Livestock depredation by large carnivores in the South Gobi, Mongolia

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Abstract

    Context. Livestock depredation is a major conservation challenge around the world, causing considerable economical losses to pastoral communities and often result in retaliatory killing. In Mongolia, livestock depredation rates are thought to be increasing due to changes in pastoral practices and the transformation of wild habitats into pasture lands. Few studies have examined the interactions between humans and carnivores and even fewer have considered how recent changes in pastoral practices may affect depredation rates.

    Aim. This study aimed to assess the influence of herding practices on self-reported livestock losses to snow leopards and wolves in two communities in South Gobi, Mongolia.

    Methods. In total, 144 herder households were interviewed and an information-theoretic approach was used to analyse the factors influencing self-reported livestock losses to snow leopards and wolves.

    Key results. The majority of self-reported losses to both snow leopards and wolves occurred when herds were left unattended in the pastures. The economic loss associated with livestock losses to snow leopards and wolves amounted to an average loss of US$825 per herder and year. The number of livestock owned by a household and the frequency of shifting campsite had the strongest influence on livestock losses to snow leopards and wolves. Other determinants of livestock losses included frequency of visiting the soum (county) centre.

    Implications. On the basis of the findings, we make recommendations for mitigating the conflict with large carnivores, with focus on guiding future herding practices.

Introduction

As the human population increases, large areas of the world's wildlife habitats are being encroached upon for human use, dramatically shrinking the habitat that wildlife species require to survive and thrive (Woodroffe *et al*. 2005). Large carnivores are at particular risk because they require large spaces and kill wild and domestic animals which, in turn, raises many conservation challenges (Chapron *et al*. 2014). In many settings, these carnivores do not depend solely on wild prey, and are increasingly associated with livestock depredation, causing considerable economic losses to pastoral communities (Mearns 1996; Ogada *et al*. 2003; Moller *et al*. 2004). Livestock depredation can also generate negative attitudes towards wildlife conservation (Mishra *et al*. 2003; Bagchi and Mishra 2006), and retaliatory killing of carnivores in response to livestock depredation is identified as a major threat to

carnivore species worldwide (Treves and Karanth 2003; Mishra *et al*. 2003). Addressing these human–carnivore interactions is thus essential for effective conservation of these species (Kolowski and Holekamp 2006).

    Across large areas of the high mountains of central Asia, herders share habitat with snow leopards and wolves (McCarthy and Chapron 2003; Clark *et al*. 2006; Aryal *et al*. 2013). In countries such as Mongolia there is little reliable information available on their population numbers and rates of livestock depredation (van Duyne *et al*. 2009). However, there are indications that livestock depredation and retaliatory killing of carnivores is a major threat to the carnivores as well as the herder economy (Hovens *et al*. 2000).

    Livestock is important to Mongolia's rural economy, with over half of the country's human population depend upon livestock production for food and revenue (particularly from

cashmere). The country holds over 55 million horses, cattle, sheep, goats and camels (National Statistics Organization 2014), and more than one-third of the country is used as grazing land (Kerven 2006). In terms of the national economy, livestock herding continues to play an important role, with this sector accounting for over 40% of the GDP (Fratkin and Mearns 2003). However, economic development and urbanisation (Harris 2010), as well as globalisation and climate change, are leading to major shifts in livestock-rearing practices (Chuluun *et al*. 2017). Incorporating different herding practices and examining how they affect livestock losses are therefore important measures to mitigate economic losses for the communities. Furthermore, these measures need to consider how rapid the shifts in rearing practices occur and how that influences livestock losses to predators.

This study aimed to assess the influence of herding practices on self-reported livestock losses to snow leopards and wolves in South Gobi, Mongolia. We describe patterns of livestock mortality, including depredation attributed to carnivores, and consider how self-reported livestock losses vary according to different livestock herding practices. On the basis of the findings, we make recommendations for mitigating conflict with large carnivores, with a focus on guiding future shifts in herding practices.

