [23], and dingoes in Australia [24]. Appreciation that lethal methods often have counter-productive effects of raising livestock losses or have no effects on losses have spurred many independent efforts to find other approaches. In some cases, the partnership between scientists and owners can lead to the transfer and dissemination of scientifically supported innovations [5,25-28].

The effectiveness of many non-lethal methods have not been evaluated using rigorous scientific experiments [5]. One such method is range riding, i.e., deploying humans using non-lethal methods of predator deterrence and livestock protection. Increased human presence among livestock is assumed to deter top predators and improve response time if predators are present [29]. However, range riding is not well defined and is practiced in myriad forms, each likely to have varying degrees of effectiveness [30,31]. The most commonly used forms of range riding are narrowly predator-focused where riders generally hired by government agencies focus on detection and deterrence of predators [30,32]. Alternatively, riders may focus more on livestock vulnerability and herding practices to foster anti-predator behavior, in addition to predator deterrence [30,33]. These varied practices are largely driven by anecdotal experience without the benefit of empirically derived data and are therefore not likely to be equally effective. We define a particular form of range riding known as Low-Stress Livestock Handling (L-SLH) which has been developed among a relatively small group of livestock owners in the North American West [34].

Low-stress livestock handling as predator deterrent – Experts such as Bud Williams and Temple Grandin first developed L-SLH by combining pressure and release herding to move livestock in a way that both enhances the choices and natural behavior of the individual animal, thereby apparently improving livestock quality of life, health and yield [34-36]. This combination of methods may restore the innate herding instinct in ungulates that is frequently lost when livestock is tightly herded and aggressively moved between pastures [34,35]. Livestock owners who have used the method in regions with high predator numbers report that since L-SLH makes herding a more positive experience for livestock, domesticated ungulates more readily maintain herds that behave similar to wild ungulate herds, which reduces vulnerability to wild predation [37,38]. Therefore, we hypothesize that L-SLH may deter predator attacks and reduce predation by encouraging natural herding instincts that reduce ungulate vulnerability [38]. This method may be particularly useful on large public lands, where other forms of deterrence are difficult to implement [39,40]. Though Barnes [35] described a quasi-experimental evaluation of L-SLH for livestock herding, it has never, to our knowledge, been rigorously investigated as a form of predator deterrence. We believe that this study is the first of its kind to experimentally evaluate and define range riding and examine the effectiveness of L-SLH for deterring predators from attacking cattle.

We hypothesize that range riders might deter predators from cattle by two primary mechanisms: First, the presence of more humans might deter large carnivores such as grizzly bears, black bears, wolves, cougars and coyotes (hereafter we refer to this assemblage in our study site as LC, for *Large Carnivores*) from the associated cattle. This predicts that the cattle guarded by a single range rider in our study (pseudo-control) would be more vulnerable than the cattle guarded by several range riders (treatment). Alternatively, a second mechanism might be that herd stress levels predict vulnerability to predation because L-SLH would encourage and reinforce innate herding instincts that would further improve the herd's ability to independently deter LCs. This hypothesis predicts that the number of range riders is irrelevant and both pseudo-control and treatment would be effective. Alternatively, the experience level of the range riders might affect the stress and hence vulnerability of the cattle. Our pseudo-control was a single, experienced range rider and our treatment was this same individual supplemented by two inexperienced range riders who had received brief training from the former. Accordingly, our experimental design could reveal if, counter-intuitively, LCs approached herds with more range riders more often. Finally, a frequent unsubstantiated claim about non-lethal methods of livestock protection is that predators will shift to less-protected neighbors. Our design can detect this effect if our experiment reveals that herds frequently visited by multiple range riders (treatment) were safer than the herds visited less often by a single range rider (pseudo-control).

In our study site, a true control was impossible because the presence of predators and past attacks by predators on cattle made cattle owners unwilling to leave their livestock unattended. We designed our measurement of large carnivore (LC) presence to detect whether different species of LCs respond to range riders in the same way or differently, so each hypothesis was evaluated for each LC species and for the LCs as a group.

The lead author (NXL) randomized condition on each herd and then reversed treatment midway (crossover design). We also implemented two levels of blinding. The second author (AT) analyzed the data unaware of which herds were in which condition. More importantly, all range riders were kept unaware of the first author's monitoring of LC presence during the experiment. This was important because we were invited to study the system by the range rider who became our pseudo-control. This range rider, who manages the ranch where we conducted our study and whom we refer to as the ranch manager, is both highly experienced in the L-SLH methods and has educated livestock owners in those methods since 2016. The two newly trained range riders were hired as part of the experiment and the ranch manager undertook their training.

Methods

Study area **–** We conducted this study on the Spruce Ranching Co-op (hereafter the Co-op), a grazing co-op used by 38 permitted cattle owners who collectively bring about 2000 cow-calf pairs and 500 bred (i.e., pregnant) heifers to the Co-op grazing area in June of each year (Figure 1). The Co-op is located on 22,500 acres of Alberta provincial lease land in the Pekisko Heritage Rangelands area, which is part of the foothills of the southern Canadian Rocky Mountains south of the Banff-Jasper-Yoho National Park complex and north of the Waterton Glacier International Peace Park (Fig 4). Despite its status as provincial lease land, no permits were required to access the Co-op as we were not handling animals or collecting samples.

