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Patterns of spatial distribution, diel activity and human-bear conflict of *Ursus thibetanus* in the Hindu Kush mountains, Pakistan

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ABSTRACT

The Asiatic black bear (*Ursus thibetanus*) is an elusive mammal and its conservation is currently a challenge in Pakistan due to the negative interaction with human communities and habitat fragmentation. We investigated the distribution, activity pattern and human-bear conflict of the Asiatic black bear in the Hindu Kush, a major mountains system in Pakistan. Our study was conducted from October 2020 to December 2020 in the Bahrain Valley, placed in the southeastern area of the Hindu Kush. We firstly carried out a preliminary sign survey for the bear's presence and, then, we installed an infrared sensor camera traps in the potential suitable habitat for the bear, 23 locations for 152 trap nights, to monitor its activity. Furthermore, to understand human-bear conflict, a questionnaire survey was submitted to 107 local people living in the bear's habitat. The Asiatic black bear was photographed in 12 camera stations with 60 different capture events. We obtained a trap success percent of 64.8% between 2,100 m - 2,400 m above the sea level while the total trap success calculated for the whole camera trapping survey of the bears was 39.5%. The bears showed a bimodal activity pattern with peaks just after sunset and during the night (88% of observations from 00:00 to 06:00 and 18:00 to 24:00). We observed that the female and male bears and their puppies were not hibernating in subzero temperatures until December. Local communities had concerns over livestock and crops losses in the area. Our findings showed once again that the Asiatic black bear urgently needs effective management plans to guarantee its conservation in Pakistan.

1. Introduction

The Asiatic black bear (*Ursus thibetanus*) is currently listed as vulnerable at the global scale (Steinmetz and Garshelis, 2008) and is mainly threatened by habitat loss and fragmentation, human conflicts, food depletion and poaching, (Sheikh and Molur, 2004; Escobar et al., 2015; Awais et al., 2016; Ullah et al., 2020). Despite the Pakistan's laws to protect the local biodiversity, illicit trade of endangered species, including the Asiatic black bear, still persist in the country (Mahmood et al., 2012; Rehman et al., 2015). The Asiatic black bear (hereafter referred to simply as bear) typically is a nocturnal and elusive mammal although it has been also observed during

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the day (Zahoor et al., 2021). It hibernates throughout the winter in the northwestern Himalayas (Prater, 1971) while it is usually active during the entire year in the eastern Himalayas (Roberts, 1977). Food availability and abundance are the main factors that determine its activity patterns during its life (Hwang and Garshelis, 2007; Kozakai et al., 2013). One of the most applied and easy methods to assess the bear distribution and activity patterns over an extensive area consists in the use of the heat-motion camera traps, as done in China (Akbaba and Ayas, 2012; Liu et al., 2017; Zhang et al., 2019). In Pakistan, the potential suitable habitat for the bear consists in temperate forest (Abbas et al., 2015; Goursi et al., 2021). The occurrence and distribution of the bear is well known in the Kaghan Valley and Azad Jammu and Kashmir area (Abbas et al., 2015; Awan et al., 2016; Ali et al., 2017). Currently, the bear presence has disappeared from most of its historical range in Pakistan including several areas as Ayubia National Park (Farooque, 2002; Lodhi, 2007), Astor (Bonji and Dayal), Chitral (Baranesh, Bakarabad and Ayun), Gilgit (Galaper, Lassan, Jaglot and Chakarkot), Diamer (Gonar Farm) and Skardu (Astak) (Abbas et al., 2015). The bear distribution and its interaction with the local community is well known but to our knowledge there are not studies in the Hindu Kush, a mountains system in Pakistan. It mainly happens due to the lack of investments in the conservation and research on the bear in an unexplored area such as the Hindu Kush mountains. In this study, we investigated the distribution, activity pattern and human-bear conflict of the bear in this uncharted region to provide important information on the conservation and population status of the bear in this area of the Pakistan.