Materials and methods

Study area

This study was conducted in the Tost and Bayasah areas in the Gurvantes soum (county) in the South Gobi province in southern Mongolia (Fig. 1). The landscape is part of the south-eastern Altai landscape and is mountainous, with elevations ranging from 1450 to 2550 m. The Tost and Bayasah areas are known

to support a carnivore assemblage that includes snow leopards (*Panthera unica*), Eurasian lynx (*Lynx lynx*), grey wolves (*Canis lupus*) and red foxes (*Vulpes vulpes*), as well as wild ungulates in the area that include ibex (*Capra sibirica*) and argali (*Ovis ammon*). Local statistical information from 2010 indicates that the Tost area held 24 964 goats and 1770 sheep, along with 1031 camels, 315 horses and 47 cattle, and that the Bayasah area held 24 894 goats, 1467 sheep, 1097 camels, 542 horses and 73 cattle (see results for livestock holding per household). Goats and sheep are herded during the days and brought back to herder camps at night, whereas horses and camels are free-ranging.

Tost was designated as a local protected area in 2010 and as a National State Nature Reserve in 2016. Research in Tost has been ongoing since 2006, focusing on snow leopard population dynamics using camera trapping (Sharma *et al*. 2014), space use based on GPS technology (Johansson *et al*. 2015), snow leopard diet analysis (Shehzad *et al*. 2012; Johansson *et al*. 2015) and snow leopard prey assessments (Tumursukh *et al*. 2016). Conservation activities in Tost include a livestock insurance program and a handicraft program operated by the Snow Leopard Conservation Foundation and the Snow Leopard Trust (Mishra *et al*. 2003). These programs aim to compensate for livestock losses and provide alternative income, as well as improve herders' tolerance towards both snow leopards and wolves. Bayasah, located 120 km east of Tost, has not had any conservation programs or conservation activities to date.

Data collection

A questionnaire-based survey was carried out within the two targeted communities, Tost and Bayasah, to assess changes in pastoral practices, attitudes towards carnivores and self-reported livestock depredation over the last year (January to December
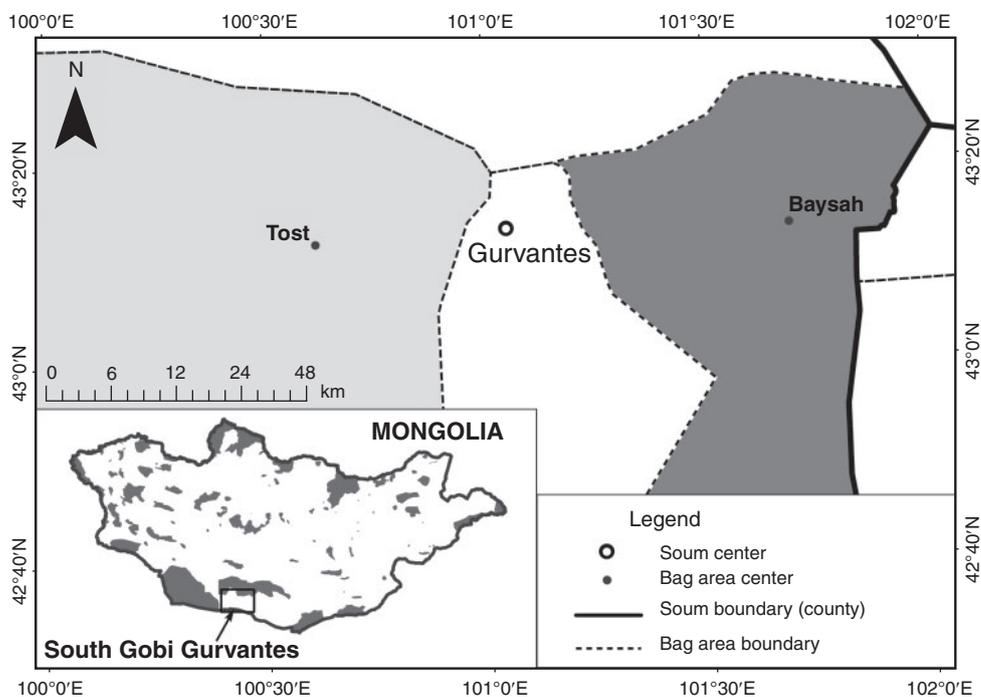

Fig. 1. Interviewed household locations in Tost and Bayasah of the South Gobi Mongolia (*n*=144).

2010, Appendix 1). Four key informant interviews were also held with government officials and herders in Gurvantes soum centre to discuss recent livelihood shifts and relevant policies within the area. All interviews took place during February 2011.

