Insight into Occupancy Determinants and Conflict Dynamics of Grey Wolf (Canis lupus) in the Dry Temperate Zone of Hindukush Range Insight into Occupancy Determinants and Conflict D...

Article *in* Global Ecology and Conservation · December 2020

DOI: 10.1016/j.gecco.2020.e01402

6 authors, including:

Ejaz Ur Rehman
Snow leopard foundation,Pakistan

Jaffar Ud Din
Snow Leopard Trust/Snow Leopard Foundation

Shakeel Ahmad
Quaid-i-Azam University

Shoaib Hameed
Quaid-i-Azam University

Global Ecology and Conservation 25 (2021) e01402

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Insight into occupancy determinants and conflict dynamics of grey wolf (*Canis lupus*) in the dry temperate zone of Hindukush Range

Ejaz Ur Rehman [a, b], Jaffar Ud Din [b], Shakeel Ahmad [a], Shoaib Hameed [a, b], Khurshid Ali Shah [c], Tahir Mehmood [d], Muhammad Ali Nawaz [a, e, *]

[a] *Department of Zoology, Quaid i Azam University, Pakistan*
[b] *Snow Leopard Trust, Pakistan Program, Islamabad, Pakistan*
[c] *Wildlife Conservation Society, Gilgit Baltistan, Pakistan*
[d] *School of Natural Sciences (SNS), National University of Sciences and Technology (NUST), Islamabad, Pakistan*
[e] *Department of Biological and Environmental Sciences, Qatar University, Doha, Qatar*

A R T I C L E I N F O

Article history:
Received 27 May 2020
Received in revised form 3 December 2020
Accepted 3 December 2020

Keywords:
Grey wolf
Khanbari valley
Hindu kush
Occupancy
Camera trapping
Conflict
Northern-Pakistan

A B S T R A C T

The grey wolf (*Canis lupus*) is a widespread but locally endangered species across Pakistan. The current study investigates the occupancy of grey wolf and conflict with humans in Khanbari Valley Gilgit Baltistan. The study was conducted from the 5th of December 2014 to the 11th of January 2015. The study area was delineated into blocks following natural watersheds, and overall 47 motion-triggered cameras were installed in various locations encompassing an area of 810 km^2 with an effort of 1428 trap nights. A human-wolf conflict survey was carried out through questionnaires, where 57 respondents were randomly chosen from 08 villages in the valley. Grey wolf was photo-captured at 11 different camera stations, occupancy estimated at 0.37 ± 0.22 S.E., and detection probability of 0.29 ± 0.19 S.E was obtained. A total of 166 livestock were killed which incurred an economic loss of USD 17,046 (USD 299 per household) in five years. Predation on goat was highest, though consumed as per availability. Sheep predation indicates selection for this animal because predation was much higher than availability. Cattle was predated as per availability and accounts for the least part of the livestock loss. Predation of livestock was greatly influenced by four factors: habitat, prey type, prey age, and time of predation. We recommend conservation initiatives like compensation for economic losses, construction of predator-proof corrals, and awareness campaigns to promote human-wolf co-existence in the area.

1. Introduction

The grey wolf (*Canis lupus*) is the largest member of the family Canidae and found in Eurasia and North America with a broad distribution range (Sillero-zubiri and Switzer, 2004). In Asia, the distribution range of grey wolf -spreads across Russia into Central Asia and China up to Mongolia and Northern Afghanistan (Stevens et al., 2011), while in the Middle East its range

* Corresponding author. Department of Zoology, Quaid i Azam University, Pakistan.
E-mail addresses: ejazrehman53@gmail.com (E.U. Rehman), jaffar@slf.org.pk (J.U. Din), shakeel_icup68@yahoo.com (S. Ahmad), sshoaibh@gmail.com (S. Hameed), kashah.pk@gmail.com (K.A. Shah), tahime@gmail.com (T. Mehmood), nawazma@gmail.com (M.A. Nawaz).

https://doi.org/10.1016/j.gecco.2020.e01402
2351-9894/

extends from the deserts of Saudi Arabia into Iran (Cunningham and Wronski, 2010; Zarei et al., 2019). In South Asia, two separate species of wolves are identified based on genetic differences, known as the Himalayan wolf or Tibetan wolf (*Canis himalayensis*) and Indian wolf (*Canis indica)* (Aggarwal et al., 2007). These were historically recognized as two subspecies viz: *Canis lupus chanco* and *Canis lupus pallipes* (Sharma et al., 2004; Shrotriya et al., 2012). Indian wolf is adopted to lower plain and desert habitat across the many southern states of India and extends up to southern parts of Pakistan (Jhala, 2003; Shahi, 1982) while the Himalayan wolf adapted to survive in the high-altitude, in Tibetan plateau, Central Asia, Nepal, northern states of India and whole alpine and sub-alpine meadows of northern Pakistan (Joshi et al., 2020; Roberts and d'Olanda, 1977; Werhahn et al., 2020, 2018). The current study has been carried out in the northern part of Pakistan, which falls in the distribution range of the Himalayan wolf (Roberts and d'Olanda, 1977). Globally, the grey wolf has been classified as Least Concern by the IUCN Red List (Accessed on May 23, 2020). However, national assessment in Pakistan considered wolf species endangered (Sheikh and Molur, 2005).