This study area is located between two sources of LCs, and therefore represents a core connectivity area for many species (Apps et al. 2007). Common LCs include grey wolves (*Canis lupus)*, grizzly (*Ursus arctos horribilis)* and black bears (*Ursus americanus)*, coyotes (*Canis latrans)* and cougars (*Puma concolor)*.

Ranch manager –This study required a pseudo-control, the presence of the ranch manager. A pseudo-control is used instead of a placebo-control because a placebo-control would require the treatment to be compared against the lack of treatment. The ideal placebo-control in this case would be no human supervision of cattle. To create a 'placebo' situation, perhaps a horse would be released with cattle to represent the method in which range riders spend time with cattle and to ensure that the measured effect of the treatment is the human presence of the range riders. However, in this study a placebo situation cannot be created because livestock owners are unwilling to leave their livestock unattended due to known risk of LC attacks on cattle. At least 4 individual cattle have been injured or killed by LCs each of the past three years prior to our study. Therefore, the ranch manager represents a pseudo-control because: 1. The ranch manager continued the same practices he has employed for the past 20 years, visiting every herd (i.e. all 8 grazing units) at the same rate he has always done without consideration for the treatment (two range riders) schedule. 2. When the ranch manager required extra help in pseudo-control fields (i.e., where range riders could not go), he hired additional help, as he would normally do. The ranch manager therefore saw each herd every 1-10 days depending on the herd and changing conditions related to weather, his own schedule, and availability of hired helpers. Therefore, we cannot infer if range riders are more effective than no protection. However, provincial statistics on cattle predation in our study region, which is comprised of rugged public lands where human supervision is scarce, reveal that 476 animals were confirmed attacked by carnivores between 2015-2019 [42]. However, cattle producers are known to systematically under report suspected predation events in Alberta [9]. These data provide some confidence that the absence of human supervision would be riskier for cattle.

The ranch manager is highly trained in L-SLH methods as he has been practicing these methods on this ranch for two decades. He began learning these methods by attending clinics with Whit Hibbard, an expert in the method, and now travels throughout the US and Canada discussing L-SLH with interested ranchers through workshops presented by The Working Circle, a California based non-profit.

Low-stress livestock handling techniques used- L-SLH practices used by the ranch manager and taught to hired range riders included keeping track of cattle behaviors during each visit and encouraging cattle to bunch together when they appeared to be spread too widely across a pasture. Cattle were moved with L-

SLH techniques (described above) such as: opening gates between pastures to allow cattle to move freely at their own pace, slow herding allowing all cow-calf pairs to pair up before moving, and the temporary use of pastures between origin and destination pastures for up to a week to keep cattle calm throughout the movement process. Range riders rarely, if ever, ride their horses at more than a walk when near or among cattle, and aggressive herding tactics such as elevated voices or swinging arms are never used. Roping is only used when doctoring animals, which is only done within a doctoring pen away from other animals.

Range riders **-** We hired two range riders (referred to as Rider A and Rider B) in accordance with institutional permissions granted by University of Wisconsin-Madison, and no human subjects were studied or experimented on for this study. This study was performed in accordance with relevant guidelines and regulations. Informed consent was obtained from all hired range riders. Range riders were responsible for up to 5 herds at a time and worked together as a pair when necessary (described below). The ranch manager trained both riders. Rider A has run their own ranch in the past and had attended a L-SLH clinic with Whit Hibbard. Rider A was also familiar with the landscape but had never spent full seasons working cattle on the Co-op before a short two-month pilot season in 2019. During the 2019 pilot season, the ranch manager trained Rider A received for a week, during which time Rider A shadowed the ranch manager and spent supervised time managing and moving cattle and learned to travel efficiently across the ranching area. This rider also received short periods of training over the past two decades when the ranch manager hired them for short periods of time (i.e., days). Rider B had worked on the Co-op in the past, with about two decades of experience on their personal land and on the Co-op. Therefore, Rider B already had some knowledge of how to travel safely and efficiently across the landscape. However, Rider B had never formally been trained in L-SLH methods. They received a week of training from the ranch manager, during which time they shadowed the ranch manager and helped move and manage cattle. This implies some potential “bleeding” of treatment and pseudo-control as the idiosyncrasies of the ranch manager’s methods might have been transmitted to the two inexperienced range riders. However, the ranch manager visited all herds including the treatment herds so his presence and behavior were a background baseline to the entire experiment and every herd (therefore a pseudo-control) and we were investigating the effect of the supplemental range riders on half of the herds.

The range riders worked in pairs when necessary, with Rider A helping to train Rider B who was less well versed in L-SLH, in areas that were likely to have higher risk from bears, i.e., areas where bears had previously been seen, or that were heavily wooded where bears are difficult to detect. Range rider pairs or single riders saw each treatment herd (up to 5 grazing units at a time) at least every 1-3 days.

