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RESEARCH ARTICLE

Studded leather collars are very effective in protecting cattle from leopard (*Panthera pardus*) attacks

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Abstract

1. Human-wildlife conflicts are widespread, particularly with big cats which can kill domestic livestock and create a counteraction between conservation and local livelihoods, especially near protected areas. Minimisation of livestock losses caused by big cats and other predators is essential to mitigate conflicts and promote socially acceptable conservation. As big cats usually kill by throat bites, protective collars represent a potentially effective non-lethal intervention to prevent livestock depredation, yet the application and effectiveness estimation of these tools are very limited.
2. In this study, for the first time we measured the effectiveness of studded leather collars in protecting cattle from leopard (*Panthera pardus*) attacks. We conducted a randomised controlled experiment during 14 months to collar 202 heads and leave uncollared 258 heads grazing in forests and belonging to 27 owners from eight villages near three protected areas in Mazandaran Province, northern Iran.
3. Our results show that none of collared cattle and nine uncollared cattle were lost to leopard depredation, meaning that collars caused a zero relative risk of damage and a perfect 100% damage reduction. Most losses occurred in summer and autumn due to lush vegetation attracting more cattle, long daytime allowing movements deep into leopard habitats and dense cover favouring leopard hunts from ambush. Losses were recorded in only six owners and four villages, suggesting local rarity and patchy distribution of leopards.
4. We suggest that collars can be successfully applied to cattle freely grazing in habitats of leopards or other felids for a long time and thus remaining persistently exposed to depredation. As grazing cattle are usually not supervised by shepherds or dogs, collars can be the only practical protection tool. Production and sales of collars can become a sustainable small-scale business for farmers to further boost conservation and rural livelihoods.

KEYWORDS

carnivore, efficacy, evidence-based conservation, human–wildlife conflict, livestock depredation, non-lethal intervention, predator

1 | INTRODUCTION

Human–wildlife conflicts represent a globally widespread challenge for biodiversity conservation and socio-economic development, especially in rural and suburban areas (Thirgood, Woodroffe, & Rabinowitz, 2005). In most cases, such conflicts arise from financial, social and psychological losses associated with depredation on domestic or game animals, damage to crops or recreational areas, nuisance behaviour, wildlife collisions with human-made objects such as vehicles or windmills, or attacks on people (VerCauteren, Dolbeer, & Gese, 2012). Conflicts also can ensue from fear or traditional hostility to wildlife species even when losses are minimal and further exacerbate when losses increase (Pooley et al., 2017). Therefore, minimisation of wildlife-caused losses is essential to alleviate human–wildlife conflicts, improve local attitudes to wildlife and promote conservation in balance with socio-economic development.

Big cats, including the lion (*Panthera leo*), tiger (*P. tigris*), jaguar (*P. onca*), leopard (*P. pardus*), snow leopard (*P. uncia*), puma (*Puma concolor*) and cheetah (*Acinonyx jubatus*), are among the main drivers of such conflicts as they may kill livestock or ranched game species and, in rare occasions, cause human fatalities or serious injuries (Khorozyan, Ghoddousi, Soofi, & Waltert, 2015a; Krafte Holland, Larson, & Powell, 2018). These conflicts are expected to increase with the global rise of the human population, livestock numbers and an overlap of grazing grounds with natural habitats (Cardillo et al., 2004; Di Minin et al., 2016; Robinson et al., 2014). Although big cats tend to kill only an insignificant portion of total living livestock, depredation losses can be substantial for small-scale livestock owners who are poor and usually deprived of alternative sources of income (Dickman, 2010; Wang & Macdonald, 2006). Retaliatory or preventive killing of big cats is common, but usually illegal as five out of seven big cats are globally threatened with extinction and officially protected, with regional populations and subspecies being much more imperilled (IUCN, 2019). As protected areas serve the main strongholds for big cats, rural communities living around or inside them are most vulnerable to depredation losses, which create a deep-seated conflict between conservation and local livelihoods (Ugarte, Moreira-Arce, & Simonetti, 2019). This is a serious challenge for conservation as protected areas are usually small, insufficient for wide-ranging big cats and have limited capacities for expansion (Di Minin et al., 2016).

The time is running out fast for predators, hence radical innovations leading to novel hands-on experience and high risk–high gain solutions are required to make tangible changes in evidence-based conservation (Hazzah, Chandra, & Dolhenry, 2019). Livestock protection interventions are required to curb depredation and promote predator conservation, but only if wild prey is sufficient and predators are not expected to reduce or disappear when the access to livestock is limited by its protection (Breitenmoser et al., 2005). Comparative studies of anti-predator intervention effectiveness are most useful to extract the best and most effective interventions for their application in practice (Khorozyan & Waltert, 2019a; van Eeden et al., 2018), with the priority being given to long-lasting interventions, which reduce the ability of predators to become habituated (Khorozyan & Waltert, 2019b). Importantly, proper estimation of effectiveness needs a methodological standardisation through the randomised assignment of control or counterfactual (without intervention) and treatment (with intervention) samples (Treves, Krofel, Ohrens, & van Eeden, 2019; van Eeden et al., 2018).

