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Impact of livestock guardian dogs on livestock predation in rural Mongolia

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Abstract

Much like subsistence farmers the world over, Mongolian herders depend directly on their herds for food, materials, and income. Consequently, any loss of livestock through predation from wild carnivores (including wolves, foxes, snow leopards, and birds of prey) is a major challenge. With a lack of non-lethal mitigation methods currently available to them, herders in Mongolia frequently manage conflict with predators with retaliatory hunting, negatively impacting populations of wild predators. Livestock guardian dogs (LGDs) are an increasingly popular non-lethal means worldwide for discouraging livestock predation. However, empirical evaluations of the efficacy of using LGDs in contemporary landscapes are rare throughout Asia. Evaluating these human–wildlife conflict prevention strategies are especially important in areas used to produce globally traded commodities, such as cashmere in the case of Mongolia. We implemented longitudinal structured interview-based surveys to evaluate the use and effectiveness of LGDs as a conflict mitigation strategy for semi-nomadic herders in three locations across Mongolia. Sixteen herders in Nomgon, Ömnögovi, Undur-Ulaan, Arkhangai, Khustain Nuruu National Park area, and Gorkhi Terelj National Park area were surveyed between 2015 and 2019, throughout the process of receiving and training LGDs. Our analysis suggested herders experienced a significant reduction in the annual losses of livestock to predation after receiving LGDs (Wilcoxon signed-rank test, $Z = -3.329$, $p = .001$, $n = 16$), including when accounting for background predation rates. Consequently, we consider LGDs likely to be a viable method for livestock protection alongside the conservation of predators in Mongolia, and potentially elsewhere in Asia. We finish by exploring important considerations should this approach be used more intensively throughout the country and beyond.

KEYWORDS
herding, human–wildlife interaction, Mongolian Bankhar dog, non-lethal control, predation mitigation, predator, wolves

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1 | INTRODUCTION

Human–wildlife interactions are almost inevitable in subsistence agricultural systems, and are increasing worldwide (Manfredo, 2015; Peterson, Birckhead, Leong, Peterson, & Peterson, 2010). The frequency and negativity of interactions increases with increasing human land use (Mishra, Prins, & van Wieren, 2001), intensified resource competition (Nowell, Li, Paltsyn, & Sharma, 2016), and more rapidly regenerative predator populations (Espuno, Lequette, Poulle, Migot, & Lebreton, 2004; Gehring, VerCauteren, & Landry, 2010). Interactions perceived negatively typically include predation on valuable livestock (Bauer, de Iongh, & Sogbohossou, 2010; Li, Buzzard, Chen, & Jiang, 2013), crop damage (McGuinness & Taylor, 2014), and the risk of wildlife directly harming humans (Thirgood, Woodroffe, & Rabinowitz, 2005)—especially in regions where there is limited access to effective prevention strategies (Bagshi & Mishra, 2006). Beyond the physical and financial toll of such wildlife interactions, researchers have found that substance agricultural communities are especially vulnerable to health impacts and opportunity costs associated with intensifying human–wildlife conflict (Barua, Bhagwat, & Jadhav, 2013).

Livestock guardian dogs (LGDs) are an ancient predation prevention method (Coppinger, Coppinger, Langeloh, Gettler, & Lorenz, 1988), though their use declined during the 20th century for socio-economic reasons and due to widespread suppression of predator populations (Gehring, VerCauteren, & Landry, 2010; Rigg, 2001). The latter has, in many places, obviated the need for culturally affiliated predation management strategies that pastoralist communities previously employed for millennia (Rigg, 2001). Such strategies had developed over long periods of time and so, once forgotten, these complex systems of coexistence with wildlife are not readily resurrected (Rust, Whitehouse-Tedd, & MacMillan, 2013).

For instance, in socialist-era Mongolia (1924–1991), predation prevention changed markedly following collectivization (Scharf, Enkhbold, & Burnee, 2003). Mongolia herding systems moved dramatically away from semi-nomadic herding towards state-mandated settlements and state-sanctioned wolf eradication became the primary predation prevention strategy—thus reducing the need for livestock guardians (Charlier, 2015; Sneath, 1998). In the post-socialist era, decollectivized herders faced a significantly altered political landscape, loss of state support, a rapidly changing system of land management, and pressure to alter practices to survive in a newly privatised economy (Chuluun, Altanbagana, Ojima, Tsolmon, & Suvdantsetseg, 2017; Scharf et al., 2003). This period saw a marked drop in productivity; total head of livestock increased by more than 20% nationally but livestock consumption fell by 20% and livestock offspring survival dropped by 10% (Sneath, 2003). The abruptly privatised and under-regulated system that emerged in the political transition in the last 20th Century has resulted in larger herd sizes and alterations in land use patterns, as well as displacement of natural prey species, leading to more frequent interactions between livestock and predators such as wolves (*Canis lupus chanco*), snow leopards (*Panthera uncia*), red foxes (*Vulpes vulpes*), and a variety of birds of prey including golden eagles (*Aquila chrysaetos canadensis*) and Pallas's fish eagle (*Haliaeetus leucoryphus*) in post-socialist era countries (Lescureux & Linnell, 2013; Mijiddorj et al., 2018). One study in Khustai Nuruu National Park, Mongolia, found that with the exception of 3 months of the year (July, August, and September), livestock constituted 50% by frequency of prey occurrence in wolf scat (Hovens & Tungalaktuja, 2005). In lieu of access to the non-lethal predation prevention methods they once employed, herders frequently rely on retaliatory killing of predators after livestock predation events (Nowell et al., 2016). This pattern exists globally when a period of low predation risk erodes culturally informed methods of damage prevention (Gehring, VerCauteren, & Landry, 2010; Rigg, 2001) that may be needed again when predator populations rebound (Lescureux & Linnell, 2013; Linnell & Cretois, 2018).

