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A pattern of livestock depredation by snow leopard to the yak herding pastoralist in western Bhutan

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Abstract

The pastoralists co-exist with wild predators and livestock depredation by predators causes an immense impact on the livelihood of the herders and instigates a negative attitude towards the conservation of these wild predators. Yak herders in western Bhutan move from place to place for herding on pasture and they face challenges with livestock predation by top predators like snow leopard (*Panthera uncia*) and dhole (*Cuon aplinus*). To investigate patterns of livestock depredation by the snow leopard and determine the attitude of herders towards snow leopard conservation, we conducted a household interview with all 56 itinerant yak herders in the west of Bhutan. Each herd was keeping a mean of 84 (\pm 29) yaks per herd. Yaks were mainly kept for milk and bulls for breeding and bullocks for meat to sustain their family livelihood. Predation of livestock by predators (42.9%) was among the top problems faced by the yak herders. A total of 398 yaks were lost to snow leopards (78.86%) followed by dhole (18.3%), Himalayan black bear (*Ursus thibetanus*) (2.7%), and common leopard (*Panthera pardus*) (0.2%) in the past 5 years (2015–2019). The majority (87.22.8%) of the kills by snow leopards were young yak and most (60.5%) kills were recorded during summer. Snow leopards are considered harmful (73.2%), and herders (71.1%) are not in favour of snow leopard conservation. Herders' conflict with snow leopards is severe in the current study site, and we recommend social development for conservation programmes like livelihood alternatives for the herders, compensation and insurance schemes, and conservation awareness programmes for the yak herders as an intervention to create harmonic co-existence between the yak herder and the snow leopard.

Keywords: Predation, Livelihood, Conflict, Attitude, Perception

Introduction

The conflict between the wildlife species and humans is inevitable because of their co-existence on the same planet and is a serious concern for the survival of the species and livelihood of the local communities in many parts of the world (White et al. 2007; Ripple et al. 2014). High-altitude Himalayan grasslands in central and southern Asian mountain ecosystems are an important habitat for snow leopards (*Panthera uncia*) and their main prey species. Moreover, livestock herding pastoral communities are also residing along with snow leopards

in this ecosystem (Kerven et al. 2011). The presence of the large carnivores with the livestock herding pastoralists is controversial because of the associated conflict with the carnivores. The conflict of livestock depredation by the carnivores instigates a negative attitude towards conservation and the conflict often leads to retaliatory killing of the carnivore, which is a generally accepted issue globally (R. M. Jackson 2015; Bagchi and Mishra 2006; K. Suryawanshi 2016; Woodroffe et al. 2005).

Bhutan is protected by 51.44% of the total area with protected areas and constitutional mandate of maintaining 60% of forest cover for all time to come (Wangyel et al. 2006), and supplemented by 69% of the population as agrarian with subsistence agriculture and livestock as their main source of livelihood (Katel et al. 2014). Human-wildlife

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conflict is a major issue and challenge towards conservation of wildlife and well-being of rural people (Sangay and Vernes 2014). Livestock predation in Bhutan is an inherent issue and it is contributed by major predators like tiger (*panthera tigris*), snow leopard (*Panthera uncia*), common leopard (*Panthera pardus*), and dhole (*Cuon alpinus*) (Rajaratnam et al. 2016). Snow leopard conflict with the yak herders in Bhutan is also one of the major forms of human-wildlife conflict (Sangay and Vernes 2008). Yak herding is an age-old tradition in Bhutan (Sangay and Vernes 2014). Semi-nomadic yak herders seasonally move with their yak along an altitudinal gradient which make their yaks more susceptible to predation by snow leopards (Sangay and Vernes 2014). The conflict between snow leopard and local herder is a serious issue when yak herding is the main source of livelihood for the yak herding pastoralist in Bhutan (Jamtsho and Katel 2019). Although the pattern of conflict between herders and snow leopards has been studied in some parts of Bhutan (Jamtsho and Katel 2019), knowledge of this aspect in the Jigme Khesar Strict Nature and its Buffer zone in western Bhutan is still rudimentary.

Snow leopards (*Panthera uncia*) are keystone species in the mountain ecosystem (Johansson et al. 2015) and their presence in the mountains depicts a healthy mountain ecosystem (P. Jackson 1997). The survival of prey species depends on the good quality of rangeland, and the quality of rangeland is determined by the extent of livestock grazing and human interference (Mccarthy and Chapron 2014). Snow leopards are dwelling along with the mountain-dwelling herders in its 12 distribution range countries (Farrington and Tsering 2019). Survivals of snow leopards are threatened by retaliatory killings, poaching, a decline of prey species, and habitat degradation (Johansson et al. 2015), and they also impact the livelihood of the mountain dwellers (Alexander et al. 2015; Maheshwari and Sathyakumar 2020). The extent of the conflict can influence the attitude of the local herders and lead to the prosecution of carnivores to get rid of the conflict species permanently or to minimize the conflict (Chetri et al. 2019).

According to Jamtsho and Wangchuk (2016), livestock depredation for the high mountain pastoralists is largely attributed to snow leopards. For instance, in the central park of Wangchuck Centennial National Park, herders lost a total of 666 livestock to five predators from 2012 to 2016, where the single majority (32.6%) was contributed by snow leopards. In contrast, herders of the Sanjiangyuan Region in Qinghai Province, China, lost 984 yaks to predators from 2009 to 2011 and only 10% were contributed by snow leopards (Li et al. 2013). Suryawanshi et al. (2013) assert that, where there are other sympatric predator species with snow leopard, the livestock depredations are shared among these

predators. Livestock predation by the predators was accounted for largely by snow leopards in their distribution range habitats (Ud Din et al. 2017). In the places where there is a presence of the wolf (*Canis lupus chanco*) with snow leopard, wolves are next to snow leopards in livestock predation (Wangchuk and Jackson 2004).

Young yaks are more vulnerable to predation by snow and dholes being social canids, adult yaks are more vulnerable to dholes (Aryal et al. 2015). For instance, Chetri et al. (2019) claimed that 94.5% of the yak depredation was accounted for by snow leopard, and as per Jamtsho and Katel (2019), 64% of the snow leopard depredation in the central park of Wangchuck Centennial National Park was made by the snow leopards. The average weight of 180 kg is considered the maximum size of prey for snow leopards (Schaller 1977; Hunter 2015). However, in some parts of its distribution ranges, snow leopard also depredated yaks weighing more than 250 kg prey (Li et al. 2013; Suryawanshi et al. 2013).