One of potentially effective non-lethal interventions to protect livestock from big cat attacks is the protective collar, which provides a physical barrier and prevents the animal's death (Khorozyan & Waltert, 2019a). Big cats are well known to kill their prey by a throat bite that blocks the windpipe and causes suffocation (Kitchener, Van Valkenburgh, & Yamaguchi, 2010). As livestock grazing practices can be spatially and seasonally variable, often bringing livestock inside predator habitats and predisposing them to depredation, it seems logical to fit livestock with protective collars against predator attacks. Protective spiked collars have been used since the medieval times for shepherd dogs against wolf (*Canis lupus*) attacks (Gräslund, 2004), but they can be ineffective as wolves usually attack from the rear and flanks (Fedderwitz, 2010). Spiked collars are also practiced to prevent the entanglement of African wild dogs (*Lycaon pictus*) in wire neck snares (Jenkins, Silva-Opps, Opps, & Perrin, 2015; Leigh, 2005). Very few studies are published about the use and effectiveness of protective collars to reduce livestock depredation by big cats and co-existing predators. Epoxy-coated metal mesh collars were very effective in protecting domestic sheep from leopards and caracals (*Caracal caracal*) and less so from black-backed jackals (*Canis mesomelas*), which are able to habituate by attacking the animal hindquarters (du Plessis et al., 2018; McManus, Dickman, Gaynor, Smuts, & Macdonald, 2015; Smuts, 2008). Leather collars with or without repellents failed to protect domestic sheep from the Eurasian lynx (*Lynx lynx*) and coyotes (*Canis latrans*) (Angst, Hagen, & Breitenmoser, 2002; Burns & Mason, 1996; du Plessis et al., 2018). Plastic collars were very effective against black-backed jackals, but not against leopards and caracals in South Africa (Smuts, 2008; Snow, 2008). Therefore, collar reinforcement with metal parts is essential to successfully protect livestock from felids, which have shorter jaws and a stronger bite than canids (Kitchener et al., 2010) and can kill an animal by puncturing a leather or plastic collar (du Plessis et al., 2018; Smuts, 2008). The application of protective collars with poison capsules is now very restricted due to environmental hazards such as scavenger poisoning (Snow, 2008; VerCauteren et al., 2012). Although not protective per se, bell collars are also able to protect livestock by warding off predators (Smuts, 2008; Snow, 2008) but their effectiveness is low as predators habituate quickly and can even be attracted by associating bell sounds with prey (Knarrum et al., 2006; Loveridge et al., 2017).

In this paper, we describe the first-ever application of studded leather collars to protect livestock from big cats on an example of freely grazing cattle, which are often killed by leopards in deep forests of northern Iran. We performed a random controlled experiment and estimated the effectiveness of studded leather collars in reducing cattle losses to leopard attacks. Finally, we suggest using these collars as a practical, effective, user-friendly and locally affordable tool to curb cattle losses to leopards and other big cats, particularly near protected areas.