Study design **-** Cattle grazed in herds belonging to one to two owners based on grazing unit allotments and permits are kept together for the duration of the grazing season. Each herd was treated as one ‘subject’, following [25]. We conducted the experiment in two phases, each lasting half of the 4-month (July – October 2020) study period, during which we randomly assigned herds to receive ‘treatment’ or ‘pseudo-control’. Phase 1 lasted for half of the grazing season (about 2 months; July - August) and then reversed in phase 2 (September – October) for the crossover, such that herds that received treatment became pseudo-control herds and vice versa. A 7-day washout period occurred at the end of phase 1 to reduce the carryover effect from one phase to another. We then compared herds to themselves from phase 1 to phase 2. Our within-subjects design minimizes potentially confounding variables between herds and randomization avoids potentially confounding order effects due to seasonal changes.

We studied 8 herds (replicates) each subject to crossover for n=16 trials. The ranch manager split one herd into two separate herds in phase 1 but combined them in phase 2. Therefore, we treated this herd as one subject in the analysis by summing the carnivore presence values for the herds when they were separate. This is accounted for in the analysis as the sampling pressure is doubled, and therefore the summed value of carnivore presence is divided by the summed sampling pressure. These herds were also treated as one subject during the study, so they have the same treatment-pseudo-control sequence.

Data collection - When range riders or the ranch manager found dead cattle, they contacted Alberta Fish and Game to determine the cause of death. In cases in which Alberta Fish and Game conservation officers implicated an LC in the death, range riders and/or the ranch manager spent more time with the herd, ensuring that predators did not return. If predators returned or were spotted, they were treated with aversive conditioning (e.g., warning shots, bear bangers and cracker shells) by range riders, the ranch manager and/or conservation officers. When possible, the ranch manager moved cattle to a new field further from known LC territories.

Trail Camera Data –active voixe especially important in methods that we did (also past tense typically) We used trail cameras to detect LC presence around herds. We monitored each herd with 3 cameras. To choose locations for camera placement, we used ArcGIS 10.7 to create a grid of 40-acre cells within each grazed pasture and selected three cells at random. Within each of these three cells, we placed cameras in locations deemed likely to be visited by LCs (e.g., cut lines, cow trails, stream banks, etc.). We moved cameras from pasture to pasture in response to herd movements.

We recorded all individual LC visits and number of visits by camera trap-days (i.e., one day per camera per field). We define Individual LC visits as visits to a camera by a single individual of a species. A new visit by an individual of the same species began when the LC was recorded on a camera 1+ hours after the last recorded photo of an LC of that species. Our criterion of one hour between photos served as an index of frequency and direction to estimate LC presence near subject herds. We recorded visits by the following LCs: grizzly bears (*Ursus arctos)*, wolves (*Canis lupus)* and cougars (*Puma concolor),* coyotes (*Canis latrans)* and black bears (*Ursus americanus)*.

LC Surveys - The lead author (NXL) was present the majority of the study period (except for the last two weeks of October due to adverse conditions from insurmountable snowfall). NXL completed weekly surveys of LC presence focused on detecting wolf, bear, cougar and coyote activity in pastures with subject herds. These surveys included visits to each of the three trail cameras where NXL conducted systematic 100m transects along the closest trail to the camera. Along these transects NXL looked for scat, tracks and other signs. During each visit to a pasture, NXL also examined primary trails, creek crossings and barbed wire fence-lines for LC signs. NXL recorded these data as presence or absence of

LC species. The LC survey data is only based on NXL's observations and not on range rider and ranch manager observations of sign. Without conducting tests to quantify the degree of uncertainty in sign identification, we minimized error by only recording one individual's observations. This approach also maintained the blinding of range riders to experimental measures of carnivore presence.

To reduce possible uncertainty in LC survey data, i.e., from possible misidentification of sign, we cross-referenced camera photos with sign data. Not all indirect sign (scat, tracks, hair) is captured in photos, so other aspects of indirect sign increase our confidence in species identification, such as location or type of sign. For example, NXL collected hair snags from barbed wire fences, but hair snags are difficult to identify, and in most cases cannot be differentiated by species, but simply by family, i.e., we were able to determine that a hair snag was from a bear, but not whether grizzly or black bear. DNA testing was infeasible. Tracks and scats are more easily identified and were used whenever possible [68]. Therefore, to account for identification uncertainty for our LC species - wolves, grizzly bears, black bears, cougars, and coyotes - wolf and cougar presence is determined solely on track and scat identification. Bear presence is differentiated by species when when NXL observed tracks and scat, and identified bear presence in general with hair snags (bear hair is distinctive), rubbing, and digging signs. Therefore, we analyzed two sets of response variables: LC presence data, derived from camera and LC survey data (Table 1), and LC attacks on livestock (for each species of LC).

Analysis – We calculated the first response variable of presence/absence for each LC species by summing the standardized value of the number of observations of each species recorded through camera traps and LC surveys. To calculate the total number of LC visits, the standardized individual species data was summed into a single response variable.

We tested normality of the data using Shapiro tests. We found Bear and coyote presence data to be normal. Therefore, for bears and coyotes we use parallel split-plot ANOVAs to analyze the effect of the treatment and phase on each species' presence. Wolf and puma presence were not normal, therefore for these species we use a non-parametric Wilcoxon sum rank test to analyze the effect of the treatment and study phase on their presence. We also combined all LC presence data into one response variable, which was found to be normal. Therefore, we analyzed the presence of the pooled LC variable using a parametric split-plot ANOVA.