The vulnerability of livestock depredation by snow leopards increases with an increase in herd size and they are more vulnerable during the summer season in Bhutan, during which the yak herders move to high altitude areas (Jamtsho and Katel 2019; Sangay and Vernes 2008; Jamtsho and Wangchuk 2016). Livestock depredation by snow leopards was significantly higher at night (Krofel et al. 2021). In parts of Narphu valley in Nepal, the majority of the depredation by snow leopard occurred during the night (38%) followed by 28% in the daytime, evening with 19%, and 15% during the morning (Tiwari et al. 2020).

Improper management of the herd and the herder's negligence in corralling the herd significantly contributed to livestock predation in Bhutan (Sangay and Vernes 2014). Poor management of livestock is also one of the major factors contributing to livestock predation (Wang and Macdonald 2006). Similarly, poorly designed livestock pens in Pakistan led to an increasing attack by snow leopards (Khan et al. 2017) to that in Nepal (Namgail et al. 2007).

Livestock depredation by snow leopards induces a negative attitude of the herders towards snow leopards, and these attitudes can have strong emotional and political consequences, ultimately threatening the survival of snow leopards (Oli et al. 1994). People's tolerance for large carnivores varies, depending on several factors, including their religious beliefs, income, education level, characteristics of carnivores, and cultural factors (Mishra 1997; Carter et al. 2012). As per the prediction by Augugliaro et al. (2020), numbers of livestock loss to snow leopards and snow leopard presence with the herders were associated with a negative attitude towards snow leopard conservation.

Most of the studies on snow leopard predation on livestock were conducted in areas where there is the presence of sympatric predators like wolves. In the present study site, there is no record of the presence of wolves or other top carnivores like the tiger (*Panthera tigris*) and it was imperative to determine the status of livestock depredation by snow leopards in such conditions to implement site-specific mitigation measures. Therefore, the objective of this study was to investigate the livestock depredation pattern of the snow leopard to the yak herding pastoralists and examine the perceptions of yak herding pastoralists on snow leopard conservation in western Bhutan.

Methods

Study area

The study area is located between the latitude of 27° 11' 58.97" N and 27° 34' 28.40" N and longitude of 88° 54' 29.41" E and 89° 16' 4.71" E. Study area is within Jigme Khesar Strict Nature Reserve (JKSNR) renamed from Toorsa Strict Nature Reserve in 2014 and its periphery buffer zone, which is located in the extreme west of Bhutan, sharing its boundary with India and Tibet (Fig. 1). The study site covers an area of 957.30 sq km of which 825 sq km is the suitable habitat of snow leopard *Panthera uncia* which is 3000 m above sea level. The area has three blocks (Bji, Katsho, and Eusu). During summer, it receives an average of less than 650 mm of rain, and during winter, 70% of its area is covered by snow.

JKNSR was declared as a Strict Nature Reserve in 1993 but it was operationalized only in 2010 with its first

management plan. There is no permanent settlement within the reserve but around 56 itinerant yak herders are moving within the reserve and its buffer zone. During the winter months, herders descend down to low elevation areas and migrate up to the alpine pastures before the onset of the summer season. Each herder has their designated user-right pastures allotted by the Royal Government of Bhutan. These itinerant yak herders depend on their livelihood on yak herding and most of their families are residing in the semi-urban area of the Haa district in the lower elevation valley. Children's education and all the living expenses are met through the income from tending yak.

The upper part of the area is dominated by alpine scrubs with meadows, and the lower part is dominated by the mixed conifer forest (Ohsawa 1987). The carnivore species in the area include snow leopard (*Panthera uncia*), dhole (*Cuon aplainus*), common leopard (*Panthera pardus*), and other wild small cats like the Asiatic golden cat (*Catopuma temminckii*), leopard cat (*Prionailurus bengalensis*), marbled cat (*Pardofelis marmorata*), and clouded leopard (*Neofelis nebulosa*). Geographically, the northern parts of the study area consist mostly of rugged mountain terrain, rocky peaks, and scree, harbouring numerous sacred alpine lakes, and southern parts are scoured steeply by streams and rivers forming narrow valleys. Heavy frost, blizzards, and snow prevail throughout the year except for a few months. The mean annual temperature record was 0.67°C. Precipitation was observed in the form of heavy rains, hail, snow, and