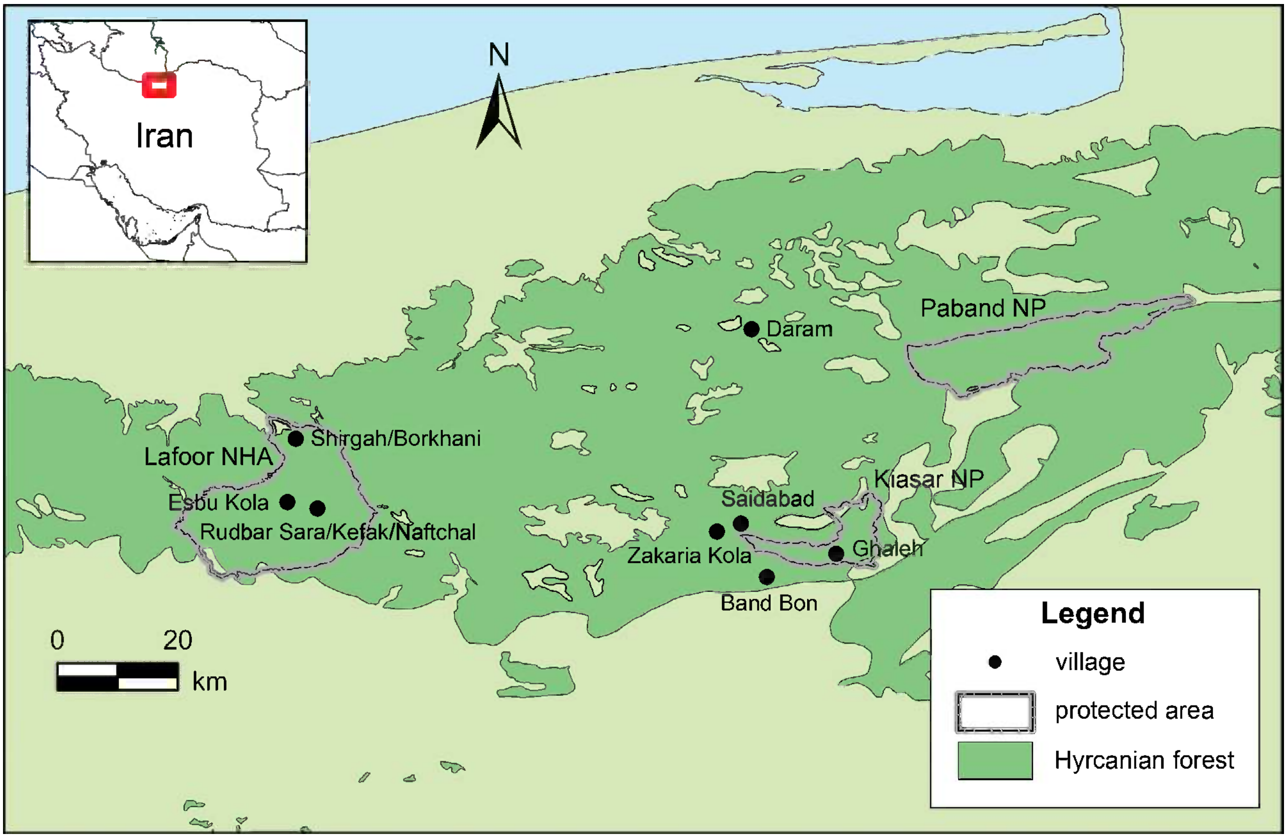

FIGURE 1 Location of villages where cattle were collared in this study. Abbreviations: NHA, no-hunting area; NP, national park

2 | MATERIALS AND METHODS

2.1 | Study area

We carried out this study in Mazandaran Province of northern Iran (Figure 1), which represents the core range of the leopard in the country and the Middle East in general (Ebrahimi, Farashi, & Rashki, 2017; Parchizadeh & Adibi, 2019). Our study area (1,644.9 km^2) was located in the Hyrcanian or Caspian forest, a Tertiary relict primeval deciduous temperate forest which is nominated as a UNESCO World Heritage Site and makes part of the Caucasus-Anatolian-Hyrcanian temperate forest ecoregion and the Caucasus biodiversity hotspot (Marchese, 2015; Olson & Dinerstein, 2002; Sagheb-Talebi, Sajedi, & Pourhashemi, 2014). The Hyrcanian forest extends over the northern slopes of the Alborz Ridge in Iran and the Talysh Ridge in Azerbaijan along the southern coastline of the Caspian Sea. In Iran, it covers the provinces of Golestan, Mazandaran and Gilan (Sagheb-Talebi et al., 2014).

The leopard in Iran and adjoining countries is represented by the globally endangered Persian leopard (*P.p. tulliana* = *P.p. ciscaucasica* = *P.p. saxicolor*). Iran retains the largest population of this subspecies (550–850 individuals) and covers over 75% of its global range, mostly within the Alborz Ridge (including the Hyrcanian forest) and the Zagros Ridge (Parchizadeh & Adibi, 2019). Leopard densities in our study area and other parts of the Hyrcanian forest are unknown, but they are expected to be low due to large-scale prey decline, habitat loss and poaching (Soofi et al., 2018, 2019). The main prey of leopards in this habitat are the bezoar goat (*Capra aegagrus*), wild boar (*Sus scrofa*), roe deer (*Capreolus capreolus*) and red deer (*Cervus elaphus*), but only wild boar not being hunted by local Muslim population can be considered as common and widespread (Ghoddousi et al., 2017). Therefore, insufficiency of prey resources can cause livestock depredation and human–leopard conflicts in this key area (Soofi et al., 2019).