2. Materials and Methods

2.1. Study area

The Bahrain Valley is extended for 790 km^2, included between 35°02'0" and 35°28'10" north latitudes and 72°22'45" and 72°48'15" east longitudes. The study area falls in temperate, dry temperate, subalpine, alpine and snowcaps zones ranging from 1,235 to 5,655 meters above sea level (a.s.l.) (Fig. 1). The maximum temperature and the mean minimum recorded in this area were 32.1 ℃ and -12.2 ℃, respectively (Working Plan for Kalam Forests, 1987 - 1988 to 2001 - 2002). Besides the bear, the leopard cat (*Prionailurus bengalensis)*, the yellow-throated marten (*Martes flavigula),* the golden jackal (*Canis aureus),* the red fox (*Vulpes vulpes),* the grey wolf

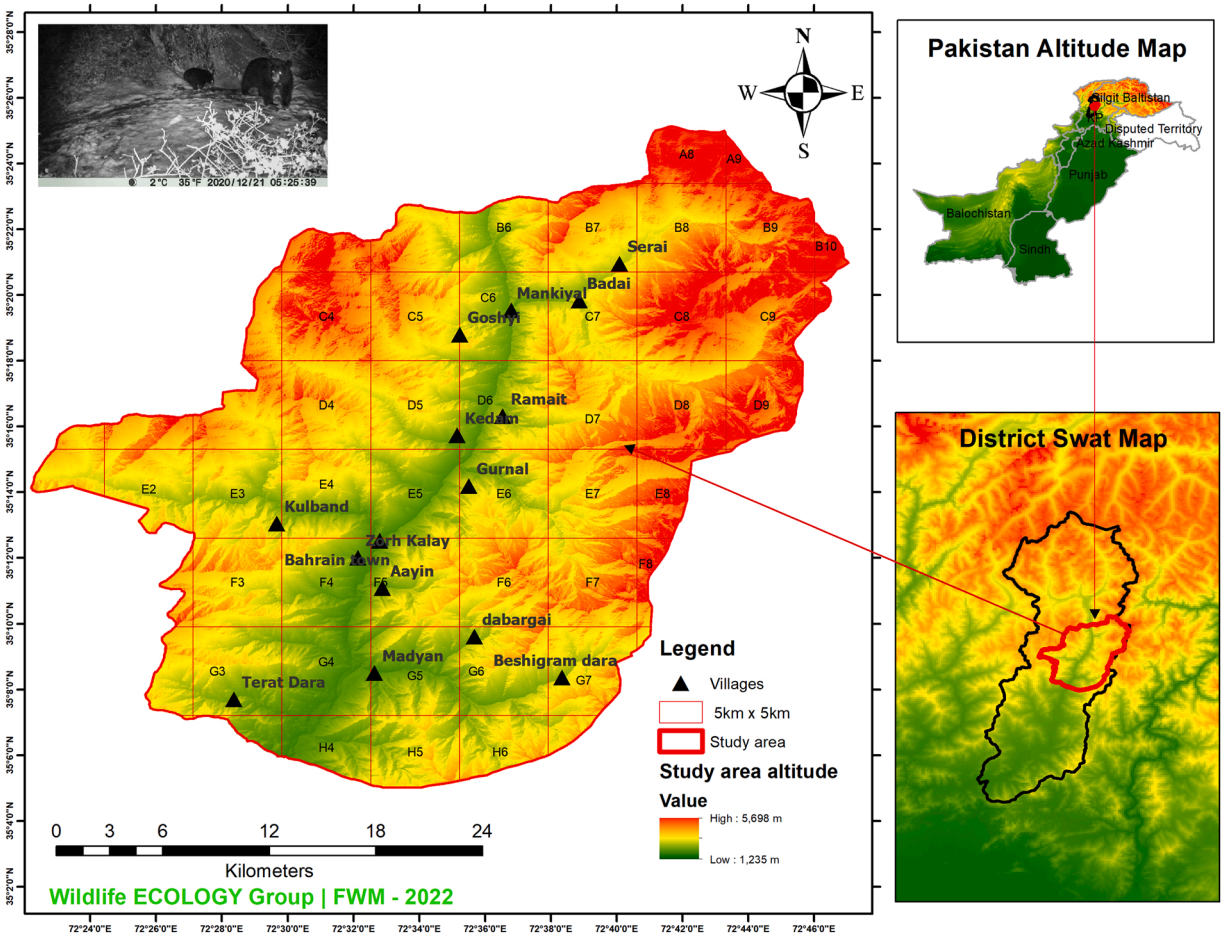

Fig. 1. Study area.

(*Canis lupus)*, the rhesus monkey (*Macaca mullata),* the Indian crested porcupine (*Hystrix indica)* and the giant Indian flying squirrel (*Petaurista petaurista)* inhabit the Bahrain Valley.