Though many other motivations for people to hunt predatory species exist (Olson & Fuller, 2017), previous studies in Mongolia have established a relationship between livestock predation and retaliatory hunting (Hovens, Tungalaktuja, Todgeril, & Batdorj, 2000; Nowell et al., 2016). New and growing access to vehicles and guns in rural areas likely contributed to the prevalence of hunting, retaliatory and otherwise (Wingard & Zahler, 2006). Hunting wolves is a logical response from herders trying to protect their livelihoods, however lethal predator control may not be effective for long-term reduction in livestock losses and is often more expensive than other approaches (Gehring et al., 2006; Lennox, Gallagher, Ritchie, & Cooke, 2018; Treves, Krofel, & McManus, 2016). Rather, a more effective strategy might be to focus on reducing predatory livestock losses, even if those losses are not the only reason that people hunt or otherwise exclude predators (Davie, Murdoch, Lhagvasuren, & Reading, 2014; Marker, Dickman, & Macdonald, 2005).

1.1 | Mitigation strategies and livestock guardian dogs, globally and in Mongolia

Mitigation strategies that increase agency on the part of land users themselves may have more lasting benefits, and prove more sustainable in the long-term compared to

indirect approaches such as compensation schemes (Madden, 2004; McNutt, Stein, McNutt, & Jordan, 2017; Naughton-Treves, Grossberg, & Treves, 2003; Ogra & Badola, 2008). In addition to ensuring strategies are culturally appropriate, literature suggests that researchers should determine how such strategies are perceived by those that will actually utilize them and experience their outcomes (Potgieter, Marker, Avenant, & Kerley, 2013). The use of livestock guardian dogs (LGDs) is particularly interesting in this regard, as it allows the people directly affected by livestock predation to personally alter their interactions with predators (Marker et al., 2005).

LGDs have been in existence since antiquity, used throughout the world as a predator mitigation method and taking on different forms based on cultural and landscape features (Coppinger et al., 1988; Coppinger & Coppinger, 2001; Gehring, VerCauteren, & Landry, 2010). Further, an emerging body of evidence suggests that LGDs are one of the most successful methods of human–wildlife conflict prevention currently documented (Eklund, López-Bao, Tourani, Chapron, & Frank, 2017; Spencer et al., 2020; van Eeden et al., 2018). LGDs are large dogs (at least 30–40 kg and 50–60 cm tall) with attentive behavior and a propensity to bond with livestock (Coppinger & Coppinger, 2001; Lord, Schneider, & Coppinger, 2016). They generally deflect predators indirectly (scent-marking, barking, consuming livestock afterbirth), while direct interaction with predators is possible but far less common (Dawydiak & Sims, 2004).