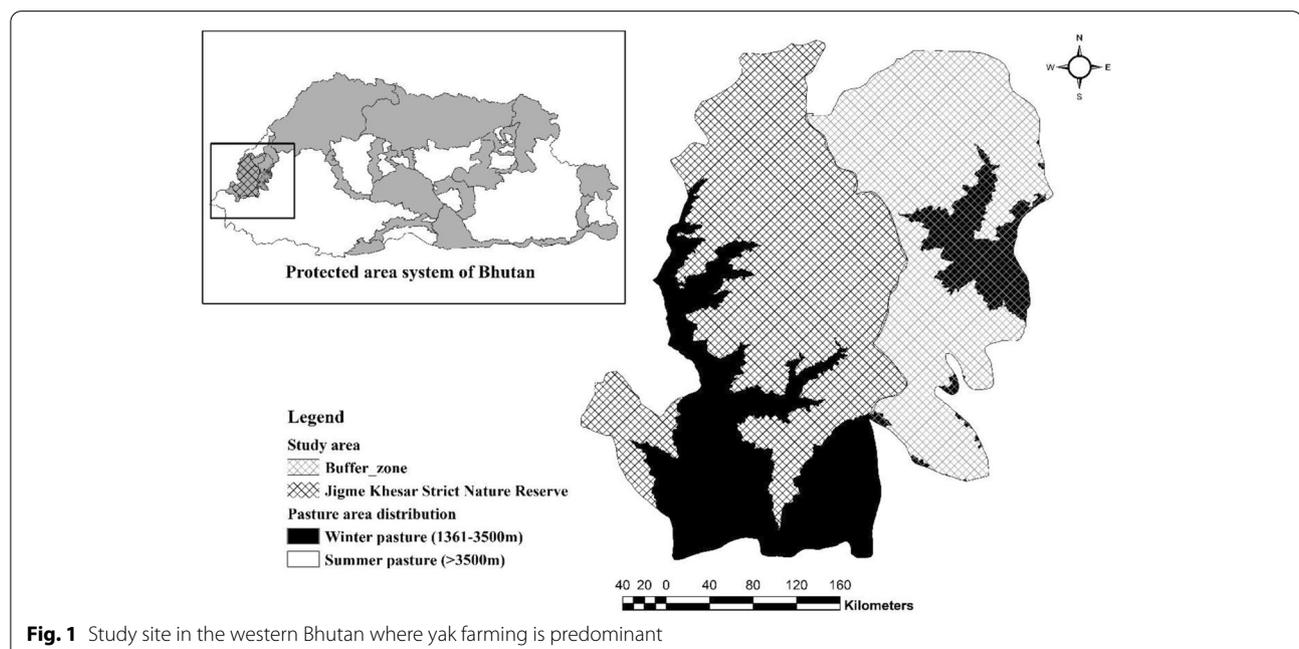


Fig. 1 Study site in the western Bhutan where yak farming is predominant

showers. Snowfall occurs from November to April and snowmelt occurs from April to July.

Sampling design and data collection

Total enumeration was done for data collection. The data on the number of yak herding pastoralists was collected from the District livestock sector of Haa District. There were 56 independent herders. Total enumeration of the herders helped in generating reliable and authentic results for the research outcome. The eldest member of the herding family was interviewed with the research survey questionnaire. The questionnaire was initially tested with five yak herders and no changes to the questionnaire were deemed necessary. Since no changes were to be made to the questionnaire, the data from the initial testing phase of 5 yak herders were included for final analysis.

Semi-structured questionnaires were developed to collect the information. The majority of the questions were in the form of close-ended, which eased the interviewee to conduct an interview survey and helped in quantitative analysis. Multiple or closed-ended questions were framed concerning information required and relevancy to the research. The main questions in the questionnaire form include (i) household demography, (ii) livestock holding and composition, (iii) livelihood source of the herders, (iv) type of livestock depredation by wild predators and snow leopards, and (v) perception towards snow leopard conservation.

The interview was carried out by visiting each yak herd by myself and forestry staff from JKSNR to conduct a questionnaire survey. To make a clear judgement and understanding of the questionnaire and ease bias in asking the questions, only two people were involved for the entire questionnaire interview. Questions were asked in Dzongkha (the national language of Bhutan) and translated to the questionnaire in English.

Data analysis

Both descriptive and inferential analyses were performed based on the type of data. Statistical Package for Social Science (SPSS) Ver.23 was used for the entire analysis of the data (Landau and Everitt 2004). All the categorical data were numerically coded and entered into SPSS 23 whereas those in numeric were kept as it. Descriptive statistics were used to describe the percentage composition of interviewee, yak holding composition, perceived yak herding problem, yak tending style, the composition of predators depredation on livestock, the composition of livestock predation by predators, the composition of yak category depredation by snow leopards, the composition of yak depredation by snow leopards in a different season, the composition of yak depredation timing, the composition of yak depredation kills verification, the composition

of interviewee's knowledge on snow leopards, the composition of attitude towards snow leopard conservation, the composition of perception on snow leopard protection by law, and the composition of perceived mitigation measures to reduce herders-snow leopard conflict. Descriptive statistics were also used to analyse the mean and standard deviation of average annual yak, horse, and guard dog holding per herd, average yak depredation per herd, and mean annual loss of yaks to wild predators.

The distribution of the data was tested for yak holding per household ($W(56) = .963, p = .84$) and numbers of yak lost to wild predators ($W(56) = .978, p = .388$) using the Shapiro-Wilk normality test and was found normally distributed. Therefore, we conducted a one-sample *t*-test, to determine their significance level among the herders. Pearson's correlation was performed to determine the correlation between the quantity of yak holding and yak loss to predators.

Results

Demographic characteristics of yak herders

Data were collected from 56 yak herders. There were a total of 77 households tending yak in the Haa district and few households kept a combined herd and only 56 yak herders were using JKSNR and its buffer area as their pastureland. The composition of the interviewee was 53.6% ($n = 30$) men and 46.4% ($n = 26$) women, which has an equal representation of the gender. The permanent family of all 56 yak herders lives in the lower part of Haa district, where they own permanent houses and agriculture fields. Each herd was having an average of two people living with the yak herd. The oldest person in the herd was a 68-year-old man and the youngest was an 18-year-old boy. The study area covers three blocks and 10.7% ($n=6$) of the herders were from Eusu, 21.4% ($n=12$) from Katscho, and 67.9 ($n=38$) from Bji block. Bji block is located in the northern part of the Haa district; it has the majority of yak herders than the other two blocks.

Livestock holding characteristics of yak herder

Yak herders kept a total of 4748 yaks in Jigme Khesar Strict Nature Reserve and its buffer zones during the year 2019 and the average annual yak holding per herd was 84 (± 29) with a minimum of 37 and maximum of 164 yaks per herd. There was no significant difference ($t(55) = -.035, p = .072$) between the number of yaks holding per herd. Among the yak category, the highest was milch yak with 23.65% and the least with breeding bulls (2.82%) (Table 1). Yaks were the main source of income, where 100% of the participants reported yak contribution as the top rank in income generation. Yaks provide dairy products and they are used for carrying the load on rugged terrains. In the past, there was a

Table 1 Yak category composition

Category	No	%
Calf, 1-year male	415	8.74%
Calf, 1-year female	460	9.69%
Heifer	703	14.81%
Milch	1123	23.65%
Dry	787	16.58%
Breed Bull	134	2.82%
Bull	739	15.56%
Bullock	387	8.15%

system where each household sacrificed a yak annually to their local deity but it is no longer practised now.

Herders were keeping a mean of 5.49 (\pm 3.07) horses for transportation purposes and a mean of 2.37 (\pm 1.39) dogs for guarding the herd. The composition of the horse herd was 49% local stallion and 26.7% local mare. They were also keeping mules and very few with improved breed horses.