2.2. Field survey

2.2.1. Sign survey

We conducted preliminary surveys to confirm the presence of the bear in the study area (Fig. 1). We performed our survey by using sign surveys, trail tracking, ridge walking, and discussion with local shepherd. Grids of 5 km^2 were plotted over the study area using ArcGIS ver.10.8 (ESRI, 2011). Secondly, we selected five random points of 50 meters radius within each grid to look for bear's signs such as feeding remains of fruits and crops, tracks, footprints and claw marking on the trees (Kabir et al., 2017; Hameed et al., 2020; Nawaz et al., 2021). Signs were divided into two categories based on their age: fresh (<1-month-old) and old (1-12 months old). Age of claw marking was determined from the color and bark regrowth in the gouges. The coordinates of each sign location were collected through a Global Positioning System.

2.2.2. Camera trapping

Motion-sensitive cameras with infrared red flash (ZopuCam, SL122C-2) were installed in 23 different locations across the study area for 152 trap nights from October 2020 to December 2020. We set the camera station in each site by keeping a minimum distance of 1 kilometer between two nearest camera trap stations except for the areas surrounded by natural barriers such as rivers and large snow-covered steep ridges. Cameras were placed on the stem of trees at the height ranged between 40 - 60 cm above the ground.

2.2.3. Human-bear conflict interview

To understand interactions between humans and bear, interview-based questionnaire surveys were conducted from October 2020 to December 2020. This is an established procedure that has proved to be informative in similar studies (e.g., Goursi et al., 2021). We used a simple random sampling method by interviewing about 10% household from all the villages taking into account similar lifestyle and sources of revenue. We interviewed one adult person (aged>18 years). We used two approaches: 1) qualitative methods included participatory observation, group discussions, unstructured interviews and group discussions; and 2) quantitative methods comprised structured interviews (Annexure 1). In the questionnaire surveys we included: 1) socioeconomic information (name and surname, age, education, livestock types and number of livestock owned); (2) livestock depredation and crop damages (kilograms) by the bear; and (3) respondents' attitude towards the bears conservation in Pakistan (Farhadinia et al., 2017). We also asked to the interviewees to provide a rank from 1 to 6 for livestock depredation and crop damage due to the bear presence (1= least dangerous / 6= most dangerous). Efforts were made during the survey to manage interviewees' expectations. We specified that the information was collected independently, without association with local government agencies, and would not lead to special compensation for financial losses due to predation or persecution for bears poaching.

2.3. Data analysis

Multiple detections at the same camera-trap station <30 min apart were removed from the dataset to ensure independence of detections (Linkie and Ridout, 2011). Trap success (capture events/trap nights × 100) is often used as a measure of relative abundance in a camera trap sampling. Trap night was defined as a complete 24-hour period during which at least one camera in a station was functioning (Kelly and Holub, 2008; Gerber et al., 2010).

$$Trap \quad success = ai/N \times 100$$

Where 'ai' is the total number of independent photos (capture events) of the bear by all cameras and 'N' is the total number of trap nights during which camera traps were installed in the stations.Kernel density was calculated by using spatial analyst tools in ArcGIS (ver. 10.8) to develop a map for the identification of conflict hotspots in the bear habitat. A geometric interval algorithm was used to reclassify the Kernel density conflict in a raster layer (Ruda et al., 2018; Hart and Zandbergen, 2014). To investigate the activity patterns of the bear, we considered only the independent photographs that were collected after one hour of the previous picture at the same camera station. The kernel density method was used to estimate the activity pattern of the bear (Schmid and Schmidt, 2006; Ridout and Linkie, 2009), using the 'overlap' package for R (Meredith and Ridout, 2014) in R version 4.0.3 (R Development Core Team, 2013). The kernel density estimates used a bandwidth parameter, which was selected following the procedure developed by Taylor (2008).

3. Results

3.1. Field survey

3.1.1. Sign survey

We recorded a total of 91 different signs such as tracks, scats, digging and uprooting of plants, food remains, scrapes, scratches/marking on trees, resting sites and trails. We found the lowest and highest altitude sign location at 1,646 m and 3,209 m a.s.l. (Fig. 2), respectively. Approximately 81.3% of the signs were registered as fresh (<1-month-old) such as pugmarks on fresh snow or claw marks

on *Diospyros lotus* trees recently damaged or fresh scats, while 18.7% was considered as old (1-12 months old). Most of the signs were collected between 2,401–2,800 m a.s.l. (Fig. 2). The resting sites or nests of the bears were found on *Cedrus deodara* trees and on the ground in the *Quercus* forests. The prey remains were found close to the village in winter. The trails made by the bears were mainly found in the *Quercus* forest near feeding sites or water points. We observed and recorded remains of maize cobs eaten by bears and their trails through maize crop fields. The bears were found active until the end of December walking at the lower altitudes of the *Quercus* forests. We did not find bear signs in the deep snow at the highest altitude in late autumn and winter.