We conducted interviews in a total of 144 herder households (70 in Tost and 74 in Bayasah). We aimed to interview all households present within both areas as identified by Gurvantes soum centre records. The list of names and location of all families were obtained from the soum records and we travelled to visit their households. Eight households, however, could not be located or were empty (three in Tost and five in Bayasah area respectively). Interviews were conducted with an adult member (age >18 years) who self-identified as a household herder. All interviews were conducted in Mongolian and took ~30–40 min to complete.

Before the start of the survey, the questionnaire was tested among 12 herders in a separate area and subsequently modified as necessary to ensure the respondents' comprehension of each question. The questionnaire was divided into four sections that provided information on the following aspects: (1) basic demographic and socioeconomic information of the herders interviewed; (2) current and past pastoral practices and changes that have taken place over the last 10 years, with enquiries about local and regional changes affecting herding practices, herd size and composition, frequency of movement between pastures, frequency of visits to permanent settlements and number of family members involved in herding; (3) self-reported livestock losses; and (4) herders' attitudes towards predators. Specifically, sections one and two posed questions about age, education, number of household members, current number of livestock holding, herding technique (1 = herding livestock on foot or by horse or camel, 3 = herding livestock using a motorcycle, or 2 = using both alternatives) and number of household members living in the soum centre versus rural mountain areas (1 = all family members lived together in the mountain area, 2 = some family members living together in the herding area, 3 = only one family member tending the livestock and the remaining family members having settled in the soum centre). It was assumed that fewer family members (with the exception of small children) living in the mountain areas meant fewer human resources for tending the livestock. Interviewees were asked at what frequency they visited the soum centre on average (1 = visit once over several months, 2 = 1 to 3 times a month, 3 = greater than 4 times per month). Visiting the soum centre frequently was assumed to lead to the livestock being left unattended more often and thus resulting in an increased risk of livestock depredation. Herders were also asked how frequently they shifted their campsite between pastures during the year and how long they tended to stay in a particular area (1 = move four times or more per year, 2 = move one to three times per year, 3 = do not move household site).

Section three enquired about self-reported livestock losses within the last 12 months (January 2010– December 2010), and how these losses were distributed between natural disasters (extreme drought, extreme cold, starvation due to heavy snow), disease and snow leopard and wolf depredation. Herders were also asked to list preventive measures they used to reduce livestock losses, and which method was most effective. Herders were also asked how they would respond if depredation were to increase.

Section four explored attitudes towards large carnivores. Herders were asked (1) if herders liked that snow leopard and wolves were living in the area surrounding their pastures (5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, 1 = strongly disagree) and (2) whether they believed that carnivores negatively impacted their livelihoods (5 = critical effect, 4 = major effect, 3 = moderate effect, 2 = minor effect, 1 = no effect). Finally, herders were asked how many livestock losses to snow leopards and wolves would be acceptable to them in a given year. The economic value of reported livestock losses was estimated using the livestock market value in 2010 obtained from the National Statistic Office of Mongolia.

Data analysis

We examined how self-reported livestock losses to snow leopards and wolves varied in relation to number of livestock holding, frequency of shifting campsite, herding technique, frequency of travel to the soum centre and number of household members living in the camp by using a general linear model (GLM) in R version 2.15.3 (R Development Core Team 2014). All independent variables were standardised before the analyses (Gelman 2008). We checked for co-linearity between independent variables by using Pearson Rank Correlation test and found that independent variables were largely independent ($r < 0.36$), given that variables with $r > 0.7$ are generally considered highly correlated (Dormann *et al.* 2013). We ran all combinations of the independent variables for each carnivore for a total of 30 models per species, and we ranked models based on Akaike's information criteria with small sample adjustment (AICc) and model weights (Burnham and Anderson 2002). Similarly, we calculated model weights as weighted average of parameter estimates, because no single model had an AICc weight that was greater than 0.9 (Johnson and Omland 2004). We compared responses related to attitudes towards carnivores from herders across the two areas using Mann–Whitney *U*-test.

Results

Herding practices

Among the herder respondents, 92 (63.8%) were men and 52 (36.1%) were women. Most herders (88%) tended to live alone, with children and other family members reported to be living in the soum centre. Only 12% of herders interviewed were living with other family members.