The perceived yak herding problems faced by the herders are as follows: the depredation of yak by the wild predators as the top rank followed by disease outbreaks and labour shortage to look after the yaks. They were facing the problem of feral dogs attacking their yak and the herder. Some of the herders were also facing the pasture competition pressure with yak herders from Tibet within the borders like Shaktoe (Table 2). The majority of the herders (69.6%) reported no grazing competition among the herds or with other wild ungulates but 30.4% assert having grazing competition in their pastures with wild ungulates and other herders.

The majority (62.5%) of the herders go along with the yaks and look after yaks during the daytime pasture grazing, whereas the rest (37.5%) of the herders just let their yaks graze freely in proximity to their herds.

Yak depredation by wild predators

All the yak herders reported yak depredation by wild predators from 2015 to 2019. Yak herders were keeping horses and dogs with yak and all three types of animals

Table 2 Yak tending problems faced by herders

Problem category	Number	%
Predators	24	42.90%
Disease	11	19.60%
Pasture pressure at the border with Tibet	3	5.40%
Feral domestic dogs	7	12.50%
Labour shortage	11	19.60%

were lost to wild predators in the last 5 years. The predation was caused by four major wild predators. A total of 428 livestock were lost to these predators in the last 5 years. The average yak lost to predators per herd for the last 5 years was 7.7 (\pm 2.68) and the total kill was 398 yaks. There was no significant difference ($t(55) = -.035$, $p = .072$) between the number of yaks lost to wild predators among the herders in the last 5 years. Yaks were the major livestock composition of the herders and were the major (92.8%) livestock lost to wild predators (Fig. 2).

Snow leopards accounted for 78.6% of the yak depredation followed by dhole with 18.3% and much less by black bear and common leopard (Fig. 3). Young yaks were highly vulnerable to depredation by snow leopards (98.5%) and they were rarely attacked by a common leopard (0.3%). Adult yaks were lost more to dholes with 75% followed by snow leopards with 17.9%. Heifer yaks were also vulnerable to both snow leopards (56.6%) and dholes (37.7%) (Table 3).

Yak depredation by snow leopard

A total of 313 yaks were lost to snow leopards by 56 yak herders in the past 5 years. The majority (87.22%) of the yak depredation by snow leopards were young yaks followed by heifer (9.58%) and less adults (3.19%). A larger portion (60.5%) of the yak depredation by snow leopards has happened in summer followed by spring (24.1%) and much less in winter and autumn (Fig. 4). The majority of the yak depredation by snow leopards was carried out at night with 76.4% and only 22% during the daytime. Half (49.8%) of the yak depredation by snow leopards were confirmed through pugmark evidence and only 28.9% of the herders saw snow leopard killing yak and 19.7% of the herders confirmed their yak kill by investigating the killed type of the snow leopards.

Herder's perception and tolerance towards snow leopard conservation

When the herders were asked the question 'do you know snow leopard?' 100% of herders reported "yes" through direct sighting or shreds of evidence. The majority of the herders (78.6%) had sighted snow leopards, 12.5% of the herders had known by seeing it on the television, and 8.9% heard from others.

When the herders were asked about the perceived population trend of snow leopards, 52% of the herders believed that the snow leopard population is increasing and 37% believed that the population is remaining the same and only 11% believed it is decreasing.

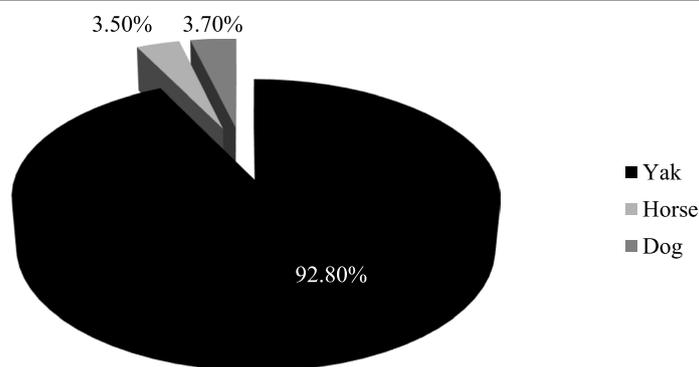


Fig. 2 Livestock depredation composition of herders

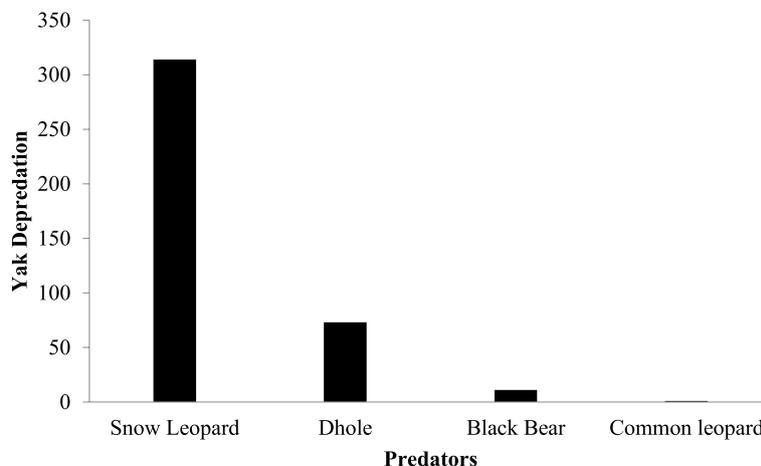


Fig. 3 Yak depredation composition by wild predators

The majority (55.4%) of the herders believed that snow leopard conflict with the herders is severe and 44.5% perceive that its problem is moderate. This indicates that snow leopard conflict with the yak herders is prevailing and causing a major threat to the yak herders. When the herders were asked about their perception of the benefit of snow leopard existence, a maximum of herders (73.2%) believed that the snow leopard is very harmful, and only a minimal (7.1%) believed it is beneficial to our ecosystem (Fig. 5). Of 56 herders, 71.1% were not in favour of snow leopard conservation, which is triggered by their frustration with yak depredation by the snow leopard.