Despite its unique biodiversity, the Hyrcanian forest is insufficiently protected and its environmental degradation is widespread (Soofi et al., 2018, 2019). The forest has been overgrazed by livestock, primarily cattle of Mazandarani breed, which are kept for milk, dairy products, beef and breeding. Stud cattle and cows with calves are usually kept in village sheds, but most cattle graze freely in forest without attendance by shepherds or dogs (Babrgir, Farhadinia, & Moqanaki, 2017; Khorozyan et al., 2017; Noack, Manthey, Ruitenbeek, & Mohadjer, 2010). Cattle numbers are heavily biased towards cows, and bulls are very few (0–2 per owner, rarely more; pers. observ.). Occasionally, cows with calves are also left grazing in forest. Grazing in forest is common during the warm season lasting usually from March–April to October–November and also during warm winters. Most owners drive their cattle to sheds in the evening and release for free grazing in the next morning, but some others let their cattle stay overnight in forest (Khorozyan, Ghoddousi, Soufi, Soofi, & Waltert, 2018).

Cattle spend most of their time in forest in this region, especially during the warm season, and thus their depredation by leopard is common (Babrgir et al., 2017; Khorozyan et al., 2017, 2018; Khorozyan, Soofi, Hamidi, Ghoddousi, & Waltert, 2015b; Soofi et al., 2019). As a result, Mazandaran Province is one of the hotspots of leopard killing from retaliation (Parchizadeh & Adibi, 2019; Soofi et al., 2019). Leopards tend to attack cattle away from villages, and we are not aware of depredation cases in villages or livestock sheds.

2.2 | Study design and data collection

We randomly sampled 27 cattle owners living in villages with the highest levels of cattle depredation by leopards in Mazandaran Province (Figure 1). Twenty-one of these owners were involved in the previous study (Khorozyan et al., 2018) and six were new in order to replace owners who sold cattle, moved to other grazing grounds or were reluctant to participate. All owners were informed about their anonymity and study aims and gave their consent to participate. Most of them (n = 24) had a previous experience of cattle losses to leopards and few (n = 3) did not lose cattle before. All owners kept their cattle overnight in sheds so they could monitor and record depredation cases immediately in the evening when cattle returned from the forest. They recorded depredation only by leopards based on their direct sightings, presence signs and carcass utilisation, and they were able to successfully distinguish it from depredation by wolves, which also can be present in the study area (Khorozyan et al., 2018; Soofi et al., 2019).

We conducted our initial survey in September 2017 to record the numbers of cattle grazing in forest and the distribution of their sex (bull, cow), age (adult > 2 years, calf < 2 years) and colouration (black, black-and-white, grey, red and red-and-white) as these factors are important in cattle selectivity by leopards (Khorozyan et al., 2018). Based on this information, we estimated the numbers of collars to be used in each household. We showed the prototype Cane Corso collars (see below) to the owners and discussed their attitudes to collars and views on collar practicality so that to make intervention planning a participatory and locally accepted process (Treves, Wallace, & White, 2009).

During the second survey in October–November 2018 (n = 23 owners) and March 2019 (n = 4), owners randomly collared about half of their cattle under our supervision and each owner held a control (uncollared cattle) and a treatment (collared cattle) sample in nearly equal proportions. We also strived to keep equal proportions for each sex, age and colouration. As each owner's cattle graze in the same place, we assumed that collared and uncollared cattle of the same owner were equally available to leopards and had the same chance to be killed. Thus, we secured a random assignment of each cattle individual as either control or treatment to fulfil the requirements of the 'golden standard' in conservation effectiveness studies (Treves et al., 2019; van Eeden et al., 2018).

We ordered collars from a workshop in Tehran, which specialised in making spiked dog collars, harnesses, saddles and similar products. The collar represented a strong reddish-brown coloured leather belt marked by the alternating rows of stainless studs and spikes (Figure 2). The size of the collar was 105 cm long and 11 cm wide. Its design was borrowed from the model C91##1033 3-inch nickel spiked and studded leather Cane Corso collar used for big dogs (https://www.all-about-cane-corso-dog-breed.com). The collar had a wide body with studs and spikes and a narrow tail to fix the collar by passing it through the buckle and putting two prongs into corresponding holes (Figure 2). When put on an animal, the studded body of the collar was placed on the throat and the collar's tail with the buckle was on the nape. To prevent theft, the collar was equipped with two D-rings near the buckle and a chain near the root of the collar's tail, which were fixed by the key lock (Figure 2). During the study, many owners complained that spikes used to be easily detached when cattle browsed in dense vegetation and some owners also noted that collars were too loose on thin necks of their cattle. To solve this problem, we shortened 50 collars and replaced their spikes with studs. The price per unit was 25 Euro for an original collar and 9 Euro for collar shortening and spike replacement. Throughout the study, we successfully used both types of collars as the detachment of spikes did not affect the functioning of collars.