The use of LGDs has been assessed as a conservation strategy in areas including but not limited to Australia (van Bommel & Johnson, 2014), Romania (Ivaşcu & Biro, 2020), the Balkans (Yilmaz, Erdal Ertürk, Coskun, & Ertugrul, 2015), Finland (Otstavel et al., 2009), France (Espuno et al., 2004), Namibia (Marker et al., 2005), Norway (Hansen & Bakken, 1999), South Africa (Rust et al., 2013; Spencer et al., 2020), and the United States (Andelt & Hopper, 2000; Black & Green, 1985; Coppinger et al., 1988; Gehring, VerCauteren, & Landry, 2010; Ver-Cauteren, Lavelle, & Phillips, 2008). However, the need for further research to investigate the efficacy of LGDs in more varied herding systems with a wider range of potential predatory species has been identified (Bauer et al., 2010; Gehring, VerCauteren, & Landry, 2010). Many unanswered questions regarding LGDs remain in terms of their uses in human–wildlife interaction mitigation and their role in conservation approaches (Gehring, VerCauteren, & Landry, 2010; Lescureux & Linnell, 2014). Some research suggests that LGDs may chase or kill non-target wildlife and cause significant ecological harm (Potgieter et al., 2013; Smith, Yarnell, Uzal, & Whitehouse-Tedd, 2020). Many studies focus on single herd systems but little assessment has been conducted on herding styles which require herd splitting (i.e., where herders seasonally separate livestock into different herds, based on sex, if they are pregnant, or other criteria; a common practice throughout Eurasia) (Garde, 1996; Lescureux & Linnell, 2014). Additionally, while examples of LGDs protecting livestock from wolves exist (Coppinger et al., 1988; Espuno et al., 2004; Ribeiro & Petrucci, 2005); Kinka & Young, 2018; Gehring, Ver-Cauteren, & Landry, 2010; Gehring, VerCauteren, Provost, & Cellar, 2010; Landry, Borelli, & Drouilly, 2020), there is a need for more evidence of the potential efficacy of this application (Gehring, VerCauteren, & Landry, 2010; Lescureux & Linnell, 2014), particularly in novel herding systems and regions such as Asia. Many regionally specific types of LGD such as the Mongolian Bankhar Dog (a traditional LGD specific to Mongolia, hereafter referred to as "Bankhar dogs") are almost entirely missing from the scientific literature (ICB, 2017). Because of the variability of herding systems worldwide, additional site-specific studies would contribute to more detailed knowledge of the benefits, limitations, and potential risks of promoting LGDs in different herding systems (Gehring, VerCauteren, & Landry, 2010). While LGDs have been used throughout the world to mitigate predation on domestic animals both historically and as a contemporary conservation method (Lescureux & Linnell, 2014; Olsen, 1985), no studies have yet been published on their use or effectiveness in Mongolia or analogous herding systems and only limited studies in former Soviet-affiliated regions (Rigg, 2001).

Mongolian herding communities maintain a semi-nomadic, transhumant system of herding that necessitates a high degree of integration with their environment through regular interaction with, conflict against, and dependence on the landscape (Fernandez-Gimenez, 2000; Rao et al., 2015). Mongolia is the second largest producer of cashmere, and extremely valuable luxury commodity, contributing about 48% of the world's supply (The Schneider Group, 2020). With such a significant contribution to the textile industry, developing improved understanding and practice for livestock protection in the country is significant to the development of more sustainable supply chains. Improved sustainability of cashmere supply chains has caught the attention of industry giants such as Kering Fashion Group, which is already investing in more sustainable cashmere as part of a global biodiversity strategy (Wildlife Conservation Society—Mongolia, 2021). Interest in sustainable cashmere has also garnered interest and support from UNDP to research approaches for reducing its ecological impact (Okamoto, 2019). With human–wildlife conflict as a key biodiversity impact of the cashmere trade, this will be a critical conservation problem to solve if the industry hopes to create a more sustainable supply chain.

Herding employs 288,700 Mongolians, approximately 36% of the working population, with over 66 million head

of livestock in the country, nearly triple the peak levels during Mongolia's socialist era (National Statistics Office of Mongolia, 2019). As environmental issues such as climate change and pastureland degradation mount, and with herders increasing their stock in order to insulate themselves against losses and economic vulnerability, human–wildlife conflict is continuously increasing in-step throughout the landscape (Lkhagvadorj, Hauck, Dulamsuren, & Tsogtbaatar, 2013). Mongolia provides a novel setting to explore the use of LGDs in relation to the scientific literature, and an opportunity to document Mongolia's own native LGD variety. The use of Bankhar dogs as LGDs is uncommon today, but herders still recognize them as a prominent cultural symbol that are regarded as highly valuable. Indeed, some claim that the presence of an endemic LGD type leads to improved conservation for predatory species (Horgan, Van Der Weyde, Comley, Klein, & Parker, 2020; Ivaşcu & Biro, 2020), though this has not yet received any empirical attention in Mongolia. According to recent genetic studies, the Bankhar maintains its genetic distinctiveness from other breeds (ICB, 2017; Shannon et al., 2015). Bankhar dogs are specially adapted to withstand the intense Mongolian climate (temperatures ranging from 43°C to −48°C) with compact body structure, dense fur, and fully furred underbellies. Beyond their physiological traits, Bankhar dogs are believed to have a millennia long relationship with Mongolian herders and potentially represent one of the earliest examples of dog domestication (Shannon et al., 2015). Further, Mongolian herders frequently perform herd splitting, which may have interesting implications for the efficacy of LGDs—making the case study even more pertinent. It has been well established that livestock predation is a significant issue for these herding communities, as it is cited as the most common reason for retaliatory killing in Mongolia (Hovens & Tungalaktuja, 2005; Olson & Fuller, 2017); therefore, a new study into the non-lethal predation prevention methods specific to this country is highly warranted.

In this study, our primary aim was to assess whether placing Bankhar LGDs with Mongolian herders is associated with a reduction in livestock losses, in the context of the semi-nomadic herding style utilized throughout Mongolia. Simultaneously, we sought to explore the wider impact of LGD placement on the herders themselves.