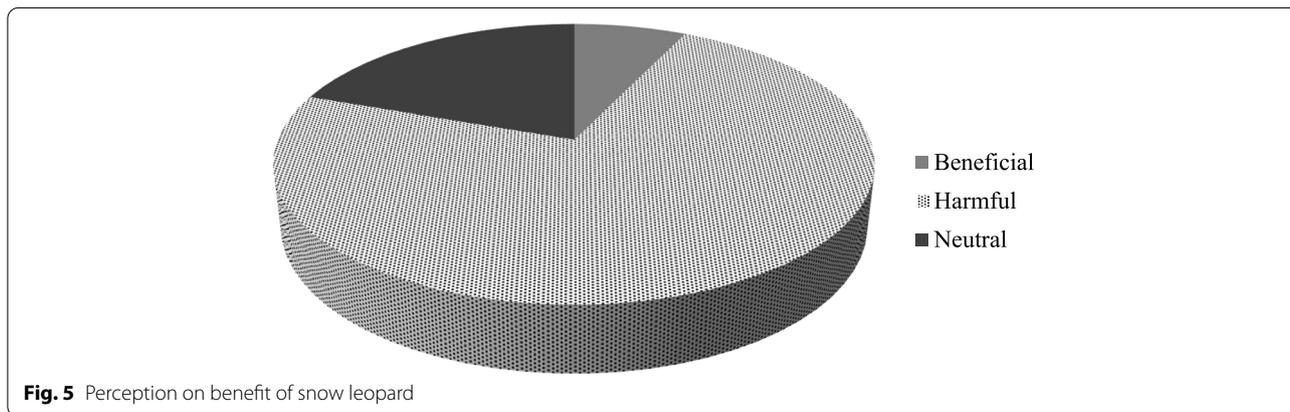
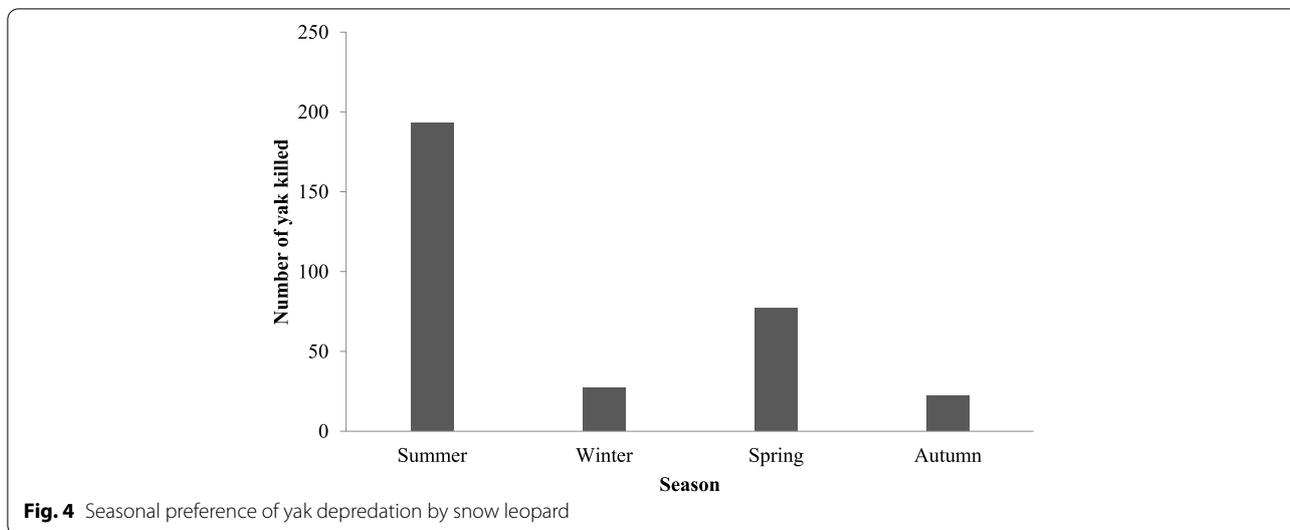
Herders were interviewed about their idea of reducing conflict and half of the herders claimed that compensation schemes followed by integrated conservation development programmes or alternative incentives will help to minimize the herder-snow leopard conflict. Only 10% of herders perceived that proper management and looking after the yak would help to

reduce herder’s conflict with snow leopards. Herders were even claiming that killing snow leopards by hunting (10.7%) and poisoning (8.9%) will reduce their conflict with snow leopards, which indicates that people were not happy with the co-existence of snow leopards with herders (Fig. 6).

Herders were asked about the laws, policies, and rules concerning snow leopards. A higher proportion (82.14%) of the herders were aware that the snow leopards are protected by the Forest and Nature Conservation Acts

Table 3 Age category of yak depredation by wild predators

Predators	Young, N (%)	Adult, N (%)	Heifer, N (%)
Snow leopard	273 (94.5)	10 (17.9)	30 (56.6)
Dhole	11 (3.8)	42 (75)	20 (37.7)
Black bear	4 (1.4)	4 (7.1)	3 (5.7)
Common leopard	1 (.3)		