Beginning from the third survey in November 2018 (n = 23 owners) and April 2019 (n = 4), we conducted monthly monitoring surveys until December 2019 inclusive to visit the owners, record their losses to leopards among collared and uncollared cattle, know about problems with collars and solve them as soon as possible. We replaced collars when they were torn, lost or when owners asked for smaller collars. During winter (November–March), collars were kept on the cattle grazing in forest but removed from the cattle wintering in sheds or grazing inside the village because here they were safe from leopard attacks. Every case of cattle loss, no matter if it was collared or not, was thoroughly investigated by the owner and reported to Department of Environment in case it was found to be associated with the signs of a leopard kill.

2.3 | Data analysis

We recorded cattle losses, including leopard kills, among collared and uncollared individuals in relation to owners, villages and seasons. We measured the shortest straight distances between village centres and boundaries of protected areas (km) and calculated their correlation with the numbers of cattle killed by leopards using the Spearman correlation coefficient (ρ). We applied the Mann–Whitney test to compare control and treatment samples and used the standard error (SE) as a measure of variation throughout the text. We measured the effectiveness of collaring as the relative risk of damage (RR; Khorozyan & Waltert, 2019a, 2019b):

$$RR = \frac{A/N_t}{B/N_c}, \quad (1)$$

where A is the number of collared cattle killed by leopards, B is the number of uncollared cattle killed by leopards, N_t is the total number of collared cattle (treatment sample size) and N_c is the total number of uncollared cattle (control sample size). So, RR represents a ratio of the probability of damage risk with the intervention to the probability