We examine a global trend using the pooled LC variable and explore how each species may have deviated or followed the global trend.

We use Split-plot ANOVAs to test the difference between the sequence of the phases, ie. whether having a treatment-pseudo-control (T-PC) sequence results in differing LC presence relative to pseudo-control-treatment (PC-T) sequence [69]. This is important because carryover effects of the treatment may result in the T-PC sequence being very different from the PC-T sequence. Further, this method allows us to test period effects, i.e., whether phase 1 and 2 are always consistently different. If LCs are more active in fall months (September and October of our study), then phase 2 might have had greater LC presence, regardless of it's status as a pseudo-control or treatment.

Results

The study took place on the Spruce Ranching Co-op between July 1 and October 31, 2020 and comprised 22,500 acres of public grazing land. The study examined 2,469 adult cattle and 1,928 calves split into 8 subjects, i.e. herds (Table 1). No predation on cattle occurred during the experiment in either pseudo-control or treatment herds using a within-subjects test made possible by the crossover design. Therefore, we infer range riders were effective in protecting cattle, supporting the hypothesis that L-SLH reduced vulnerability.

The number of range riders did not predict LC presence near herds in a within-subjects analysis that met the assumptions of normality and equal variance (Fig 1, split-plot ANOVA df = 1, F=0.660, p =0.447). Therefore, we reject the first hypothesis that the number of range riders had an effect in our experiment, and we reject the possibility that LCs were attracted either to the herds with pseudo-control or to the herds with inexperienced range riders (treatment). Nor could we detect an effect of experience or inexperience of range riders, undermining another of our hypotheses about human supervision.

LC Presence – We observed every carnivore species within pastures where subject herds were grazed, using either camera traps or indirect sign surveys for scat, track, hair, etc., throughout the study period, regardless of treatment condition or study phase (Table 1; Fig 2, Fig 3). The presence of LCs throughout the study period and treatments suggests that risk of predation was present for every replicate throughout our study [41]. There were equal number of calves in each treatment condition due to the cross-over design (Table 1). However, the average number of calves was somewhat higher in treatment conditions during phase 1 (Table 1). In phase 2 that reversed and there were slightly more calves in pseudo-control conditions. By then calves would have gained weight, reducing their vulnerability, so we address this potentially confounding effect below.

Table 1. Large carnivore visits by species throughout the experiment.

Number of large carnivore (LC) visits by replicate (herd), species, and phase, recorded using LC surveys and camera traps. Number of visits are reported as visits per 10 LC surveys, visits per 100 camera trap days. Treatment sequences are pseudo-control-treatment (PC-T) and treatment-pseudo-control (T-PC).

Herd	Treatment Sequence	Number of cattle, number of calves	Wolf		Bear		Cougar		Coyote	
			Visits		Visits		Visits		Visits	
			Phase		*Phase*		*Phase*		*Phase*	
			1	*2*	*1*	*2*	*1*	*2*	*1*	*2*
1	PC-T	400, 400	2.0, 0	5.0, 0	8.0, 5.0	7.5, 1.0	0, 0	2.5, 0	4.0, 0	5.0, 2.1
2	PC-T	355, 355	0, 0	5.0, 0	6.3, 3.9	6.7, 1.9	0, 0	0, 0	2.5, 7.9	3.3, 0
3	PC-T	82, 82	0, 0	2.3, 0	4.4, 2.1	7.1, 0.8	1.1, 0	0, 0	4.4, 0.9	4.3, 2.3
4	PC-T	161, 0*	0, 0	0, 0	2.8, 1.6	8.0, 0	0, 0	0, 0	5.7, 0.6	6.0, 2.4
5	T-PC	250, 250	0, 0	2.9, 0	1.4, 1.3	2.8, 0.63	0, 0	0, 0	1.4, 0	10.0, 0
6	T-PC	480, 480	2.5, 0	3.3, 0	11.3, 2.1	6.7, 4.3	0, 0	0, 2.6	1.3, 0.3	1.7, 3.4
7	T-PC	361, 361	3.8, 0.7	5.7, 0	3.7, 4.0	4.2, 7.5	0, 0	0, 0	2.5, 1.3	4.3, 3.0
8	T-PC	380, 0*	2.5, 0	6.7, 0	2.5, 0	6.7, 0	0, 0	0, 0	2.5, 6.7	0, 0

*** Herds with no calves were all pregnant yearlings, i.e., heifers**

Cattle mortalities – There was one confirmed livestock attack during the study period, by a grizzly bear on a calf. This attack occurred during the wash-out period in a herd that was transitioning from pseudo-control to treatment, therefore it is not counted for either treatment or pseudo-control conditions. There were 8 recorded cattle mortalities from cattle ingesting poisonous plants, all occurred during phase 1, and 4 known mortalities from other non-predator causes, 1 occurred during phase 1 and 3 during phase 2. All were mature cattle.

Human presence - treated herds experienced on average 2.75 times more human presence than pseudo-control herds (n = 15.5 combined visits by range riders vs. n= 5.62 visits by the ranch manager alone).