2 | METHODS

2.1 | Mongolian Bankhar dog project

The Mongolian Bankhar Dog Project (MBDP) is an American non-profit established in 2011 to place LGDs with herders in Mongolia for the purpose of reducing negative interactions between herders and predators (MBDP, 2019). MBDP breeds Bankhar dogs within Mongolia, and provides them to selected herders in participating cooperatives and communities throughout the country. In 2013, MBDP began a breeding program with an initial group of 12 adult Bankhar dogs from several locations around Mongolia, and in 2014 MBDP began placing Bankhar pups from the breeding program with participating herders.

From 2015 to 2019, MBDP carried out detailed and systematic evaluation, placement, and follow-up concerning the placed LGDs. The MBDP team collaborated with cooperative leadership and other organization partners to identify potential participant herders, and administered a 42-question evaluation questionnaire with interested families. Potential participants were selected based on recommendations from herder group leaders and elders, and then evaluated for suitability through the questionnaire and a home visit. Suitability for participation in the program depended on herders responding favorably to questions regarding the care of dogs (if they agreed to vaccinate their Bankhar dogs, feed them sufficiently, would attempt to keep non-LGD away from the Bankhar, etc.) and other factors, such as if they had many other dogs in their camp and whether they exhibited interest in the program. Selected herders were provided with industry-standard LGD training protocol based on Dawydiak and Sims (2004), and collaboration with Mongolian herders and other experts.

Bankhar pups were born between mid-November and early January. All pups born at the facility were birthed in enclosures with 8–15 sheep and/or goats present, allowing them close contact with livestock throughout their early life. Because they were placed in remote areas with limited access to veterinary care, pups were placed after 4 months of age: though relatively late for placement compared to LGDs elsewhere, this permitted them time to be microchipped, neutered or spayed, and vaccinated. All female pups were spayed, but since there is a significant cultural aversion to neutered male dogs, most male pups were given to herders intact. Pups were generally placed in pairs in alignment with best practice among LGD users, although MBDP also placed single pups. After placement, MBDP remained in regular contact with herders to provide input and advice about dog training and to informally track progress between follow-up visits. Herders were encouraged to collaborate with other participants to share training methods. Systematic formal follow-up questionnaires were administered during visits to the participants when the MBDP team observed the Bankhar dogs and further discussed the training process with the herding household. Observational assessments ranged from 1.5 to 2 hr and always during the daylight when the herd would be active. We observed the placed dogs at several levels:

from afar while they were on the pasture with livestock, at close proximity on the pasture, and at the homestead. We assessed their suitability for being livestock guardians based on: their willingness to follow and remain with the herd during the day on the pasture, their relationship with the homestead (i.e., whether they stayed with the herd in the evening or gravitated towards the *ger*, or house, as well as where they were fed and if they had a sleeping shelter near the livestock), and their behavior towards livestock (unsuitable behavior included chasing animals).

Placed dogs were considered "successful" if the MBDP team observed expected LGD behavior as defined by Dawydiak and Sims (2004). Successfully placed dogs do not chase, bite, or intimidate livestock; they may demonstrate protective behaviors (e.g., a pair of LGDs may split up with one guarding the rear of the herd and the other in front, or they may seek out and protect stray individual livestock), but their bond with the herd and ability to follow livestock was considered the determining components.

Dogs that were assessed not to be following the herds but exhibited some guarding behaviors (e.g., going with the herder out to pasture, but not staying with the herd all the time, or still requiring encouragement to follow the herd) were considered "partially successful." Dogs were categorized as "unsuccessful" if they exhibited no guarding behaviors, typically staying by the herders' domicile, ignoring or chasing the livestock, not following the herd or herder to pasture, or returning to the domicile area frequently. Occasionally a Bankhar dog or pair of dogs might be considered successfully trained, but were nevertheless removed from their herder because of mistreatment or other welfare concerns. In other cases, one individual of a pair of LGDs could be unsuccessful (e.g., because of an injury), but the other one successful. For this reason, our study reports on the outcome of individual dogs as well as the overall outcome per herding household.

2.2 | Placed LGDs

MBDP placed 71 Bankhar dogs with herders between 2015 and 2019. Of these placed dogs, 12 were not placed with the intention of becoming LGDs or were otherwise not viable for training. The outcomes for the 59 Bankhar dogs placed with the intention of becoming LGDs are summarized in Table 1. Only herders that responded to contact for follow up visits or interviews were able to be included for assessment an analysis, which narrowed our sample of herders from 27 to 16 participant herders. Among the 16 herders, they had 28 LGDs placed between them (Figure 1). Placed Bankhar dogs were categorized as successful, partially successful, or unsuccessful based on the observations by MBDP staff and interviews with herders during periodic visits.