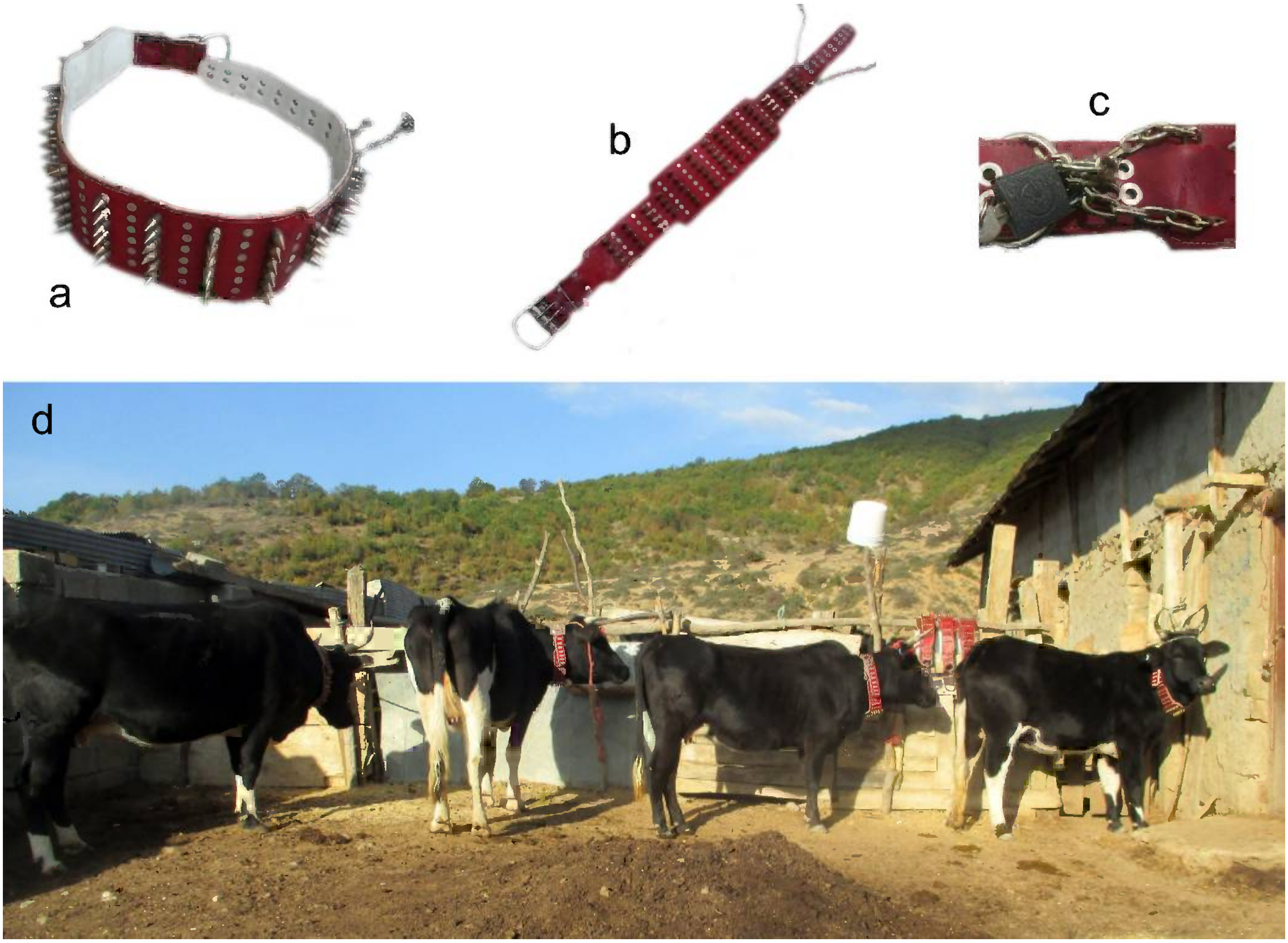

FIGURE 2 Protective collar designed for cattle protection in this study: general appearance (a, b), chain lock (c) and collared cattle before being released into the forest (d). Photos: I. Khorozyan (a–c) and S. Ghoddousi (d)

of damage risk without the intervention. Interventions are counter-effective at $RR > 1$, ineffective at R close to 1, effective at $RR < 1$ and become most effective at $RR = 0$ when $A = 0$ (Khorozyan & Waltert, 2019a). We calculated RR for each owner, monitoring month, and in total in cases when cattle were killed in control samples (i.e. $B > 0$), otherwise RR was undefined. We transformed RR into the percentage of damage reduction (DR) as $DR = (1 - RR) \times 100$ (Khorozyan & Waltert, 2019a, 2019b). We used IBM SPSS 26.0 for statistical analysis.

3 | RESULTS

We conducted our experiment with 460 heads of cattle belonging to 27 owners (26 men, 1 woman) living in eight villages near Kiasar National Park, Paband National Park and Lafoor No-Hunting Area, Mazandaran Province, northern Iran (Figure 1). Out of this stock, we collared 202 heads (43.9%) as a treatment sample and left the remaining 258 heads (56.1%) uncollared as a control sample. Each owner had on average 17.0 ± 2.5 (range 3–50) heads including 7.5 ± 1.1 (range 1–23) collared and 9.6 ± 1.5 (range 1–30) uncollared individuals. The sample included 22 collared versus 46 uncollared males, 180 collared versus 212 uncollared females, 178 collared versus 235 uncollared adults, 24 collared versus 23 uncollared calves, 73 collared versus 99 uncollared black individuals, 90 collared versus 109 uncollared black-and-white individuals, 4 collared versus 3 uncollared grey individuals, 32 collared versus 45 uncollared red individuals, and 3 collared versus 2 uncollared red-and-white individuals. All collared and uncollared cattle were healthy. The distribution of total number, sex, age and colouration of cattle did not differ between treatment and control samples across the owners (Mann-Whitney U varied from 278.0 to 364.0, p value varied from 0.110 to 0.979).

We recorded 31 cases of cattle loss from November 2018 to December 2019, including 12 collared cattle and 19 uncollared ones (Table 1). None of collared cattle and nine uncollared cattle were lost to leopard depredation, meaning that $RR = 0$ and $DR = 100\%$ due to the use of collars. This pattern of perfect protection by collars was consistent across the owners and monitoring months in spite of changes in numbers of collared and uncollared cattle over time (Figure 3). The numbers of collared cattle decreased, and those of uncollared

TABLE 1 Numbers of lost individuals of collared and uncollared cattle in this study

Causes	Collared cattle	Uncollared cattle
Killed by leopards	0	9
Consumed a plastic bag	1	0
Died in flood	1	0
Fell from cliff	1	0
Lost	2	0
Sold	7	10
Total	12	19

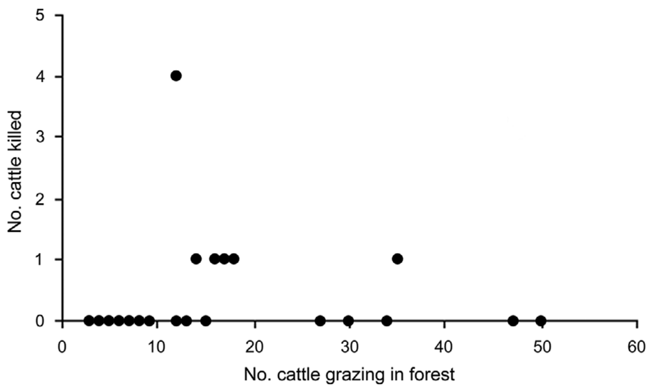

FIGURE 4 Relationship between the numbers of cattle killed by leopards and the numbers of cattle grazing in forest per owner

cattle increased, in winter time (November–March) when many cattle were kept grazing inside villages or stayed in sheds (see above). Also, cattle numbers changed due to additional collaring in March 2019 (56 collared and 54 uncollared individuals), mortality and sales (Table 1).