The majority of herders (71%, $n = 102$) visited the soum centre four times a month or more. Of the remainder, 21% ($n = 30$) of the herders visited the soum centre once a month and a minority of them, 8% ($n = 12$) visited the soum centre less than once a month. Herders stated that their families spent more time in the soum centre from 2008 onwards, when the Mongolian school entrance age was reduced from 8 to 6 years. One of the parents, usually the mother, stayed with the younger children in the soum centre. Among the herders, 58% reported shifting campsite twice a year, at an interval of about 6 months (i.e. one summer and one winter camp where summer is defined as April to

August and winter as October to March), and 27% were sedentary. Only 15% ($n=22$) of herders moved more than four times a year. The herders that moved more frequently stated that during the summer they needed to do so to feed livestock before the cold winter arrived. The majority of herders, 57% ($n=82$), used motorbikes to herd their livestock whereas 43% tended their livestock by foot. The average size of the livestock holding (goat, sheep, camel, horse and cattle combined) was 209.7 heads per family for Tost and 178.4 heads per family for Bayasah. Of the 70 herders interviewed in the Tost area, 11 (16%) were members of a livestock insurance program.

Livestock losses and related attitudes

Between January 2010 and December 2010, the 144 herders interviewed reported a total of 6704 livestock losses (Table 1). This corresponds to 23.9% of the total livestock holding – an average of 46.5 (s.d. = 119) livestock losses per household and year. Most losses (4778 head) were a result of the harsh winter. Herders stated that the period from November 2009 to March 2010 had been particularly harsh, with greater livestock losses than usual. Due to the winter disaster, some families reported losses of up to 300 heads.

Carnivores emerged as the second major cause of livestock losses in both areas. The wolf was the most important livestock predator, reported to be responsible for 1141 livestock losses, which corresponds to 17% of all livestock losses and 4.1% of the total livestock holding. The majority (63%, $n=91$) of herder households were affected by wolf depredation. The snow leopard was held responsible for 740 livestock losses, corresponding to 11% of all livestock losses and 2.6% of the total livestock holding. Nonetheless, a substantial proportion of all households (47%, $n=68$) was affected by predation events attributed to snow leopard.

The patterns of livestock depredation differed between the two areas, with mean annual livestock depredation losses being higher in Bayasah (15.4 ± 14.43 s.d.) than in Tost (10.4 ± 13.71 s.d.). Livestock losses to snow leopards per family and year were 6.9 ± 11.8 s.d. in Bayasah and 3.2 ± 7.5 s.d. in Tost. Livestock losses to wolves per family and year were 8.5 ± 10.8 s.d. in Bayasah and 7.3 ± 10.5 s.d. in Tost. Depredation of camels by wolves, in contrast, was greater in Tost than in Bayasah, with a total of 45 and 5 camels lost in each area, respectively. The total annual losses to snow leopards per family for both areas combined was 5.1 ± 9.8 s.d., and total annual livestock losses to wolves for both areas combined was 7.9 ± 10.7 s.d.

Across both areas, most of the wolf depredation occurred while herders left their livestock unattended in the pasture overnight (53.4%, $n=609$), followed by leaving the herds unattended in the pastures during the day (27.5%, $n=314$), when returning home from the pastures (15.1%, $n=172$) and when livestock were free ranging near the household (2.7%, $n=31$). Only (1.3%, $n=15$) of the wolf depredation events occurred while herds were held at night in traditional corrals.

The majority of depredation by snow leopards also occurred while herders left their livestock unattended in the pasture overnight (50.5%, $n=368$), followed by leaving the herds unattended in the pastures during the day (14.4%, $n=105$), when livestock were kept at night in traditional corrals (13.4%, $n=98$) and when returning home from the pastures (10.8%, $n=79$). The timing of the depredation event by snow leopards was unknown for (10.9% $n=80$) of the losses.

Attitudes towards wolves and snow leopards differed between the two study areas (Mann–Whitney $U=1.82$, $z=-3.07$, $P=0.002$). Herders in both study areas did not like wolves in their pastures (Tost mean = 1.17, s.d. = 0.37; Bayasah mean = 1.20, s.d. = 0.60). Herders in Bayasah also did not like snow leopards in their pastures (Bayasah mean = 2.12, s.d. = 1.06), but herders in Tost were neutral to snow leopards in their pastures (Tost mean = 3.11, s.d. = 1.08). The majority of herders in Tost and Bayasah said that wolves were a major threat to their livelihood (Tost mean = 4.42, s.d. = 0.08; Bayasah mean = 4.58, s.d. = 0.08). Similarly, herders in Tost and Bayasah considered that snow leopards were a moderate threat to their livelihood (Tost mean = 3.17, s.d. = 0.11; Bayasah mean = 3.20, s.d. = 0.14).