2.3 | Evaluation of LGD placements

Follow-up evaluation of participating herders consisted of administering a questionnaire survey in person, as well as observing the placed Bankhar dogs. The follow-up questionnaire regarded the training process, activities and behaviors of the dogs, interactions of the dogs with livestock, certain impacts on the herder's daily work such at time spent herding or training the dogs, interactions with predators and wildlife, and loss of livestock. A simple health examination of the dogs was performed, and the homestead area observed. Such follow-ups occurred at varying intervals after placement based on logistic constraints, such as the herders' frequent moves, weather conditions and logistical considerations, which prevented standardized increments of follow-up visits. MBDP typically visited placed Bankhar dogs around 6 months after placement, but some initial follow-up visits occurred as soon as 3 months to as much as 9 months after placement. Though more regular follow-up visits among different herders would have been more comparable, we consider this unlikely to substantially change the overall findings.

Herders did not always answer every question on questionnaires. In 2018, additions were made to the follow-up survey, such that certain questions are only represented by 1 year of assessment rather than by four. Translation from Mongolian into English was provided during the interview by one of two Mongolian staff members, with further clarification of translations afterwards where necessary.

All herders consented to participate before questionnaire sessions. Ethical approval for publication of study findings was obtained in 2019 from the University of Kent, prior to conducting the analysis of the interviews collected between 2015 and 2019. A signed statement of consent was collected at the time of the interview wherever possible. Where consent was obtained verbally at the time of the interview, a signed consent statement was requested retrospectively to confirm the informed consent of the participant.

Herders that had one or more follow-up evaluations after receiving LGDs were included in the dataset for analysis. Because many herders were not able to give a precise number of livestock lost to predators each year, livestock losses were reported in ranges; herders could report their losses as none (0), 1–5, 6–10, 11–15, 16–20, and so on up to 50. These bands were chosen since they are small enough to enable some precision, while not overwhelming survey respondents with too many range options. In addition, herders were asked a variety of questions pertaining to their herding style (if they practiced herd splitting, how they typically observed their herd, what types of transportation they used to follow their

TABLE 1 A summary of outcomes for Bankhar dogs placed by Mongolian Bankhar Dog Project between 2015 and 2019 in different areas of Mongolia. Sections marked * are dogs placed that are still in training or undergoing assessment

Year	Location	Bankhar dogs placed	Outcomes				
			Successful	Partially successful	Unsuccessful due to training	Removed for welfare	Injury, death, lost, stolen
2015	Gorkhi Terelj NP	6	0	1	4	0	1
2015	Khustai Nuruu NP	5	0	1	3	0	1
2015	Ömnögovi	6	0	3	2	0	1
2016	Gorkhi Terelj NP	1	0	0	1	0	0
2016	Khustai Nuruu NP	4	0	0	3	0	1
2016	Ömnögovi	7	3	2	0	0	1
2017	Khustai Nuruu NP	2	0	2	1	0	0
2017	Ömnögovi	7	4	0	0	2	1
2018	Ömnögovi	6	4	0	0	2	0
2018	Arkhangai	4	0	4	0	0	0
2019	Ömnögovi	7	*	*	*	*	*
2019	Arkhangai	4	*	*	*	*	*
	Total placed	59	11	13	14	4	6

herd) and about their Bankhar dogs' behavior (where the LGDs spend the majority of time, their disposition with livestock, if they chased or killed wildlife, etc.). The data were not normally distributed, so a Wilcoxon signed-rank test was used to compare the reported livestock losses due to predation prior to participation in the program and after approximately 1 year (10–14 months) of the herders working with the Bankhar dog(s) provided to them.

We retroactively developed an average baseline among the herders we interviewed in the previous 4 years to qualitatively demonstrate that livestock losses to predation were relatively constant and changes in rate of predation is more likely due to the study treatment.

3 | RESULTS

3.1 | LGD placement outcomes

The reasons for dogs having unsuccessful outcome of placement were (a) inconsistent or insufficient training ($n = 14$), (b) dogs may have been successful but were removed for welfare concerns ($n = 4$), or (c) injury, illness, being lost or death prevented dogs from functioning ($n = 6$). The outcomes improved as the program gained experience and implemented defined protocol for herder selection, increased cooperation with local groups, and established repeatable methods (Table 1). In 2015, more

than half of the dogs placed (9 out of 17) were unsuccessful due to inadequate training by herders as determined by observation of applied training protocol (e.g., feeding the dogs near the domicile), and no dogs were determined to be entirely successful. In the following 3 years (2016–2018), only 9 out of 42 dogs were unsuccessful due to inadequate training ($n = 5$) and welfare issues ($n = 4$).

Herders were asked which predators preyed on their livestock most frequently, which the majority citing wolves as the most common threat (Figure 2).