Effect of treatment on individual LC - Bear (F=0.19, p = 0.678) and coyote (F = 0.155, p=0.707) presence analyzed individually did not differ across treatments (Fig 1). Cougar and wolf presence data were found to be non-parametric, therefore we used a Wilcoxon rank test. Cougar (Wilcoxon two-tailed, W = 28, p = 0.59) and wolf (W=35.5, p = 0.78) presence analyzed individually did not differ across treatments (Fig 1).

We also ruled out any order effects and carry-over effects. Order effects might confound comparisons by altering conditions across all replicates in unison and carry-over effects might arise if an effect of the treatment lasted after the herd was no longer being treated.

Order effects - Order effects might confound comparisons by altering conditions across all replicates in unison. Presence of all LC, pooled into one response variable, did not significantly differ across study phases ($F = 1.581$, $p = 0.255$). Wolf presence, however, did differ across phases, with more wolves observed during phase 2 (Fig 1, $W = 13$, $p = 0.042$). However, for bears (both species, $F=0.70$, $p=0.435$), coyotes ($F = 0.107$, $p=0.754$) and cougars ($W=27$, $p = 0.49$) there was no effect of study phase (Fig 1).

Carryover effects – Carry-over effects might arise if the response to the treatment lasted after the herd was no longer being treated. We attempted to eliminate any such effect by implementing a 7-day 'washout' period (see *Materials & Methods)* but tested for carryover effects in case the washout period was not long enough. We did not detect carryover effects for wolves ($F = 2.108$, $p = 0.197$), bears ($F=0.265$, $p=0.625$) or cougars ($F=0.07$, $p = 0.80$). However, we found that treatment herds experience slightly fewer coyote visits during the second phase of the study, when they were pseudo-controls ($F=5.702$, $p = 0.0542$).

Discussion

We report a randomized, controlled experiment showing that grazing cattle safely in a five-carnivore habitat that includes grizzly bears and wolves, can be accomplished by 1-3 range riders practicing low-stress livestock handling (L-SLH) and non-lethal, carnivore control. We used a pseudo-control because cattle owners refused a control without human presence due to past experience with livestock attacks, and we could not implement a placebo such as a riderless horse moving through herds. Our results show that range riders inexperienced in L-SLH can be trained quickly by an L-SLH experienced range rider, and that herds protected by one L-SLH experienced range rider were as safe from carnivore attacks as herds protected by this same experienced range rider and two range riders newly trained in the method.

Furthermore, despite a consistent presence of grizzlies, black bears, wolves, cougars and coyotes throughout our study period, these species did not switch to one or the other pseudo-control or treatment herds when confronted with both. In other words, carnivores did not change their behavior or presence within either treatment or pseudo-control herds. We reject the hypothesis that the risk to cattle is affected by the single variables of number of range riders or their experience in practicing L-SLH. We cannot rule out that a single experienced range rider practicing L-SLH every 10 days was as effective as one such experienced range rider supplemented by 1-2 inexperienced range riders, all practicing L-SLH and visiting herds every 1-3 days. We can reject the hypothesis that large carnivores moved from the better-protected herds to less well-protected herds within a large public grazing land allotment. We hypothesize L-SLH can be trained in a short period.

L-SLH is a form of livestock handling designed to reduce livestock stress, thereby increasing livestock health and yield. It has been identified by some livestock owners in Western North America as a useful means of retraining herding instincts in livestock and reducing livestock vulnerability to carnivore attacks, especially in free-ranging herds [35,38]. However, this method is still relatively uncommon, many owners instead preferring 'traditional' handling methods, which prioritize speed and efficiency over animal welfare and stress [34]. Antithetically, when speed is prioritized, animal handling appears more difficult as animals resist herding, leading to increased stress, reduced body condition and yield [34,36]. This combination of factors could make free-ranging livestock particularly vulnerable to attack by carnivores [37,38]. Given much livestock grazing worldwide is free-ranging, L-SLH range riding may have wide utility and co-benefits as a mobile predator deterrence method[27,28]. Among the co-benefits are protection of livelihoods, improved animal welfare and preservation of predators.

However, range riding comes in many forms, and must be clearly defined and experimentally tested in each new application, if it is to be confirmed as effective [30]. A lack of consensus on its definition and methods of use reduce its functional and perceived effectiveness, and risk wasting government and community resources [30].

No difference in livestock attacks

No carnivores attacked livestock during either treatment or pseudo-control condition. The presence of carnivores throughout the study period suggests, however, that risk of attacks did exist. Furthermore, shortly before the study began, a wolf attack was confirmed within one of the study area's cattle herds. Wolf and grizzly bear attacks on calves were commonly reported throughout the ecosystem in which we worked in the past, with 92 livestock losses reported in the previous 5 years [42]. While we continued to observe carnivores during our experiment, we received no news of heightened attacks. We infer that L-SLH range riding worked on the large Spruce Ranching Co-op and it did not push carnivores into neighboring areas. Therefore, our results seem contrary to claims that non-lethal methods simply displace predators to less-protected livestock. Indeed, such spill-over effects have been reported for lethal control. Several studies found lethal control counter-productive [5,11]. Santiago-Ávila et al. [22], for example, estimated that while targeted, lethal wolf control may reduce the risk of attacks on livestock on treatment farms, it may simultaneously increase the risk of attacks on neighboring farms. By not displacing carnivores, L-SLH can help to teach resident individual carnivores that cattle are an unsafe resource [43]. More specifically, by not harming carnivores through displacement or unbalancing social structures (e.g., wolf packs) L-SLH also presents itself as a non-lethal predator control method which is effective for both target and adjacent properties without harming the carnivores [44].