3.1.2. Camera trapping

Camera traps took 2,641 photos including different wildlife species in 152 trap nights. We collected 60 capture events of bears and the total trap success was of 39.5% (Figs. 3 and 4). The highest trap success for the bear was recorded between altitudinal range of 2,100 m - 2,400 m a.s.l. (64.8%) followed by 1,800 m - 2,100 m (19.1%), 2,400 m–2,700 m (12.7%) and 2,700 m–3,000 m (3.3%) (Fig. 4). The lowest altitude of the camera trap with bear detection was 1,835 m, while the highest altitude was 2,991 m. The bears were observed feeding mainly the acorns of several *Quercus* species. The bears showed a bimodal activity pattern with peaks after the sunset and during the night (88% of observations from 00:00 to 06:00 and 18:00 to 24:00) (Fig. 5). We noticed that the female and male bears and their cubs were not hibernating in subzero temperatures until the end of December.

3.1.3. Human-bear conflict interview

We interviewed 107 participants in our questionnaire which centered on the livestock depredation by the bear in the study area. The total of the domestic animals mentioned by the interviewees was 4,180 including goats (57%), sheep (35%), cattle (5%) and equine (2.9%) (Fig. 6, Tables 1 and 2). During the interview, the participants reported 182 livestock killed by the bears within the period of one year (Fig. 6, Tables 1 and 2). Bears attacks on goats and sheep were higher than the other domestic animals. The bear mainly damaged *Diospyros lotus* trees and its fruits and maize in the autumn and winter. The participants also reported seven bear attacks on humans (shepherds or hunters) in different seasons: summer (2), autumn (2), winter (2) and spring (1) (Fig. 6, Tables 1 and 2).