Herders from Tost said an average of 4.5 livestock losses per family and year was acceptable to them (range = 0–30), whereas herders in Bayasah said that an average of 1.3 livestock losses per family and year were acceptable to them to carnivores (range = 0–5).

The total economic loss associated with self-reported carnivore depredation during 2010 amounted to US$11 8790 (snow leopards = $36 180, wolves = $82 610), which is equivalent to an average loss of $825 per family and year (range = $0–$2650, Table 2).

Factors influencing livestock depredation patterns

The number of livestock per household and frequency of shifting campsite had the strongest influence on livestock losses to snow leopards (summed AICc weight = 0.71 and

Table 1. Total number and percentage of perceived livestock losses to various causes of mortalities in January to December 2010 in Tost and Bayasah areas in South Gobi, Mongolia

Cause of mortality	No. of household affected	Percentage of household affected by each of different losses	No. of goats lost	No. of sheep lost	No. of camels lost	No. of horses lost	Total no. of livestock losses	Percentage of all livestock losses	Percentage of total livestock holding
Natural disaster	112	78%	4481	259	15	23	4778	71.2%	17.1%
Disease or poison	18	13%	34	8	1	2	45	0.60%	0.2%
Snow leopard	68	47%	702	34	0	4	740	11%	2.6%
Wolf	91	63%	857	231	50	3	1141	17%	4.1%
Total	135	94%	6074	532	66	32	6704	100%	23.9%

Table 2.   **Market value in US dollars ($) for different livestock species and the total estimated economic loss to snow leopard and wolf depredation in 2010 for the Tost and Bayasah areas**

Mean losses per herder and year in parenthesis

Livestock species	Unit value (US$)	Total loss to snow leopards (US$)	Total loss to wolves (US$)	Total loss to both predators (US$)
Goat	$50	$33 000 ($229)	$42 850 ($297)	$75 850 ($526)
Sheep	$60	$1980 ($13.7)	$13 860 ($96.2)	$15 840 ($110)
Horse	$300	$1200 ($8.3)	$900 ($6.2)	$2100 ($14.5)
Camel	$500	$0 ($0)	$25 000 ($173)	$25 000 ($173)
All livestock		$36 180 ($251)	$82 610 ($574)	$118 790 ($825)

Table 3.   **Model selection for the variables that best explained livestock depredation by snow leopards and wolves in the Tost and Bayasah area in 2010, where only the models with Akaike Information Criterion corrected (AICc) weights <2 are included**

Model	Number of Parameters	AIC	AICc	AICc weight	Cum.weight
Snow leopard depredation					
Livestock numbers + shifting campsite	2	397.77	0.00	0.26	0.26
Livestock numbers	3	398.87	1.18	0.14	0.54
Livestock number + shifting campsite + frequency of visiting soum centre	7	398.95	1.18	0.14	0.54
Wolf depredation					
Livestock numbers + shifting campsite	5	398.75	0.00	0.23	0.23
Livestock numbers	3	399.61	0.87	0.15	0.37
Shifting campsite	4	400.25	1.51	0.11	0.48
Livestock numbers + shifting campsite + frequency of visiting soum centre	7	400.35	1.60	0.10	0.58

0.58, respectively) with number of livestock holding occurring in all three top models. The number of livestock losses to snow leopards increased with 0.011 (s.e. = 0.0068) losses per family and year for every additional animal held. Herders who were more sedentary (no shifting of campsite) lost livestock to snow leopards at a slightly higher rate (0.58 ± 0.27 s.e.) than those that moved twice a year (0.47 ± 0.24 s.e.). Travelling to the soum centre and the household family size had less impact on livestock losses to snow leopards (summed AICc weight = 0.27 and 0.15, respectively) (Table 3).