More wolves later in the season

Wolves were observed more frequently during phase 2 of the study (Fig. 1, Fig. 3), which may be a result of wolf breeding behavior. Wolves select breeding sites further from human activity where humans persecute them, as they do on this landscape, which may explain why few wolf signs were observed during phase 1, which occurred while pups are young and wolf packs remain close to breeding sites [37,45]. Phase 2 occurred during the autumn (September-October), when pups are older and wolf packs become nomadic, increasing the likelihood that we would observe them in our study area [32,46,47].

Increased wolf presence, but not attacks, among treatment herds

Though the effect was not statistically significant, wolves were the only carnivore to be observed more in treatment herds than in pseudo-control herds during phase 1 of the study (Fig. 1). There are two possible explanations for this observation. The first is that the larger number of calves in the treatment condition during phase 1 attracted wolves. Calves are smaller and weaker than mature cattle, and therefore are more vulnerable to predation. Smaller calves are also less independent and rely on their mothers and the herd for protection [48]. However, if wolves were attracted to the increased number of calves in the treatment condition during phase 1, it is probable that range riders aided in reducing the vulnerability of these herds, leading to no attacks on cattle. We did not observe this same trend in phase 2 when the pseudo-control condition had the increased number of calves. Wolves in Alberta have been observed to increase predation on livestock in late summer and fall (during phase 2) [49], and appear to preferentially select for cattle less than 9 months old. Therefore, we would expect to observe more wolves in pseudo-control herds in phase 2, where there were more calves. During this time calves are larger in size, but they are also more independent which may increase their vulnerability in different ways (Engelhart, J. pers. comms). However, there was no difference in wolf presence between treatment conditions during phase 2.

The second possibility for increased wolf activity in treatment herds in phase 1 is the novelty of new range riders. We presume the intelligence of wolves leads them to investigate novelties such as range riders [50]. The ranch manager has practiced L-SLH on this landscape for 20 years, therefore local wolf packs may know him and have already learned that his presence is not associated with favorable hunting conditions. Carnivores explore novel situations to gain information about their environments and territories [43]. Repeated exposure to certain circumstances can, however, reduce curiosity and exploratory behavior [51]. It may be, therefore, that wolves are accustomed to the presence of the ranch manager but investigated the presence of novel humans within their territories by increasing their visits to treatment herds.

Carnivores use exploration behaviors to seek out new resources or protect their territories [52]. Many individual wolves avoid new objects and circumstances [52]. This avoidance is thought to be a primary driver of the success in fladry, a form of fencing that uses evenly spaced flagging, to reduce wolf encroachment into fladry surrounded areas [39,53–55]. However, despite fladry deterrent effects in keeping wolves out, in most studies which have recorded wolf approaches to fladry, more wolf approaches were recorded in proximity to fladry fencing, than to control areas where no fladry was installed, despite wolves rarely if ever crossing the fladry barriers [53,55]. Therefore, our finding of increased number of wolf visits in treatment herds may be a result of the novelty of the new range riders. Furthermore, as with fladry, this increased number of observations does not imply increased risk to livestock, but instead an opportunity for wolves to learn about their environment. This learning is an important aspect of the deterrence work of range riders [43]. If wolves explore their territory and learn that range riders are a threat or that livestock are not vulnerable, we might expect them to become accustomed to the presence of range riders and focus their energy on hunting of wild prey. This may explain why, despite more frequent visits by wolves in phase 2 of our study, there was no difference between treatment conditions and wolf presence.

Natural mortalities attracted bears, but not livestock attacks

During our study period there were 8 recorded cattle mortalities from cattle ingesting toxic plants, such as larkspur, water hemlock or saskatoon blooms [56], and 4 mortalities from other non-predator causes. This is not uncommon in our study area, and occurs more regularly earlier in the grazing season, during the first phase of our study, when the majority of poisonous plants are at their most toxic [56]. An assumed benefit of range riding is the ability of range riders to quickly observe and manage attractants of predators among livestock. These deaths would have attracted bears, which may explain why our results show a non-significant but observable increase in both species of bears during phase 1 of the study (Fig. 1). Range riders or the ranch manager identified these areas and were either able to remove dead stock or increase their own presence within these herds.

Evidence is mixed regarding whether diversionary feeding of carnivores [57] is effective at reducing conflict [58,59], attracts bears and could increase conflict [60] or is effective by diverting carnivores to other sources [61]. A primary attractant of grizzly bears in this region of Alberta are dead animals [62], so the predominance of poison killed cattle might be attracting bears into the study area. Attacks by bears on livestock did not increase however, either due to the supplemental feeding of the already dead animals, or the increased presence of range riders during these times. We did not observe that these dead animals attracted wolves or other carnivores.