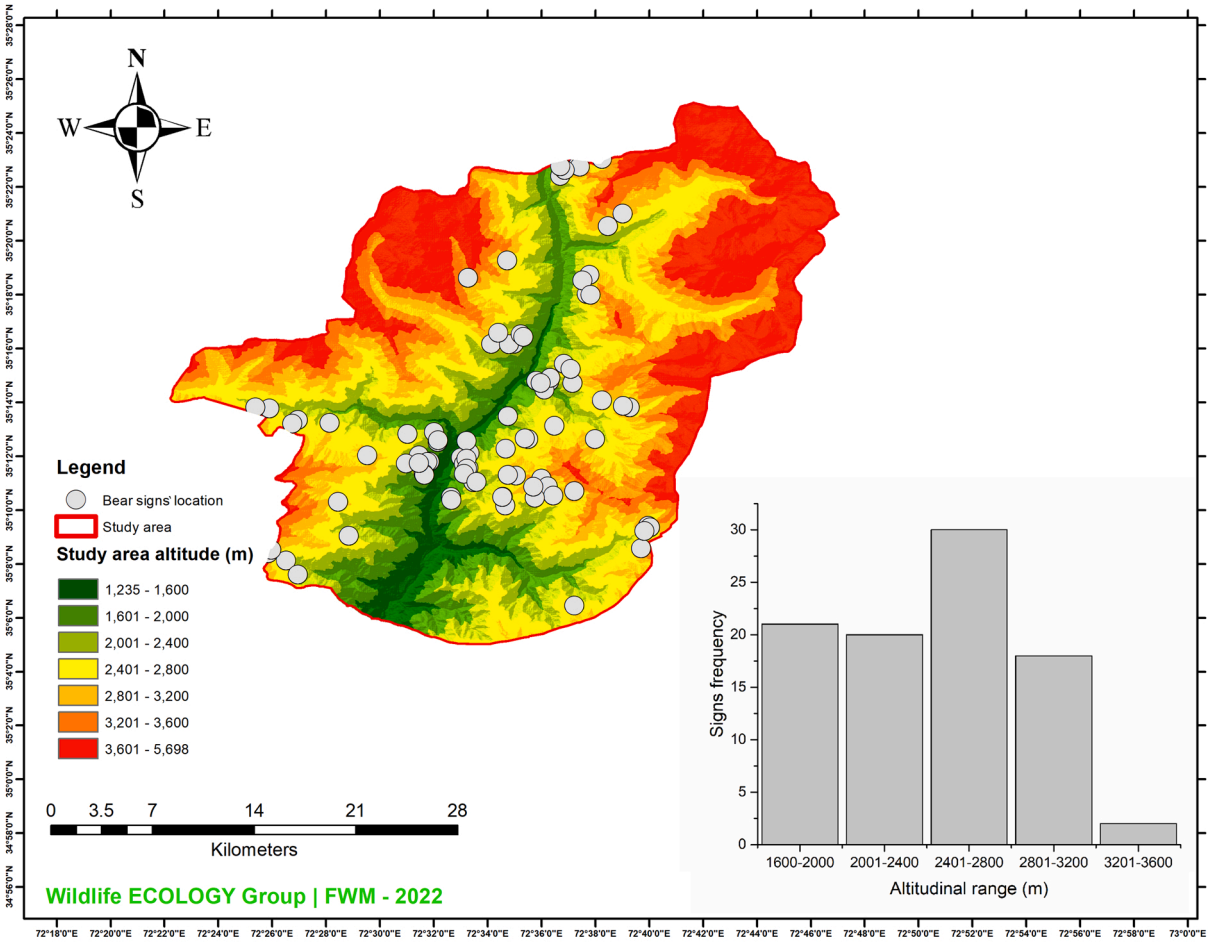

Fig. 2. Occurrence of Asiatic black bears (*Ursus thibetanus*) signs along altitudinal gradients in the study area.

Fig. 3. First photographic evidence of the Asiatic black bear (*Ursus thibetanus*) in the Hindu Kush mountains system, Bahrain Valley.