3.2 | Impact of LGDs on livestock losses

Fourteen out of 16 herders reported an absolute reduction in livestock losses. One herder experienced no change in their annual losses and another had zero annual losses prior to receiving a LGD, so no reduction was possible. Herders experienced rates of annual loss as follows: One herder started the program with zero annual losses, four herders had 1–5 losses, one herder 6–10, three herders 11–15, two herder had 16–20, four herders had 21–25, and one herder experienced 46–50 livestock losses annually. Of all the herders that reported livestock losses to predators prior to receiving LGDs ($n = 15$), 11 saw no losses due to predation 1 year after LGD placement. An additional three herders saw no losses after 2 years. A Wilcoxon signed-rank test suggested that herders experienced significantly lower annual livestock
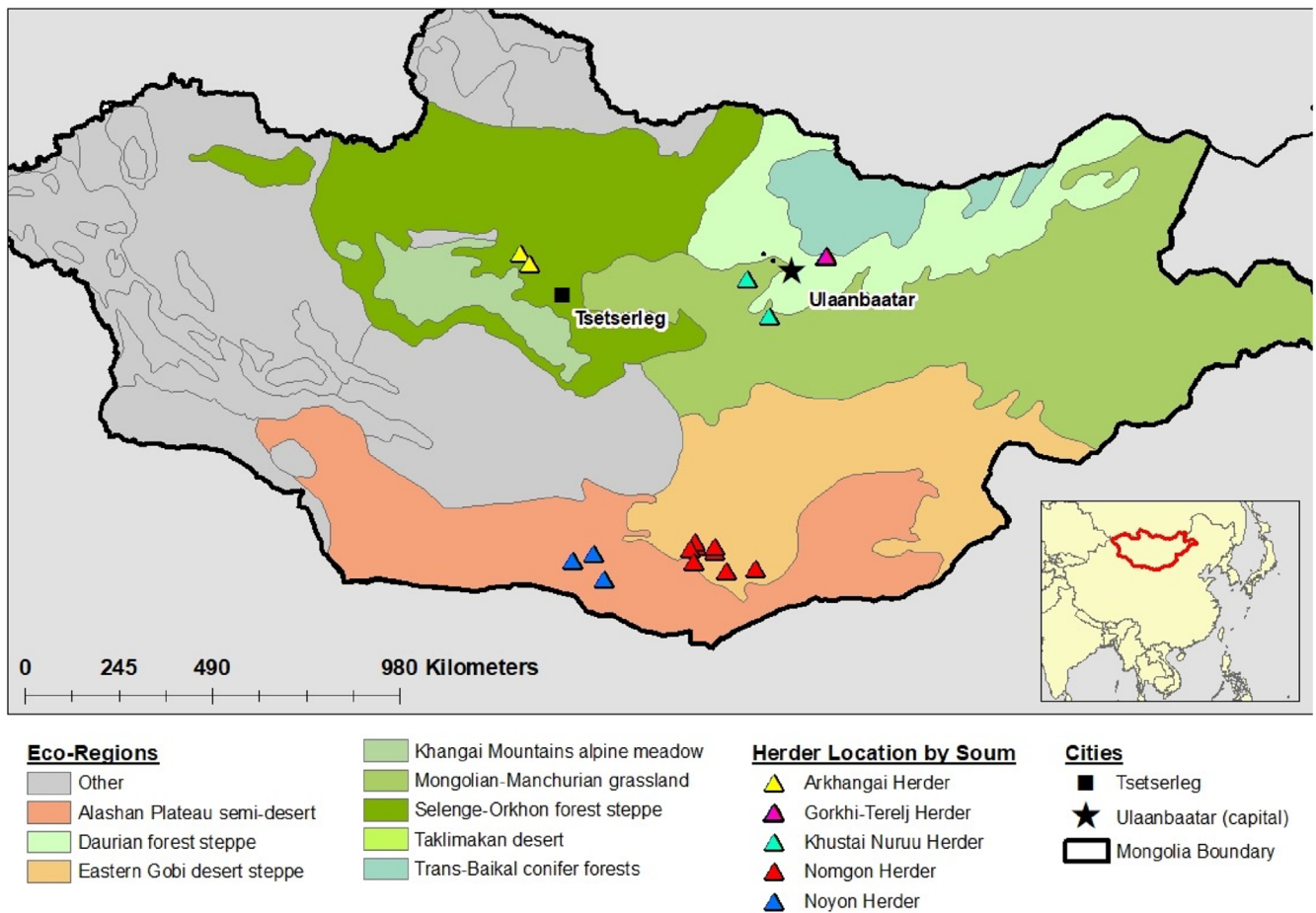
FIGURE 1 A map of Mongolia with relevant eco-regions as defined by World Wildlife Fund (Olson et al., 2001). Herder locations during one of their follow-up interviews are color coded to indicate their affiliated soum center or area with which they are associated
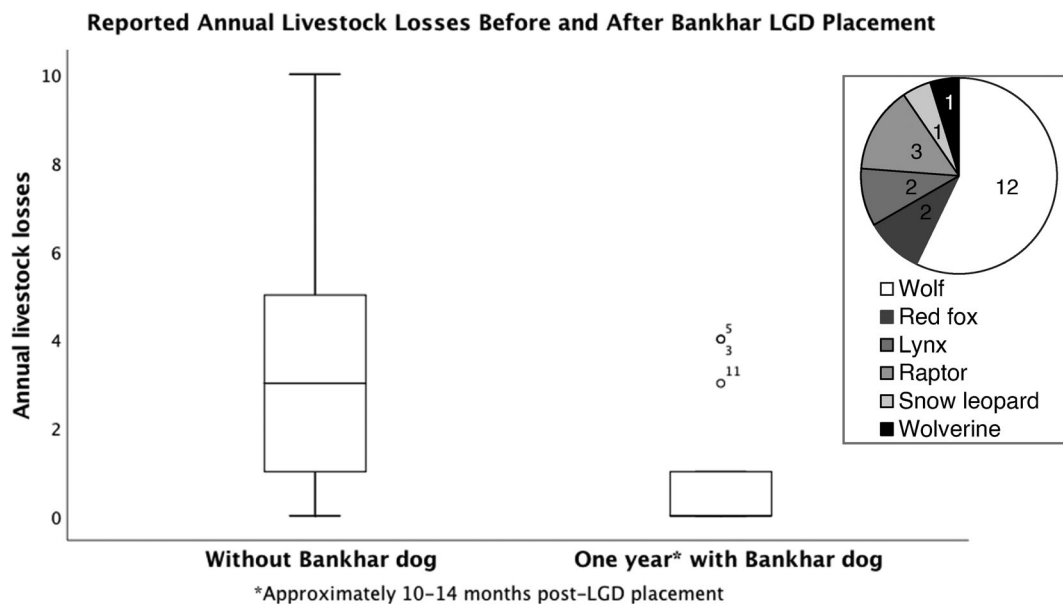