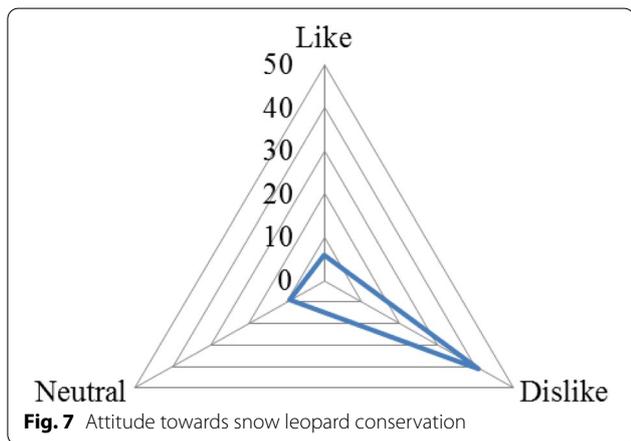
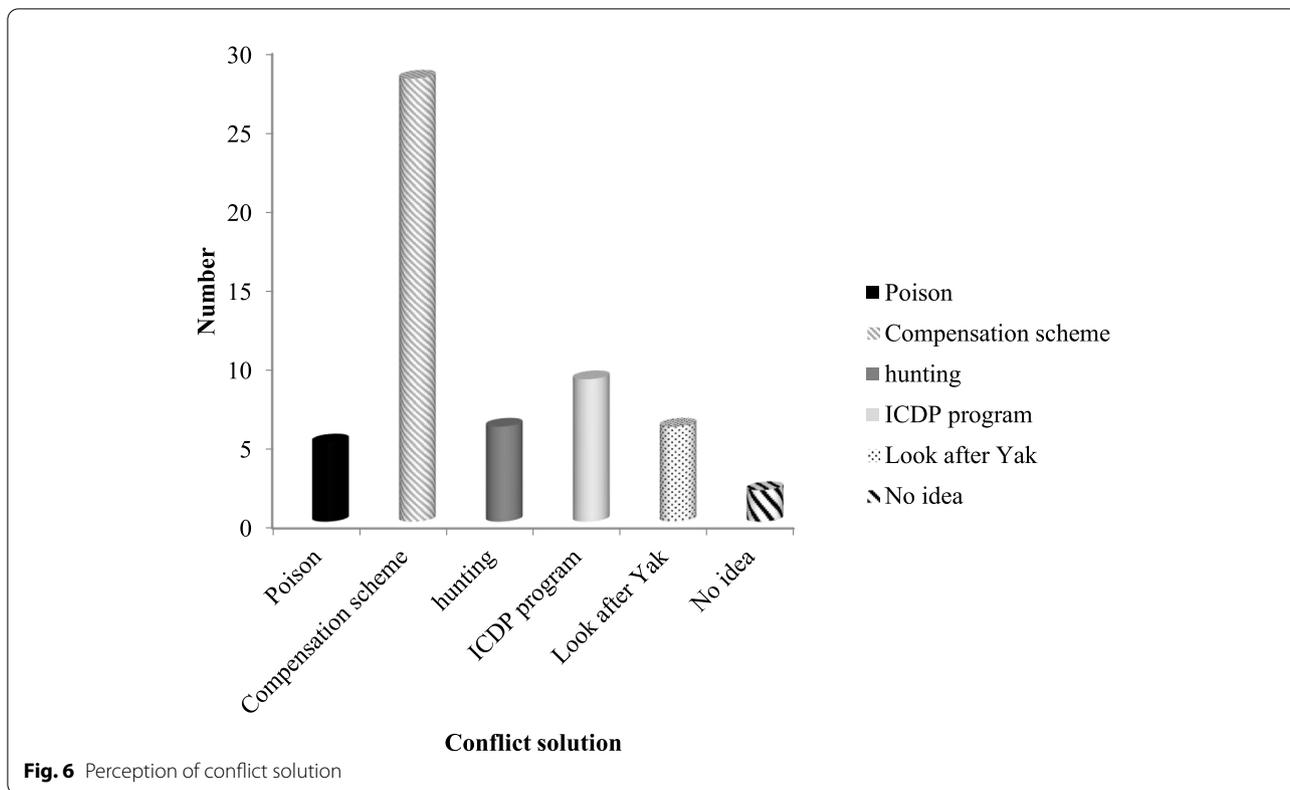
and Rules of Bhutan and the rest 17.86% were not aware of the snow leopards being protected by forest and nature conservation acts and rules of Bhutan. Near half (41.1%) of the herders perceive that it is good as snow leopard is being protected by acts and rules, 25% were neutral in this view, 23.2% are not sure of such protection, and only a few (10.7%) said it is not good to protect snow leopard through acts and rules. The majority (73.2%) of the herders desire to kill the snow leopard if it is not put under protection by acts and rules and 19.6% said that they will not kill a snow leopard even if it is not protected by acts and rules, while 7.1% are neutral in this situation. Their attitude towards snow leopards showed that 73.2% of the respondents did not like snow leopards, 16.1% were neutral, and only 10.7% liked snow leopards (Fig. 7).

Discussion

The majority (69%) of the Bhutanese population are agrarian with animal husbandry as their main source of livelihood and which contributes significantly (33%) to

the gross domestic product of the nation (Sangay and Vernes 2008). Livestock rearing and the by-products from livestock are the most important source of income for the people living in rural villages (Wang and Macdonald 2006; Dorji 2021). Highlanders in north-central Bhutan are more dependent on yak rearing as the main source of income (Sangay and Vernes 2014) until the legalization of *cordyceps* (*Ophiocordyceps sinensis* harvesting for commercial purpose was legalized in 2004, where the mountain dwellers were allowed to collect the fungus and sell) collection in 2004 (Cannon et al. 2009).

Yak herders in the western part of Bhutan are itinerant herders and their permanent residents are located in the lower valley of the Haa district which is similar to the herders in Wangchuck Centennial Park (Jamtsho and Katel 2019). An average of two people per herd was living with the yaks in the present site and the herders indicated it as a manpower shortage challenge faced by the herders. One herd was managed by a single young youth. He was



left with no option to tend his yak herd because he is the only child of his old parents and yak tending is their main source of income and livelihood to his family. Yak farming is also vulnerable due to an increase in literacy rate, leading to a reduction in the population of younger rural people (Wangchuk and Wangdi 2015). The reason for the present youths not taking interest in yak herding could be due to globalization where most of the children are being educated and exposed to a more luxurious part of living (Chettri et al. 2012). The majority (88%) of the herders

of Gurvantes *soum* (county) in the South Gobi province in southern Mongolia were having lone people to tend the yak and the rest of the family lived in the lower areas (Mijiddorj et al. 2018). This indicates that herding cattle in the cold mountainous pasture is tedious and most of the mountain herders tend to have their permanent settlements in the lower elevation areas.

The average yak holding per herd was 84 head, which is similar to the yak herders in the mountains of Wangchuck Centennial Park (Jamtsho and Katel 2019), whereas the rural people of central Bhutan in the lowlands are having an average of 12 heads of stock per household, which are composed of local and improved breeds of cattle (Wang and Macdonald 2006). Tshering and Thinley (2017) assert that larger numbers of yaks in herds are tended in the larger numbers in the herd with pasture herding practices compared to rearing of other livestock types in Bhutan, where other livestock type herding practice includes both tending with pasture herding and stall feeding at home. Herders of Narphu valley in Tibet were rearing an average of 17 yaks per household because unlike herders in the current site, they were also rearing sheep, goats, and cattle with yak (Tiwari et al. 2020).