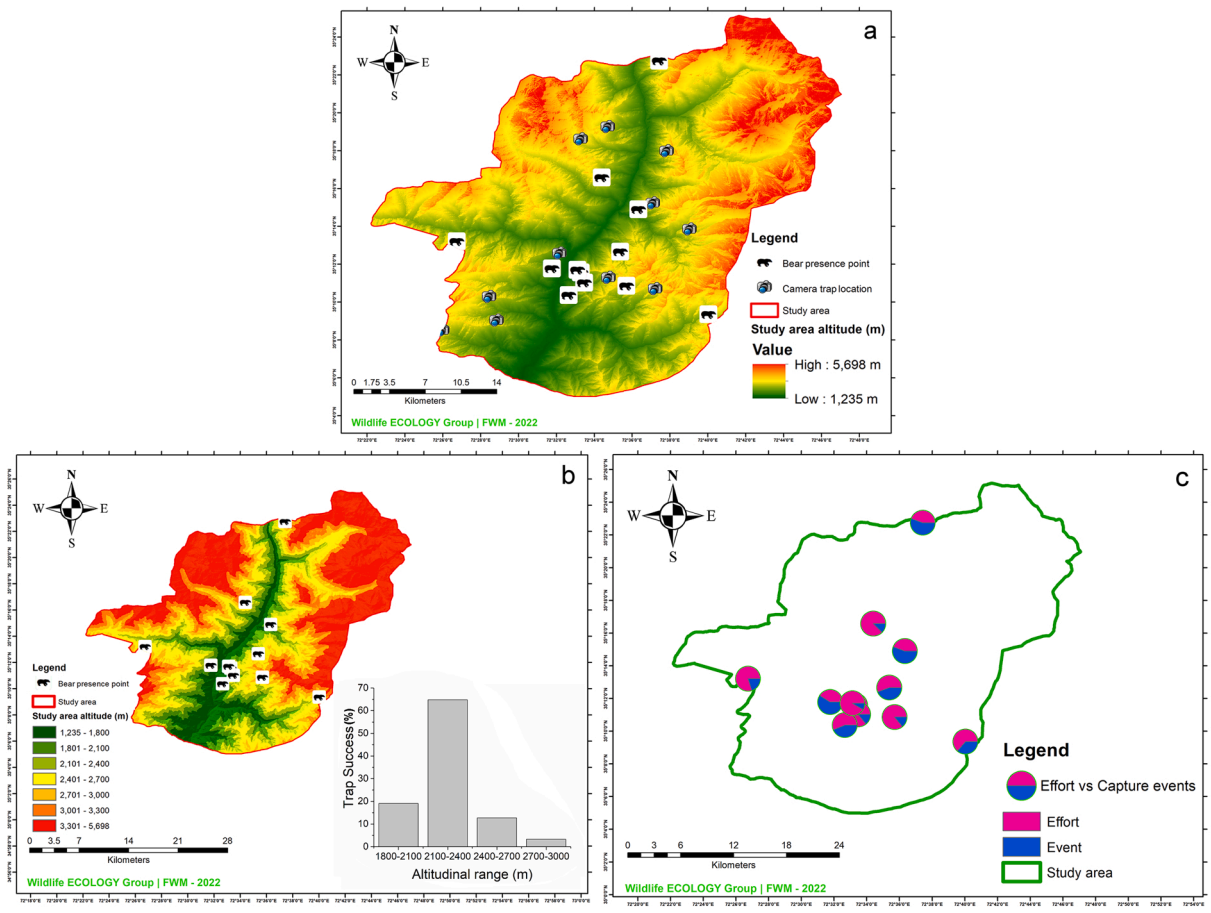

Fig. 4. Current occurrence and spatial distribution of Asiatic black bear (*Ursus thibetanus*) in the study area: (a) all camera traps stations and camera stations where we recorded the occurrences of the bear; (b) altitudinal distribution of trap success; and (c) comparison between survey efforts and capture events.

The bear was perceived by the local community as an important threat to livestock and agriculture. In fact, the participants indentified the bear as a serious threat to the livestock evaluating it as rank 5 (32.71%), followed by rank 4 (31.77%), rank 6 (26.16%) and rank 3 (9.34%). Instead for crop damage, 40.18% of the participants assessed the bear as a threat of rank 3, followed by rank 2 (28.03%), rank 4 (23.36%) and rank 1 (8.41%).

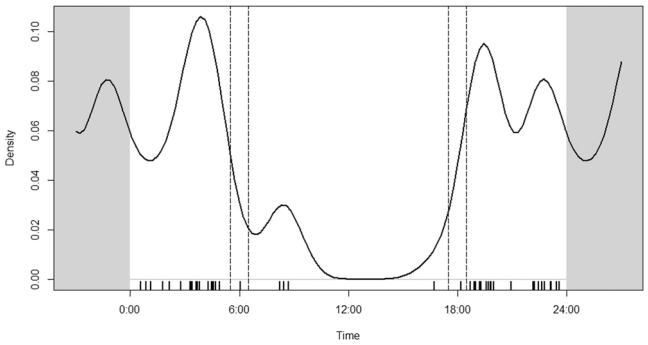

Fig. 5. Density estimation of the daily activity pattern of Asiatic black bear (*Ursus thibetanus*) in the temperate zone of the Hindu Kush mountains system.