Q1

Livestock depredation by wolves showed a similar pattern to depredation by snow leopards, with the number of livestock holding (summed AICc weight = 0.62) and shifting campsite (summed AICc weight = 0.59) being relatively more important, whereas frequency of visiting the soum centre (summed AICc weight = 0.22) and number of family number present in the field (summed AICc weight = 0.18) were less important. The number of livestock losses to wolves increased with 0.0082 (s.e. = 0.0075) losses per family and year for every additional animal held. Herders who were more sedentary (no shifting of campsite) lost livestock to wolves at a slightly higher rate (0.59 ± 0.27 s.e.) than those that moved twice a year (0.44 ± 0.24 s.e.).

Measures used to reduce carnivore depredation

In total, 105 respondents (73%) reported that they used some measure to prevent livestock losses to carnivores, and most of the respondents that used preventative measures (18%, $n = 26$) used more than one measure. The majority of the respondents that used preventative measures (55.6%, $n = 80$) stated that supervised livestock herding was the most effective technique

to reduce depredation (55.6%, $n = 80$). Improving traditional corrals (10.4%, $n = 15$), use of guard dogs in pastures (10.4%, $n = 15$), scarecrows near corrals (9%, $n = 13$) and wire barriers around potential entrance to livestock corral (4.9%, $n = 7$) were other commonly used measures. Other preventive measures such as burning bones, dung smoke, flags, shooting guns in the air to frighten the carnivores, putting discarded compact disks on the back of young domestic animals to (reflect the sun and thereby deter the carnivores) and using crackers to scare predators were used by 14 (9.7%) of the respondents that used preventative measures.

Discussion

Livestock losses and depredation patterns

This study showed that harsh winter conditions were the main cause of livestock loss in the Tost and Bayasah areas in 2010. Mongolia is vulnerable to extreme climatic events (Fratkin and Mearns 2003; Begzsuren *et al.* 2004; Reading *et al.* 2006), including a phenomenon particularly dangerous for livestock known locally as 'dzud' (Begzsuren *et al.* 2004). This results from a combination of a spring drought followed by harsh winter conditions with heavy snowfall, which leads to many animals starving to death (Chuluundorj 2006). In the winter of 2009–10 (Nov 2009 to March 2010), a total of 10.3 million livestock, which is 22% of Mongolia's total livestock, was estimated to have died as a result of the dzud (Bohensky and Maru 2011). Our study was done in a year that was particularly hard for the livestock and it is thus possible that vulnerability to extreme weather conditions may not always be the main cause of livestock losses in all years. It would be useful to repeat data

collection over several years to assess whether harsh winters is the main cause of livestock losses over time; this initial research provides important baseline for future studies and evaluation of conservation initiatives.

Carnivores emerged as the second source of livestock losses in the Tost and Bayasah areas in 2010. The wolf was the most important livestock predator, reported to be responsible for more livestock losses than snow leopards (17% for wolves versus 11% for snow leopard). Similarly, the depredation events ascribed to wolves affected more households than those ascribed to snow leopards (65.7% for wolves versus 34.3% for snow leopards). Moreover, these depredation events resulted in an average loss of $825 per herder and year. Wolves were associated with the greatest economic loss both because they killed more livestock in general, but also because they were responsible for all camel losses, the most economically valuable livestock type. For instance, wolf depredation in Hustai National Park in Mongolia has been reported to lead to losses of $600–$1900 per herder per year in the buffer zone surrounding the park (van Duyne *et al*. 2009).

Our study assessed self-reported losses, thus it is difficult to document number of livestock losses to carnivores retrospectively, because reported losses maybe biased through recall, attitudes and other factors. However, we cross-referenced reported losses with those reported through the livestock insurance program when possible and therefore suggest that the losses reported in our study are representative.

About two-thirds of the depredation events by both snow leopards and wolves were reported to take place when the livestock was left unattended on the pastures overnight or during the day. Such a high skew of the losses occurring when animals were left unattended or when left on the pastures overnight suggests that programs to encourage greater attendance and discourage leaving animals on the pastures overnight are crucial, not only for reducing livestock losses but also for improving the conservation status of the carnivores, by reducing the losses and thereby also the conflict related to livestock depredation. Similarly, development of other methods to reduce livestock losses on the pastures will be important for both herder economy and for the conservation status of the carnivores. In addition to livestock losses being related to herder attendance and animals left on pastures overnight, herders also reported that it was difficult to protect their livestock in the pastures because of the large size of their herds and because of the rugged mountain habitat.