FIGURE 2 Box plot of herders' reported annual livestock losses due to predation before and after using livestock guardian dogs at a predation prevention method with a significant difference based on the Wilcoxon signed-rank test ($Z = -3.329$, $p = .001$, $n = 16$) (Inset: frequency that herders cite predatory species when asked which species preys on their livestock)

losses to predators 1 year after receiving their Bankhar dogs ($Z = -3.329$, $p = .001$, $n = 16$) (Figure 2).

We compared the losses reported in initial interviews of herders ($n = 40$) before they received Bankhar dogs in 2017, 2018, 2019, and 2020 to determine a baseline of losses. Average annual losses fluctuated from 13 in 2017, 15 in 2019, 14 in 2019, and 13 in 2020 among herders interviewed for participation in the program.

3.3 | Impact of LGD ownership on herders

All herders that participated in follow-up questionnaires after dog placement reported that the provided protocol was reasonable and they were able to follow the guidelines. Of the 16 herders included in this analysis, 9 out of 10 reported that they split their herds seasonally and 4 of the remaining 6 herders (who were not asked if they split herds) were observed to do so.

Three herders of the eight that were asked about their time budget after receiving dogs reported that they had to spend "a bit less" time guarding their herd after receiving and training their LGDs. Four herders of those asked this question reported that they had a greater reduction ("a lot less time") in the amount of time they needed to spend guarding their herd. More subjects and more detailed questions with specific time budget alterations are needed to clarify this finding.

When asked about the annual cost of keeping a dog, seven herders (43.8%) expressed that they thought it was a negligible, and some even laughed considering dogs a natural part of countryside life which has no cost. Three herders (18.8%) responded in the range of 30,000MNT and 300,000 Mongolian Tughrik (MNT, equivalent to 11.27–112.72 USD) while also commenting that the cost was reasonable if it meant protecting their herd. When the MBDP team mentioned the cost to vaccinate their dogs for rabies annually (20,000MNT or 7.51 USD), every herder agreed it constituted a manageable cost.

4 | DISCUSSION

Our analysis suggests that Bankhar dogs, when used as livestock guardians in Mongolia, can effectively decrease predation on livestock from wolves and other predators after 1 year of placement. These findings are consistent with assessments of LGDs elsewhere (Andelt & Hopper, 2000; Gehring et al., 2006), corroborating those results and extending the potential for this non-lethal predation mitigation strategy to Mongolian herding communities and regions with similar herding practices.

Further, this adds a highly cold-adapted type of LGD to the repertoire of available guardian breeds previously unknown to literature (Kinka & Young, 2018). We have extended Gehring, VerCauteren, and Landry (2010) call for "the need for effective, nonlethal, producer-based tools to allow producers to manage these conflicts themselves" beyond the more commonly studied North America and Europe and into Central Asia—a region in need of revived of non-lethal predation prevention methods.

Effective and non-lethal livestock predation prevention would be a useful tool to the cashmere industry, both safeguarding herders from economic risk, and improving the deep environmental footprint for the textile industry. Thus, Bankhar dogs could be a key tool in the development of more sustainable systems of cashmere production.