4. Discussion

The photographs collected by our camera trap stations confirmed the presence of the Asiatic black bear in the study area and its activity until late December, unlike the other reports from Pakistan. For example, a recent study conducted in the Mansehra district (Pakistan) showed that no signs of the bear was found during the winter or autumn season (from November to March) when the temperature was below 0℃, suggesting that the bear in this area hibernated in this period (Waseem et al., 2020). The bear was active during the night and just after the sunset, mostly in the autumn and winter seasons, when acorns was abundant as suggested also by Hwang and Garshelis (2007) in the central mountains of Taiwan. Instead, different results were found by Noor et al., (2017) in the temperate forest of the Dachigram National Park where the bears mainly were active in the diurnal summer season. A potential explanation could be in the difference in the camera trap sampling. We conducted our study in autumn and winter and in this period the bear activity shifts from diurnal/crepuscular to nocturnal (Reid et al., 1991).Our study provided new information on the occurrence of the bear in the Hindu Kush mountains system in Pakistan. Although our research efforts were made between 1600-3600 m a.s.l., we found that the majority of the bear signs in the autumn and winter seasons were detected especially at elevations between 2, 401-2,800 m a.s.l. in the transition area between oak and pine forests. Similarly, Bista and Aryal (2013) reported a high occurrence of the bear in Nepal at 2,301-2,700 m a.s.l. (> 40%) and 2,701-3,100 m a.s.l. (> 25%). Ali et al., (2017) found 70% of the bear signs at an elevation of 2,000-2,300 m a.s.l. in a forest including *Abies pindrow*, *Picea smithiana*, *Cedrus deodara*, *Pinus wallichiana*, *Quercus* spp. and *Juglans regia*. Steinmetz and Garshelis (2008) showed that the home-range altitude of the bears can reach up to 4,500 m a.s.l. depending on food availability in the area.During heavy snowfalls in late autumn and winter, the bears were mainly captured at low altitudes in areas with abundance of acorn in *Quercus* forests and in *Diospyros lotus* orchards near villages. Several authors reported that the bear shifts their habitats following a change in food abundance, i.e., the seasonal migration of bears at different altitudes change with the food availability (Izumiyama and Shiraishi, 2004; Sathyakumar and Choudhury, 2007; Wang et al., 2008; Hwang et al., 2010; Kozakai et al., 2011; Garshelis and Steinmetz, 2016). The bears have a strong association with *Quercus* forests at a lower elevation because they are an important source of acorn mainly in autumn and winter seasons (Hwang et al., 2002; Hashimoto et al., 2003; Huygens et al., 2003; Sathyakumar and Viswanath, 2003). *Quercus baloot* and *Parrotia jacquemontiana* forests, with scattered trees of *Quercus dilatata,* were the main habitat for the bear where they can find food, nest and protection especially from other carnivore species and feral dogs in the autumn season. Habitats near water points such as streams and rivers with rich shrub biodiversity are well known for providing food supplies and a good canopy cover to prevent predation by other carnivore species on bear cubs (Sathyakumar et al., 2013).The bear remained active during the winter months (November and December) in the Bahrain Valley as seen in the Andean, Sun and Sloth bear (Hwang and Garshelis, 2007). A similar case to our study was reported from the central mountains of Taiwan, where the bears were active during all months, including winter (Hwang and Garshelis, 2007). In several areas of its distribution, the bears hibernate during the winter season (Schaller et al., 1989; Nowak and Walker, 1999; Reid et al., 1991) i.e., from October to May (Seryodkin et al., 2003).Our discussion with local community revealed that the human-bear conflict increased in the autumn and winter because the bears descend to lower altitudes looking for food as showed also by Awan et al. (2016) in Kashmir, Pakistan. In the autumn season, the bears occupy areas with high acorn production and regularly visit the maize fields and *Diospyros lotus* orchards near villages. Most of the incidences due to human-bear interaction occurred at the edges of the forest and in the orchards close to the villages (Honda et al., 2009). In the Kashmir area in India, Charoo et al., (2011) showed that maize, apple, cherry, pear and walnut were recorded as main food for the bear as noted also in China (Liu et al., 2011) and other regions of Pakistan (Abbas et al., 2015). To avoid human-bear conflicts and to increase the bear conservation could be useful for example to plant trees as *Quercus dilatata, Quercus baloot* and *Quercus semecarpifolia* that provide food and shelter. Acorns, wood and leaves produced by *Quercus* species are often harvested by local communities for multiple applications increasing the chances of human-bear conflict. In India, very important tree species for the bear are plant belonging to *Bambusa* spp., *Chimonobambusa* spp., *Arundinaria* spp. and *Dendrocalamus* spp. but, also in this case, these plant are commonly collected for various uses by local Sikkim people interfering with the bear activity (Sathyakumar, 2001; Stubblefield and Shrestha, 2007; Bista and Aryal, 2013).The main causes of livestock predation by the bear were poor herding practices and freely grazing livestock without proper guarding practices and precautionary measures. Goats and sheep