The relative importance of carnivore depredation varies across the mountains of south central Asia. For example, in one study conducted in Ladakh in India, 18% of the livestock losses were attributed to wolves and snow leopards – equivalent to about half the annual herder income (Mishra 1997). In another study conducted in Upper Mustang area 74.5% (Aryal *et al*. 2013) and Annapurna in Nepal, snow leopards were held responsible for 63% of all livestock losses (Jackson *et al*. 1996). However, in the Gansu Province in China, only 8% of livestock mortality was attributed to depredation by snow leopards and wolves (2% and 6% respectively) (Alexander *et al*. 2015). However, the relative importance of livestock depredation can be high also in China, where 55% of the livestock losses in the Qinghai Province were attributed

to snow leopards and wolves (10% and 45%, respectively) (Li *et al*. 2013). The relative importance of livestock depredation by snow leopards (11%) and wolves (17%) in our study was thus on the lower end of the scale in comparison with that found in other areas of central Asia, where livestock herders coexist with both predators.

Our modelling result showed that families who owned more livestock tended to lose more animals to carnivores. Larger herd sizes may have led to increased risk of stragglers being left behind in the rugged terrain and herders having difficulties watching their livestock. Other factors affecting livestock losses included frequency of shifting campsite and how often herders visited the soum centre. Our study also showed that key informants said that herders were visiting their families in the soum centres more frequently and shifting campsite less often than before, which likely results in increased livestock losses. Key informants also suggested that herders now increasingly use motorcycles to do spot checks on their livestock rather than staying in the pastures with their herds. As a result, herds are left unattended for longer periods of time and are thereby subjected to an increased risk of depredation. Livestock loses to carnivores while unattended in pasture is common among pastoralists throughout the world, and similarly to our study, have also been reported in Bhutan (Wang and Macdonald 2006), China (Alexander *et al*. 2015) and Nepal (Jackson *et al*. 1996). Our results also indicate that families who did not shift campsite and settled in one place lost more livestock to snow leopards and wolves. This finding strongly suggests that when herds stay in one area, they may become more vulnerable to carnivores, but this may also be explained by there being more predators in these areas. The potential relationship between depredation rate and herder movement rate requires further verification and exploration of the potential causes.

Conservation strategies and approaches

This study illustrates the large economic burden of livestock losses to predators that the herder communities of south central Asia carry (Bagchi and Mishra 2006), as illustrated by the average income by rural herders in Mongolia being less than $2500 per herder and year in 2010 (Khadbaatar 2015; Save the Children 2016). Our study also highlights that changes in herding practices may increase the vulnerability of these communities and should be considered in the context of the rapid social and economic shifts that are taking place in Mongolia and other parts of south central Asia (Fratkin and Mearns 2003; Sneath 2003). Strategies to conserve carnivores under threat, such as snow leopards, need to take these factors into account in an effort to mitigate any negative impacts these carnivores have on local communities.

Preventive measures to reduce livestock losses that are locally relevant are needed to reduce the burden on herder communities and thereby avert the risk of retaliatory killing (Jackson *et al*. 1996; Mishra 1997). Herders reported using a range of measures such as wire and stone fencing, flags, fire and scarecrows, with frequent changes among them to reduce predator habituation (Gilsdorf *et al*. 2002). Similarly, development of more efficient livestock management and herding practices may help to reduce

livestock losses (Ogada *et al*. 2003). One example of such measures is predator-proof corrals, which have been promoted in several settings, with a specific focus on preventing night time losses (Jackson *et al*. 1996; Ogada *et al*. 2003). This approach would be most relevant for the increasing numbers of herders who no longer regularly shift campsites, because the predator-proof corrals are generally permanent structures that cannot be moved between campsites. The development of predator-proof corrals that can be easily moved would therefore be very useful in Mongolia, where herders often move between campsites a few times per year. Our findings suggest that this could prevent a proportion of losses, mainly to snow leopards, but would need to be complemented with other methods to mitigate livestock losses in the pastures where the majority of losses occur.