It is difficult to untangle the effects of human presence, diversion feeding, and competition between bears and other LCs. However, Morehouse & Boyce [59] found that diversion feeding of grizzlies in Alberta resulted in a few dominant males protecting the food source against other individuals. Therefore, depending on the individuals attracted to the dead livestock, bears could have repelled other bears or species from the area.

Effect of treatment long lasting on coyotes

Coyotes had a non-significant but measurable response to the treatment and showed a statistically significant response to treatment-pseudo-control sequence. In other words, the effect of the treatment might have been long-lasting and could not be mitigated after a 1-week washout period. As coyotes are the primary source of carnivore-livestock conflict in much of their range [63–65], though not in our study area, we suggest this method may be particularly effective in deterring coyotes. Furthermore, coyotes are known to avoid wolves, as wolves are known to dominate coyotes in interspecific species conflict [63,66,67]. Therefore, a wolf population that knows not to attack livestock may also help prevent coyote attacks.

Conclusion

We observe that when properly executed L-SLH protects livestock with fewer riders. Furthermore, it is a method that is easily taught. Our recommendations are that (1) L-SLH be tested in a randomized controlled experiment against non-L-SLH (i.e., 'traditional') livestock handling and/or a true control. This would help to determine whether other forms of human presence deter, attract or have no effect on predator attacks on livestock. However, we demonstrate in this experiment, how difficult it is to implement a true control, as many livestock owners are unwilling to leave their herds unattended; (2) L-SLH methods should be studied to examine the number of newly trained range riders that are optimal for predator deterrence and cost effectiveness. The results of this study suggest that fewer riders may be just as effective on the predators being deterred. However, studies comparing numbers of newly trained riders would produce evidence regarding what level of training must be attained for effective predator deterrence, particularly as there are few L-SLH veteran range riders working today; and (3) These results are useful in proving that L-SLH can deter predators if riders are properly trained. Therefore, given a lack of further research on range riding, and a lack of consensus on the efficacy of other forms of range riding, L-SLH should be prioritized as the only form of range riding, to our knowledge, to be experimentally tested.

Methods to reduce risk of attacks on livestock must be implemented, particularly as free-ranging livestock occur throughout the world and present a challenge to co-existence with carnivores. Human-caused mortality, often in response to perceived conflicts, is the primary form of mortality in large carnivore populations, and risks undermining conservation efforts to restore carnivore populations [1]. We recommend the prioritization of high-quality research, and implementation of livestock attack deterrence methods that are both experimentally proven to be effective and reduce harm to predators.