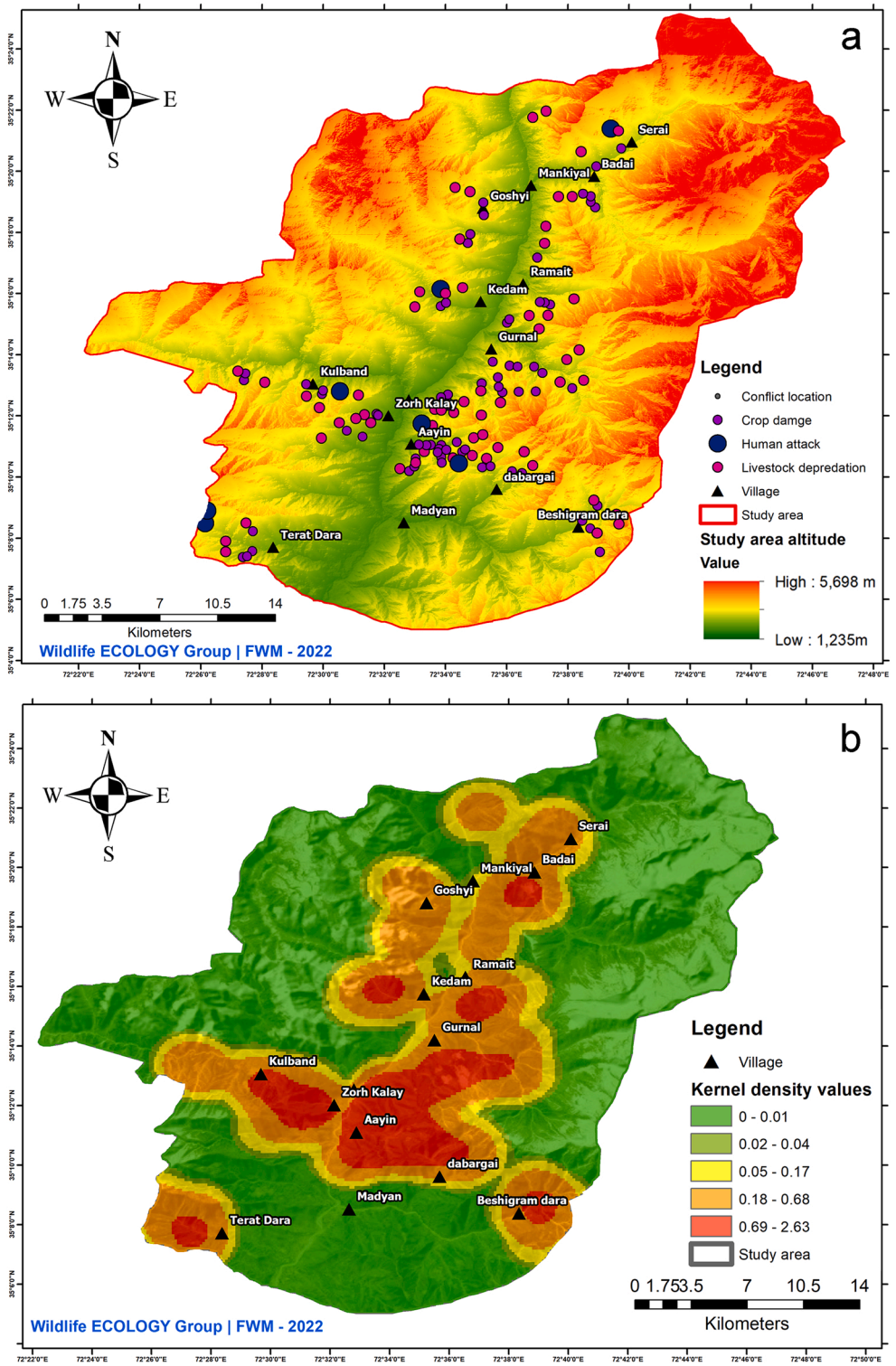

Fig. 6. Map of human-bear conflict locations and villages (a) and reclassified kernel density results of conflict intensity in Bahrain Valley (b).

were the bear's favorite prey in our study area as occurred also in the Kaghan Valley, Pakistan (Ali et al., 2018). People living close to suitable habitat of the bear need to more guarantees from the state in the protection of their livestock and orchards. For example, livestock compensation and insurance programs should be launched in these areas to compensate the economic losses of the local community due to bear attacks. But, another important alternative could be the financing of sustainable tourism activities involving of

Table 1
Details of livestock farming and predation by the Asiatic black bear (*Ursus thibetanus*) in Bahrain Valley.

	Goat	Sheep	Cattle	Others	Total
Reported livestock losses	100	51	20	11	182
Proportion by type of animal (A)	0.54	0.28	0.10	0.06	1.00
Proportion of livestock holdings in the community (B)	0.57	0.35	0.05	0.02	1.00
Selection ratio (W=A/B)	0.94	0.8	2	3	6.74
Average loss of livestock per household (mean ± SE)	0.93 ± 0.14	0.47 ± 0.09	0.18 ± 0.04	0.10 ± 0.03	1.70 ± 0.26
Livestock loss (USD)	13,500	5,100	6,250	1,031	25,881

Table 2
Details of crops damage by the Asiatic black bear (*Ursus thibetanus*) in the study area.

	Maize	*Diospyros lotus*	Total
Reported crop damage (kg)	1,419	603	2,022
Proportion by type of crop (kg)	0.77	0.33	1.00
Average crop loss per household (kg) (mean ± SE)	13.26 ± 1.41	5.63 ± 0.75	18.89 ± 1.86
Crop loss (USD)	355	188	543

the local community to decrease pressure on the habitat of the bear.

5. Conclusions

Our results confirmed the presence of the bear in the Hindu Kush mountains system and provided crucial data for its conservation and management. This species is already extinct in the Ayubia National Park and Chitral Gol National Park and further studies to increase its survival chance in the remaining area of its distribution are urgently needed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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