Collared individuals were sold ($n = 7$), lost in forest without traces of depredation or other causes ($n = 2$) or died from accidents ($n = 3$). Leopard kills were limited to only six cattle owners from four villages distant from each other (Saidabad, Shirgah/Borkhani, Daram and Esbu Kola; Figure 1). Of these, only one owner, from Daram, experienced the loss of four individuals (two calves and two cows) and the others incurred only one loss each. Most cattle were killed by leopards in summer (two in June and one in August) and autumn (two in October and two in November), with one more killed in spring (April) and another one in winter (December). The numbers of cattle killed by leopards were not associated with the numbers of cattle grazing in forest per owner (Figure 4) and with distances between villages and protected areas ($\rho = 0.156$, $p = 0.711$). Because of the small sample of cattle kills, we did not estimate leopard selectivity for sex, age and colouration of cattle.

4 | DISCUSSION

Our study has shown that studded leather collars put on cattle protected them very effectively and, overall, the losses of cattle to leopard depredation decreased by 100%. We suggest that this tool can be successfully applied to cattle freely grazing in habitats of leopards or other felids for a long time and thus remaining persistently exposed to depredation. As grazing cattle disperse widely and their control by shepherds or dogs is difficult (Khorozyan et al., 2017), they are usually left unsupervised during grazing and collars can be the only practical tool to protect them from predators. We did not test collars on sheep, goats and other livestock species but suppose they could work well also in these cases, when adjusting collar size appropriately. Production and sales of these collars can become a sustainable small-scale business for farmers (Smuts, 2008).

Depredation of cattle, all of which had no collars, occurred mostly during summer and autumn. These seasons are marked by lush vegetation attracting more cattle for free grazing, long daytime allowing movements deep into leopard habitats and dense cover favouring successful predation by leopards from ambush (Khorozyan et al., 2018).

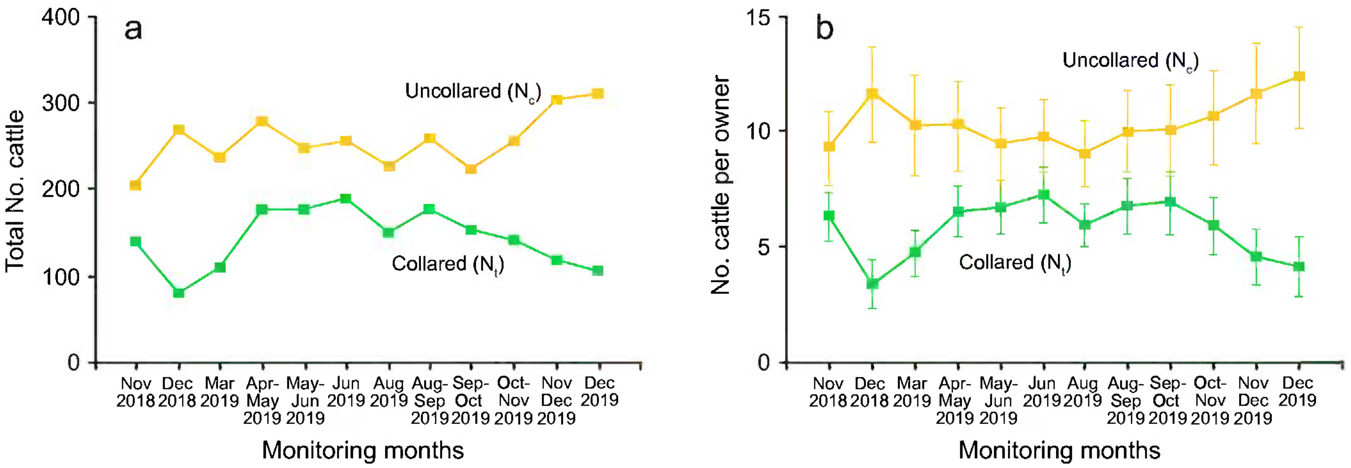

FIGURE 3 Changes in total numbers of collared and uncollared cattle (a) and in average numbers of collared and uncollared cattle per owner (b) during the monitoring. Variation of numbers in (b) is given in standard error. Abbreviations of N_t and N_c are taken from Equation (1)