Declarations

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Figures

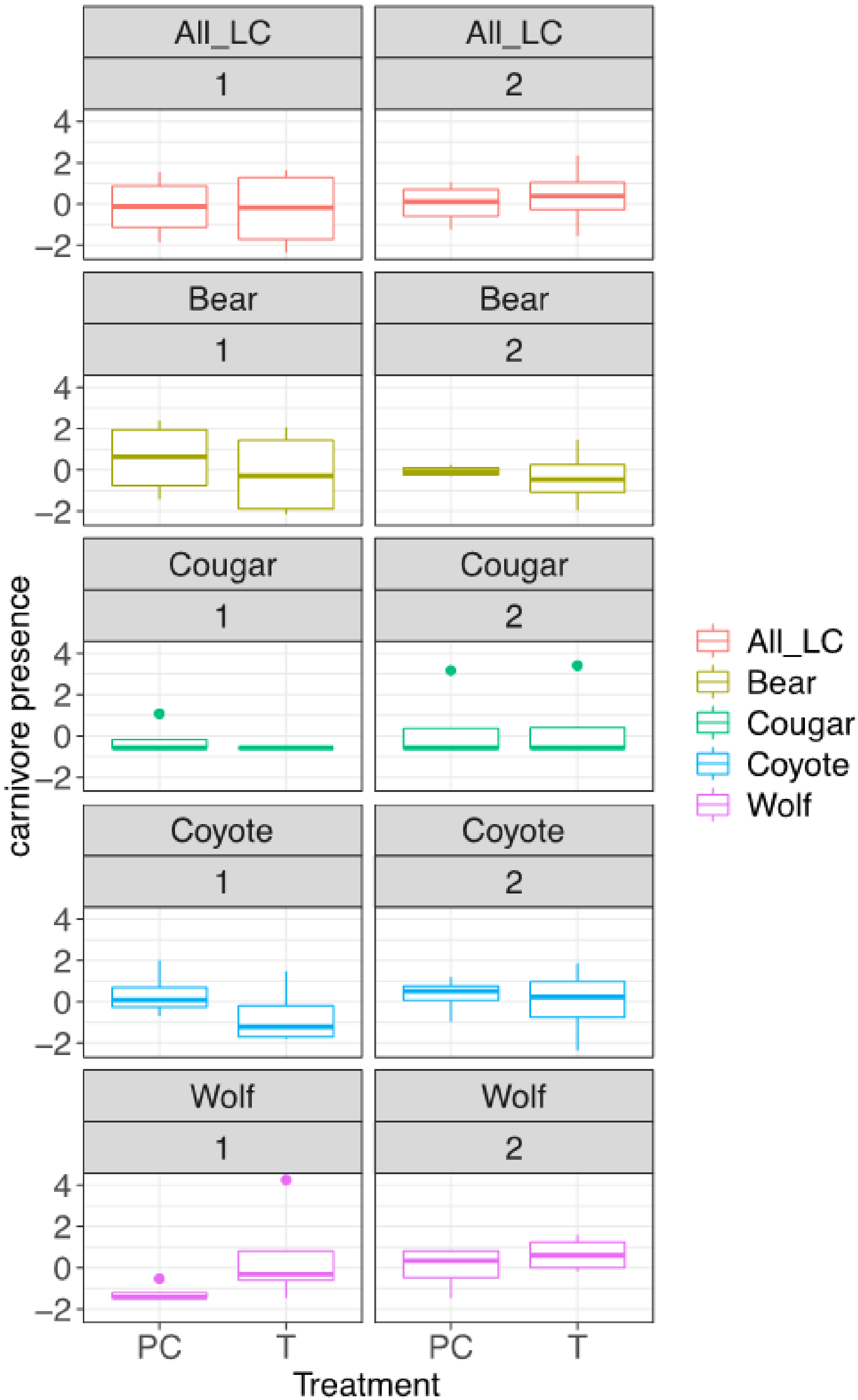

Figure 1

Standardized large carnivore presence by treatment condition, phase and species. Large carnivore presence standardized to include trail camera and LC survey data by carnivore species, phase (1 or 2) and treatment condition (PC = pseudo-control, T=treatment). All_LC represents the combined response variable of summed presence of all species of carnivores allowing a comparison of the global trend to individual species responses to treatment conditions.

Figure 2

Images of predators captured by trail cameras positioned within pastures with study herds. (A) Grizzly bear (Ursus arctos) (B) Black bear (Ursus americanus) (C) Coyote (Canis latrans) (D) Wolf (Canis lupus). (E) Cougar (Puma concolor)

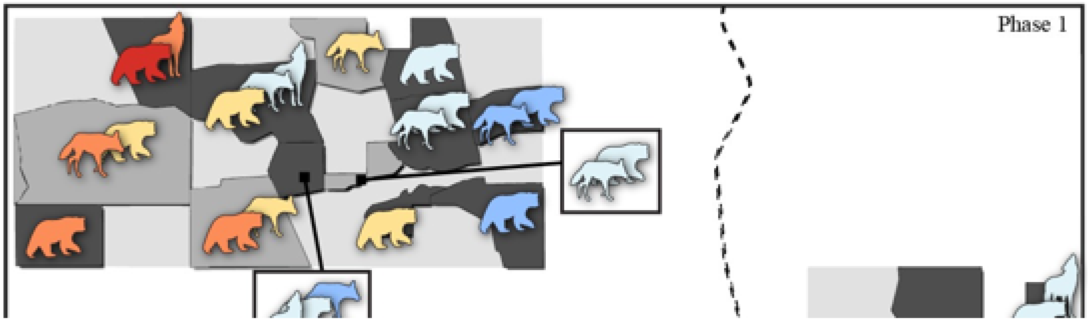

Figure 3

Large carnivore presence in grazed pastures by experimental phases. Cougar, wolf, bears and coyote presence within pastured grazed by both pseudo-control and treatment herds during each phase of the study. LC visit frequency is ranked based on number of visits per 10 LC surveys or visits per 100 camera trap days (CTD), whichever was greatest. All pastures depicted, including ungrazed pastures, are legally part of the Spruce Ranching Co-op.

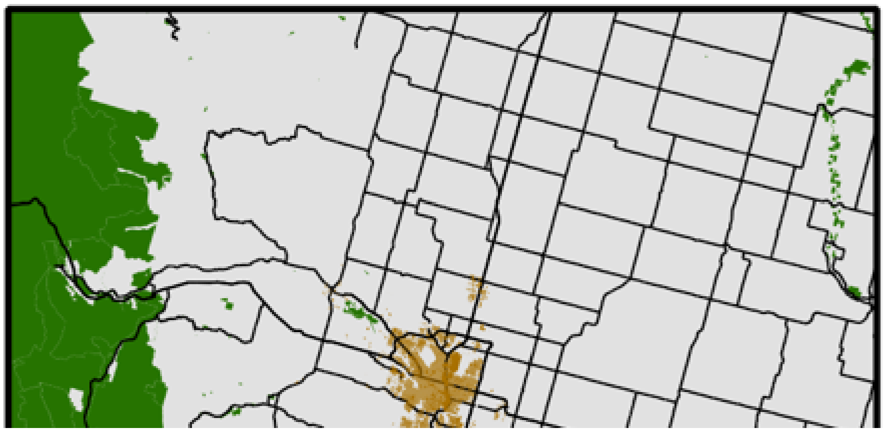

Figure 4

Study area map of the Spruce Ranching Co-op. Extent map of the Spruce Ranching Co-op, located in the foothills of the Rocky Mountains in Southwestern Alberta, Canada. Protected areas refers to areas designed either by the Canadian federal government or the Alberta provincial government as protected.

Supplementary Files

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