4.1 | Bankhar as LGDs in wolf habitat

This is the first contemporary scientific study of Bankhar dogs used as LGDs known to the authors in English or Mongolian. Complementing the body of evidence that LGDs can effectively reduce predation on livestock by wolves, this study also adds Bankhar to these types of LGD. While other predatory species were also cited by herders, every herder cited wolves as their primary or secondary predatory species of concern (Figure 2). Even as subsequent yearly rounds of initial evaluation interviews suggested a continued robust presence of wolf populations in the study areas, herders with successfully trained Bankhar dogs saw significant reductions in their livestock losses due to predation contemporarily. This corroborates other studies that suggest that LGDs can be used to reduce livestock losses in wolf-inhabited landscapes, and updates current knowledge of Bankhar dogs and their capacity for protecting livestock (Espuno et al., 2004; Kinka & Young, 2018). This study also expands upon the evidence supporting LGD methods to include Mongolia, a country where herding is a major cultural and economic pillar, which has been largely overlooked for LGD studies thus far.

4.2 | Herd splitting and LGDs

The vast majority of the sample group participated in herd splitting (which was consistent with our observations of the practices of the wider herding communities) and still exhibited an overall reduction in livestock losses, suggesting that LGD can operate effectively in herd splitting systems. This elaborates our understanding of the application of LGDs for different herding styles and

suggests that there is potential for this method in herd splitting systems.

4.3 | LGDs' impact on time budget and expense

Herders' responses regarding alterations in time budget suggest that the use of LGDs can reduce the strain on a family to maintain constant vigilance over a herd; this frees up family members to pursue other work, or for young people to attend school in village centers. This aspect of the questionnaire was not implemented continuously from the beginning of the study, however, and deserves more focus in future studies. The potential for LGDs to assuage the opportunity cost herders incur when they need to spend much of their time guarding their herd warrants further study (Barua et al., 2013).

This study briefly touches on the perceived expense of LGDs as a predation mitigation strategy. The fact that most herders have owned dogs previously, are familiar with caring for them, and think the cost of caring for a dog is either insignificant or manageable, indicates that the implementation of this method is not seen as a burden by the herders. However, it should be noted that the main cost of providing the dogs, breeding and rearing them from birth, was absorbed by MBDP.

4.4 | Further work

This study revealed some context for the impact of LGD on non-target wildlife. Herders reported infrequent incidents of their LGDs chasing or killing wildlife species, and reported incidents were typically not repeated over subsequent follow-ups. Because the structure of the interview questions about such occurrences are not specific enough to understand the extent of these behaviors, this study cannot sufficiently assess the risk LGDs pose to non-target wildlife species and further study is required.

4.5 | Limitations

The data for this study were collected over 4 years by a non-profit project in its early stages of development. At certain stages in the project, questionnaires were altered and updated as the project team improved their interviewing method and as new lines of inquiry developed.

We were unable to obtain a quantitative counterfactual of livestock predation losses for those herders in the relevant regions who did not have LGDs placed. However, though robust wildlife surveys are unavailable for

the predator species in the study areas, herders continued to report the presence of predators throughout the study period both anecdotally and during formal evaluation interviews over progressive years (as is reflected in our reported baseline). A sharp reduction in the presence of such predators would likely have been reported by households as part of survey responses, and therefore it is reasonable to suggest that the reduction in livestock losses is more likely due to the placement of LGDs than a reduction in the threat of predation overall.

Additionally, the dataset used here is limited to only include herders for which follow-up questionnaires could be collected. Some herders who dropped out of the program (and constitute a group of potentially less successful applications of this method) could not be included because the data collection team lost access to these individuals for further questionnaires. Therefore, this study does not suggest that providing LGDs is always successful, but that when a dog is trained successfully and develops into a guardian, its ability to reduce predation on livestock is significant in a Mongolian herding setting.

Going forward, with sufficient support—here, and in many other parts of the world—LGDs could be an incredibly important ally in reducing human–wildlife conflict, while contributing towards the wellbeing of those at the very front line of global nature conservation efforts.

CONFLICT OF INTEREST
The authors acknowledge that there are no known conflicts of interest.

AUTHOR CONTRIBUTIONS
Zoë Lieb and Bruce Elfström conceived and designed the analysis; Zoë Lieb and Batbaatar Tumurbaatar collected the data; Zoë Lieb, Batbaatar Tumurbaatar, and Joe Bull performed analyses; Zoë Lieb, Batbaatar Tumurbaatar, Bruce Elfström, and Joe Bull wrote the paper.

DATA AVAILABILITY STATEMENT
Anonymized data can be made available by request from the corresponding author.

ETHICS STATEMENT
Consent to participate was secured from all individuals interviewed at the time of data collection (interviews performed between 2015 and 2019). Full ethical approval for

eventual publication of the study findings was obtained in 2019 from the University of Kent, prior to conducting the analyses. This manuscript describes original work, has not been published, and is not under consideration for publication elsewhere.

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