Yaks were considered the main source of income for the herders and their families and the major component of the yaks was milk. Milch yaks were used for milk and

the production of dairy products such as butter and dry cheese for sale. The number of bullocks was much less because due to a surge in the price of yak meat at the local market, the herders kill yaks for meat around January to March months every year to top up income for their families. This practice of killing yaks for meat is now becoming less common in Bhutan due to the influence of the religion and there are even religious groups who buy and save the yaks which are bought to slaughter for meat.

Generally, yak herders in Bhutan and the region keep horses and dogs with the yak herd (Mijiddorj et al. 2018; Jamtsho and Katel 2019; Farrington and Tsering 2019) and it is no different in western Bhutan. Dog breed of the herders is considered a good breed of dog and few herders of the study site sell their puppies as pet dogs to the people living in the lower valleys and get a good price. In central Bhutan, few herders also keep sheep with their yaks as they have a family tradition of rearing sheep (Jamtsho and Katel 2019) but there is no tradition of rearing sheep in western Bhutan. Horses in the herds were kept for transportation of the ration and by-products from the yaks to the market and are similar to the yak herders in other parts of Bhutan (Wangchuk and Wangdi 2015) and China (Farrington and Tsering 2019).

Besides the livestock depredation by wild predators, herders were facing the problem of manpower shortage to look after the yaks, and in the past 5 years, four herders sold their entire yak to the yak herders of north-central herders and the number of yak herders in western Bhutan decreased to 65. The main reason they give up herding yak was due to manpower shortage, whereas the decrease in the number of herders in Wangchuck Centennial Parks was aggravated by the collection of *cordyceps* as a lucrative income source (Kinga 2014) and *cordyceps* are not present in the current study sites. Feral dog attacks on the yaks were also one of the concerns for the herders. During the winter months, when they bring their yaks to the lower pastures, most of them face attacks by feral dogs on the young yaks. Herders perceive that they are not having any grazing competition pressure with other herders and wild ungulates on a larger scale.

No herder could escape from yak predation by predators in the past 5 years (2015–2019) and all the three livestock (yak, dog, horse) types were lost to predators. The result showed that a total of 428 livestock were depredated by the four wild predators in the past 5 years. In Bhutan, the high density of livestock held by the household creates probable opportunities for the carnivores to predate on livestock as noted by Wang and Macdonald (2006). A study by Chetri et al. (2019) suggests that the probability of livestock depredation by predators increases with herd size but in the current site there was no correlation between the yak holding

and the number of yaks lost to predation, which was assumed to be influenced by the low density of the snow leopard in the study site and it is claimed that higher density of snow leopard is one of the major factors contributing towards larger incidences of livestock depredation concerning the higher number of livestock holding (Khan et al. 2017). Yak depredation was contributed highest by the snow leopard followed by dhole, and it was minimally depredated by the black bear and common leopard in western Bhutan. Adult yaks are more vulnerable to dhole than other predators. This is because dholes are pack-hunting canids and they can hunt down big prey (Aryal et al. 2015). In contrast, other regions of the snow leopard-dominated habitats, wolves accounted next to snow leopards in livestock predation (Wangchuk and Jackson 2004). The study was not designed to analyse the food habits of snow leopards through scat analysis, and in the questionnaire survey, there could be response bias in reporting livestock loss (Maheshwari and Sathyakumar 2020) and it is crucial to validate through scat analysis on the snow leopard's food habits.

The result showed that a total of 313 yaks were lost to snow leopards by 56 itinerant yak herders in the past 5 years. Yak depredation by snow leopards was reported in the northern mountains of Bhutan including Jigme Dorji National Park (Thinley et al. 2017) and Wangchuck Centennial Park (Jamtsho and Katel 2019). Depredation of the yaks by snow leopard is also reported in its distribution habitats like India, China, Nepal, Russia, and Pakistan (Chundawat & Rawat 1994; Oli et al. 1994; Bagchi and Mishra 2006; Augugliaro et al. 2020; Anwar et al. 2011). Livestock depredations in the snow leopard habitats are largely contributed by the snow leopard (Ud Din et al. 2017).

Young yaks are more vulnerable to predation by snow leopards which constitute 94.5% of kills. According to Prasad Devkota et al. (2013) and Chetri et al. (2017), adult yaks with an average body weight of 250 kg are too large and are less vulnerable to predation by snow leopards. The prey weight of up to 180 kg is considered the maximum size of a prey that a snow leopard can handle (Schaller 1977; Hunter 2015). In contrast, as per Li et al. (2013) and Suryawanshi et al. (2013), local herders reported snow leopards killing adult yaks weighing more than 250 kg. The study conducted by Krofel et al. (2021) in Sutai massif in the Altai mountain range observed adult yak weighing approximately 200–250 kg being killed by snow leopards. The detailed literature on prey size predation by snow leopards is lacking in the literature. Larger depredation cases of the yak by snow leopard were reported during the summer season; this is because during the summer season the herders move from lower

valleys and graze their herd in the alpine meadow which shares its habitat with the snow leopards and it is similar with the herders in the other park of Bhutan (Jamtsho and Katel 2019). Whereas the herders living permanently in the high mountains have no significant difference between the seasons (Oli et al. 1994). Snow leopards are most active during the night for hunting yak, during which the young ones of the yaks are left along with the adults in proximity to the herd and exposed to the predation. Snow leopard predation on livestock mostly occurred at night in Bhutan and its other distribution range (Tiwari et al. 2020).

Sighting of snow leopards hunting on yaks was very rare and most of the yak kills were identified through pugmarks and kill types. Similarly, in the Upper Spiti landscape of trans-Himalayan India, most of the snow leopard predation on the livestock was confirmed through signs around the kill (Suryawanshi et al. 2013).