So, at the large scale of the study area cattle depredation rates appear to be related to the availability and catchability of cattle, which is in agreement with other studies (Balme, Hunter, & Slotow, 2007; Ghoddousi et al., 2016). However, we did not find a relationship between depredation rates and available cattle numbers at the fine scale of households. Possibly, this is caused by large space requirements of leopards and the distribution of several grazing grounds of the households and villages within a single leopard's space use area. Leopards in Iran use areas up to 2,269 km^2 and, like elsewhere, non-resident individuals wander over much larger areas than resident conspecifics confined to their smaller home ranges (Farhadinia, Johnson, Macdonald, & Hunter, 2018). In light of this, it is plausible that leopards would kill cattle once they become available throughout a space use area, with these kills being random in relation to individual households. This is also supported by the fact that cattle were killed across different households and only one owner experienced repeated losses to leopard attacks. All this indicates local rarity and patchy distribution of leopards (Soofi et al., 2018) and the spatial confinement of their space use areas to certain villages and grazing grounds. Lack of correlation between distances to protected areas and the numbers of cattle killed by leopards could be linked to the spatial fragmentation described above and also indicate a small size of protected areas for local leopards (Figure 1).

Scientific information about the effectiveness of protective collars against predators is limited, particularly for felids. The analysis of data from McManus et al. (2015) demonstrates a 68% decrease in sheep depredation by caracals, leopards and black-backed jackals in South African farms due to the use of epoxy-coated metal mesh collars in comparison with lethal control. In this study, data were lumped for all three species so it was impossible to determine the effectiveness against each of them. The effectiveness of leather collars in protecting sheep from Eurasian lynx in Switzerland could not be calculated because of no kills in control samples, but collared sheep comprised over half of all lynx kills and it was concluded that these collars were ineffective (Angst et al., 2002). Using original data for effectiveness calculations, we found that bell collars increased sheep losses to brown bears (*Ursus arctos*) in Norway by 2.5 times (Knarrum et al., 2006) and cattle losses to lions in Zimbabwe by two times (Loveridge et al., 2017) instead of reducing them because predators learned to associate the sound of bells with available prey.

Previously, we already borrowed the South African experience with metal mesh collars (McManus et al., 2015; Smuts, 2008) and applied them to cattle, sheep and goats in villages near Golestan National Park, Iran, to the east of our current study area. However, that study was unsuccessful as collars caused skin irritation and cattle could not properly feed and lick their calves, what led to decrease in cattle productivity. In sheep, these collars could be applied only during the periods of fully grown fleece but not in summer when sheep were sheared. For these reasons, we immediately stopped collaring. Following this experience, it became evident that collars may work because their application is convenient for livestock owners and local attitudes to collars are generally positive, but these collars must essentially be flexible and soft. The development and application of studded leather collars was a result of this rethink.

The application of collars in the present study had only minor problems, all of which were correctable. Many cattle owners said that spikes could be detached from collars when cattle browsed in dense vegetation, and some others informed us that collars were too long for their cattle, which often have thin necks. We produced a new batch of shorter collars with studs only, and the problem was generally solved. A few owners expressed fears that collars could make their cattle entangled in branches and die, but we dissuaded them from non-use through informal discussions and demonstrations on available animals. We also heard that collars could be wider to cover a larger area of the throat, but we did not make changes as they could limit neck movements and cause the same problems as with metal collars mentioned above. We found that a few collared cattle died from man-made and natural accidents, but uncollared cattle did not (Table 1). We are confident that this is a small sample bias and not a sign of the predisposal of collared cattle to potentially deadly actions as our surveys showed no effects of collars on animal behaviour. Therefore, a key requirement for successful application of collars is having a local team of specialists who could monitor the situation regularly, keep close contacts with locals and support them and react fast for troubleshooting.

We also did our best to make collars harmless for leopards. The spikes used in collars were only 1-cm long, and the studs did not protrude over the surface. Producers of our collars and South African farmers and conservationists with whom we cooperated (J. McManus, pers. comm.) informed us of no complaints about the damage to dogs, leopards or other predators that collars might inflict.

We conclude that studded leather collars were very effective in reducing cattle losses to leopard attacks and suggest them as a practical tool to alleviate human conflicts with leopards and possibly other felids over livestock depredation. Testing of collars for their effectiveness in different localities and livestock species against felids should be practiced and published in the scientific literature even if results are negative, contradictory or inconclusive. Production and sale of collars can become a small-scale local business for farmers, but their use requires appropriate size adjustments and careful monitoring.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

IK, MahS and MW conceived the ideas and designed methodology; SG, MS, IK and MahS collected the data; IK and MW led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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PEER REVIEW

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DATA AVAILABILITY STATEMENT

Data available from the Dryad Digital Repository https://doi.org/10.5061/dryad.h9w0vt4ft (Khorozyan, Ghoddousi, Soufi, Soofi, & Waltert, 2020).

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