Attitudes towards carnivores were more positive in Tost comparatively than Bayasah, where community-based conservation programs were in place. Conservation efforts in Tost seek to engage communities in conservation efforts, support herders in protecting their livestock from depredation and provide access to an insurance program to compensate for livestock losses (Mishra *et al*. 2003). Our study suggests that these efforts can improve attitudes towards wildlife by reducing the threats that they pose to livelihoods, as has also been reported by Kideghesho *et al*. (2007) and Mehta and Heinen (2001).

Finally, national and local policies need to be carefully considered. For example, herder families in Mongolia are encouraged to increase the size of their herds and receive awards accordingly (Endicott 2012). However, this policy poses challenges to herder families that, in addition to having limited capability to feed and protect large herds, may also increase the vulnerability to depredation, as illustrated in our study.

Conclusion

Herding practices in Mongolia and central Asia are changing (Mearns 1993; Fernandez-Gimenez 2000; Hilker *et al*. 2014). Our study showed that herders are reducing the amount of time they spend with their herds, even while the number of livestock is increasing and the majority of losses occurring when herds are unattended in the pastures, suggesting that herders need to adjust their herding practices accordingly to reduce livestock losses. This study also showed how herders that are more sedentary tend to lose more livestock to predation and thereby also suffer greater economic losses than herders than move more often. Finally, our study also highlights an urgent need to help and support the herding communities in the mountains of central Asia to adopt more sustainable herding practices, which can complement measures to conserve carnivores and other wildlife that share the mountains with the herders.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

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Appendix 1

Dear Sir or Madam,

I am student from Mongolia's National University. I have come to South Gobi in order to conduct research on explore the herder current pastoral lifestyle whether herding technique affecting livestock losses due to carnivores or not. Your opinion about carnivores in this area in southern Gobi.

The questionnaire is completely anonymous and I will not write down your name, meaning that no-one will be able to tell that the answers you give belong to you. The results of the research will be used to inform future conservation activities in Gobi. To help us with this study, we would be grateful if you could answer the following 20 questions. The interview should take no more than 40 minutes. The only persons to see your answers will be myself and a few other researcher. There are no wrong or right answers, only your answers. If you are not sure of the answer to a question please answer "I'm not sure". Feel free not to answer any question if you do not wish to and feel free to stop the interview at any time. Thank you for taking part in this important study.

Questionnaire for herders' pastoral practice change, livestock losses and attitude.

Note: All the questions will be translated to Mongolia and thus the wording may be a bit awkward.

Interview Code _____

Date __ __/__ __ /__ __

GPS: Lat _____ Long_____ Alt_____

Interviewees age_____ Gender_____ Education_____

Herder current pastoral practices

(1) How many times do you move per year?

	Summer	Fall	Winter	Spring
Freq of movement				
Duration of stay				

(2) Why do you move this many times or don't move?
    Reason._____
(3) How do you herd your livestock?   /By foot/by motorcycle/Both/
(4) How many livestock do you have?   Goat____ Sheep_____Horse_____ Camel_____
(5) Who herds your livestock?   Age___ gender_____
(6) How often do you go to the soum center? (meanwhile who tends your livestock)_____
(7) Are all your family members living together in your herding area?_____
(8) What is the major obstacles facing herders' lifestyle?_____

Herders' perceived livestock losses

(9) How many livestock losses did you have last year? (Jan-Dec).

REASON	Species	Number	Where?	When?	Loss value
Disaster					
Disease					
Snow leopard					
Wolf					
Other					

(10) How many times did you encounter carnivore species?_____
(11) What kind of preventive measure do you use for protect livestock from carnivores?_____
(12) What suggestion you give to make it better?
(13) How will you respond if depredation were to increase?_____

Herders' attitude towards carnivores

(14) What do you think of this statement; I think it's necessary to keep those animals in the mountain and it's nice to live with them.

	Strongly disagree-1	Disagree-2	Neutral-3	Agree-4	Strongly agree-5
Snow leopard					
Wolf					

(15) How much do the predators below affect your livelihood negatively?

	No affect-1	Minor affect-2	Moderate affect-3	Major affect-4	Critical affect-5
Snow leopard					
Wolf					

(16) How much livestock loss by carnivore species is acceptable for you?
(17) If numbers exceed acceptable limits what will you do?

    a) kill   b) ask others to kill   c) scare them   d) shift site   e) don't do anything f) other..

AUTHOR QUERIES

1. Author: please provide an in-text citation for Table 3.