All the herders were aware of the snow leopard and its existence in the alpine mountains and the majority have sighted snow leopards in their lifetime as a herder. Herders perceive that the population of the snow leopard is increasing and only 11% believe that its population is decreasing. This perception could be influenced by the yak depredation cases reported by snow leopards. Augugliaro et al. (2020) predicted that livestock loss to snow leopards and the presence of snow leopards in the same landscape were more connected with negative attitudes towards snow leopards. When herders lose yaks frequently to snow leopards, they perceive that the population is abundant and it is increasing. But in reality, the population of snow leopards can be ascertained only through intensive systematic study. Herders were not happy with the existence of snow leopards, and 73% of the herders believe that snow leopards are nuisance wild animals and believe that there is no benefit of snow leopards' existence to the ecosystem. The herders are not in favour of conserving snow leopards and this could be triggered by their frustration with yak depredation by snow leopards. A study conducted in Kanchenjunga Conservation Area in Nepal found that the livestock depredation (Estimate = -1.20873 ; $p = .029866$) by the predators attributed to a negative attitude towards the conservation of the species. During our questionnaire survey, we got evidence of snow leopard carcass, which was claimed to be natural death by the herders, wherein we could not identify any injury from the photo and assumed that this could have been poisoned by the herders.

Herders were asked to express their idea to reduce snow leopard-herders conflict to create harmonic co-existence and the majority of the herders expressed that compensation schemes and livestock depredation alternatives to their livelihood can help to minimize the

conflict, but in contrast in Manang area of Nepal half of the households reported eradication of snow leopards as a measure to prevent herders' conflict with snow leopards and also proposed livestock insurance schemes if the eradication programme fails (Oli et al. 1994).

Herders in the study site are mostly (82%) aware of the snow leopard being protected by the laws and rules of Bhutan, and when people know more about the species being protected by laws, it helps in reducing the retaliatory killing of the animals and hunting in general. When herders were asked about their perception of hunting and killing a snow leopard if it was not protected by laws, the majority (73%) were willing to kill the snow leopard if it is not protected under the conservation laws and similarly herders of Annapurna Conservation Area in Nepal suggested that total extermination of snow leopards could mitigate their predation conflict (Oli et al. 1994). This indicates that the protection of threatened species by law is pivotal in the conservation of species. Moreover, when the herders were asked about their attitude towards snow leopards, the majority do not like snow leopards.

Most of the studies on pastoralist attitudes towards snow leopards in the mountain pastoralist of Asia usually showed a negative attitude towards snow leopards (Alexander et al. 2015; Bagchi and Mishra 2006; Chen et al. 2016; Ud Din et al. 2017; Mishra 1997; Namgail et al. 2007; Oli et al. 1994). Suryawanshi et al. (2014) assert that the positive attitude of the local communities towards the acceptance of carnivores in their surroundings is attributed to the prevalence and practice of Buddhism in the local communities. However, our study was not designed to determine the factors affecting the attitude of the yak herders; therefore, further investigation is imperative.

Conclusion

Our study highlights the pattern of livestock depredation of the yak herding pastoralists in western Bhutan. The yak herding pattern in the study area has been described as transhumance, as the herders move their livestock from one grazing ground to another in a seasonal cycle. The yak herding practice is similar throughout Bhutan. Yak herders in Bhutan keep a majority of yak and less of other livestock as compared to the other mountain range countries.

All the yak herders own permanent houses in the lower valleys and yak herding provides the main source of income for the family. The income is generated through the sale of products and yak meats. Yak depredation by predators and manpower shortage were reported to be the challenges faced by the yak herders in western Bhutan, but the study was not able to determine why younger youths are not willing to herd yaks. It is presumed that these were due to an increase in literacy rate and youths

being exposed to modern amenities. If this status keeps at the same pace, the number of yak herders will decrease drastically in the future. Although it is difficult to achieve, appropriate initiatives and schemes are needed to change the attitude of the mountain youths and make yak farming attractive for them.

Our study concluded that yaks in western Bhutan are more vulnerable to depredation by snow leopards. In most of the yak herding range, wolves contributed equivalent to snow leopard but there is no presence record of wolves in the current study site. Yak depredation is assumed to be mostly contributed by the improper corralling of the yaks at night but the influence of snow leopard density on yak depredation is not clear, which is recommended for further study. Young yaks are more vulnerable to snow leopards and depredation was mostly accounted for at night; thus, proper yak herding practice with proper corrals and enclosure is key to reducing yaks' loss to snow leopards. The majority of the yak herders suggested compensation of the livestock killed by snow leopard and livelihood alternatives measures to reduce yak herder's conflict with snow leopards and create harmonic co-existence between snow leopards and yak herders.

The majority of the yak herders expressed a negative attitude towards the conservation of snow leopards and they consider snow leopards as nuisance predators and do not believe in the role of snow leopards in protecting the mountain ecosystem. Few yak herders even expressed their frustration of poisoning snow leopards but most of the herders were aware of snow leopards being protected by the Forest Act and Rule of Bhutan and because of this fear, they were reluctant to kill snow leopards. The majority expressed that if snow leopards are not protected by law, they have no hesitation in killing snow leopards. The negative attitude of the yak herders towards snow leopards was assumed to be influenced by their frustration with snow leopards depredating their yak but the study lacks the design to determine factors influencing yak herder's attitude, which need further investigation. The negative attitude of the herders towards snow leopard conservation needs to be challenged by displaying goodwill from the Department of Forest and Park Services, to build trust and improve the relationship between the conservation agency and the herders. A conservation outreach programme on the role of snow leopards in keeping a healthy mountain ecosystem concerning the livelihoods of herders can educate the herders and a conservation programme aimed at both species and yak herding pastoralist level will help to improve their tolerance level for snow leopard presence and direct towards a positive perspective on snow leopard existence.

To better balance between conservation of snow leopards and the livelihood of the yak herding pastoralists,

we recommend the development of comprehensive yak herding management policies that will ensure minimal livestock losses to snow leopards and direct positive attitude of the yak herding pastoralists towards the conservation of snow leopards and maintaining healthy mountain ecosystem.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13570-022-00247-3>.

Additional file 1.

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Authors' contributions

PD designed the project, collected and coordinated field data collection, and did the analysis and drafting of the manuscript. RBP assisted in the project design and data analysis and helped in drafting of manuscripts. Both authors read and approved the final manuscript.

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Availability of data and materials

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