Occupancy for a given species can be explained in terms of its occupation of a certain area at a specific interval of time specified in the sampling period. The substantial factor in monitoring the species is its detectability but it is mostly imperfect as certain species cannot always be detected in areas where they occur (MacKenzie et al., 2002). The issues of detectability should be considered to make precise inferences because non-detection of species does not indicate the genuine absence (Buckland et al., 2000; MacKenzie and Nichols, 2004). The occupancy and detection of species can be influenced by many biotic, physical, and anthropogenic factors which include season, topography, biological rhythms, weather, and sampling methods (O'Connell et al., 2006). The proportion of changes in the occupied area of a species may be associated with variation in the size of its population (Royle and Nichols, 2003). Application of presence/absence data has amplified recently for monitoring wild animals and particularly in the investigation of habitat selection (Fleishman et al., 2001; MacKenzie et al., 2002). Site occupancy delivers realistic inference being a cost-effective and reliable alternative for monitoring species hard to be individually recognized (Pollock et al., 2002). The data derived from detection/non-detection encounters of a species obtained from camera trapping can be used for estimation of occupancy of a species (Marnewick et al., 2008; Oberosler et al., 2017).

Most often, large carnivores are deemed keystone species, for the reason that as apex predators they regulate the population of prey species, which possibly have substantial effects on the ecosystem and related species as these are connected through trophic cascades (Ripple and Beschta, 2012; Treves and Karanth, 2003). Globally, human-carnivore conflict is a product of several factors including, developmental activities of humans, depredation on livestock and game species, spreading of diseases, and attacks on humans (Distefano, 2005). All these have negative repercussions for humans as well as carnivores, particularly when people reside near or inside protected areas (Mishra, 1997). Due to livestock depredation, local communities incur huge economic losses, especially where livestock is their sole source of revenue. There are also rare and random occurrences of wolves attacking humans (Krithivasan et al., 2009). Resultant to these losses, humans retribute against wildlife by shooting, hunting, or poisoning. All these reactions of people are subject to the acceptance level to the species in conflict (Frank et al., 2005). The human-wolf conflict has adverse effects on the animal and ends up in retaliatory killings of grey wolf (Fritts et al., 1997).

This phenomenon of human-carnivores conflict exists in severity across northern Pakistan due to excessive predation of livestock. Interestingly, there is a scarcity of information available on human-wolf conflicts in the country, despite the widespread significance of the burning issue (Din et al., 2013, 2017; Khan et al., 2019).

The objective of the current study was two-fold; First to understand the occupancy of the Himalayan wolf concerning environmental factors in the Khanbari Valley, Gilgit-Baltistan. Secondly, to document human-wolf conflict and its consequences for the grey wolf as well as humans in order to develop a baseline for the future conservation of the species in the area.

2. Materials and methods

2.1. Study area

The present study was conducted in Khanbari Valley (35°41′38.92"N 73°54′22.91"E) located in the Diamer District of Gilgit Baltistan. This study area is located in the dry temperate zone of Hindukush Range of Gilgit-Baltistan and it shares borders with Darel, and Karga Valleys to the north-east and River Indus lies in south respectively with an elevation range from 900 to 4700 m as shown in (Fig. 1).

This whole area falls in the arid climatic zone. The precipitation at elevated peaks and pastures may be higher and the temperature is expected as low as −15 °C, but it could n't be recorded due to the absence of a weather station. The whole study area has a richness in flora and fauna. The dominant plant species found in the area include *Pinus wallichiana*, *Pinus gerardiana, Cedrus deodara*, *Abies pindrow*, *Picea smithiana*, *Quercus ilex,* and *Juniperous communis* (Akbar et al., 2014). Fauna of the study area include snow leopard (*Panthera uncia*), grey wolf (*Canislupis*), Himalayan brown bear (*Ursus arctos*), Asiatic black bear (*Ursus thibetinus*), Musk deer (*Moschus moshiferus*), and Ladakh urial (*Ovis vignei vignei)* Roberts and d'Olanda (1977).

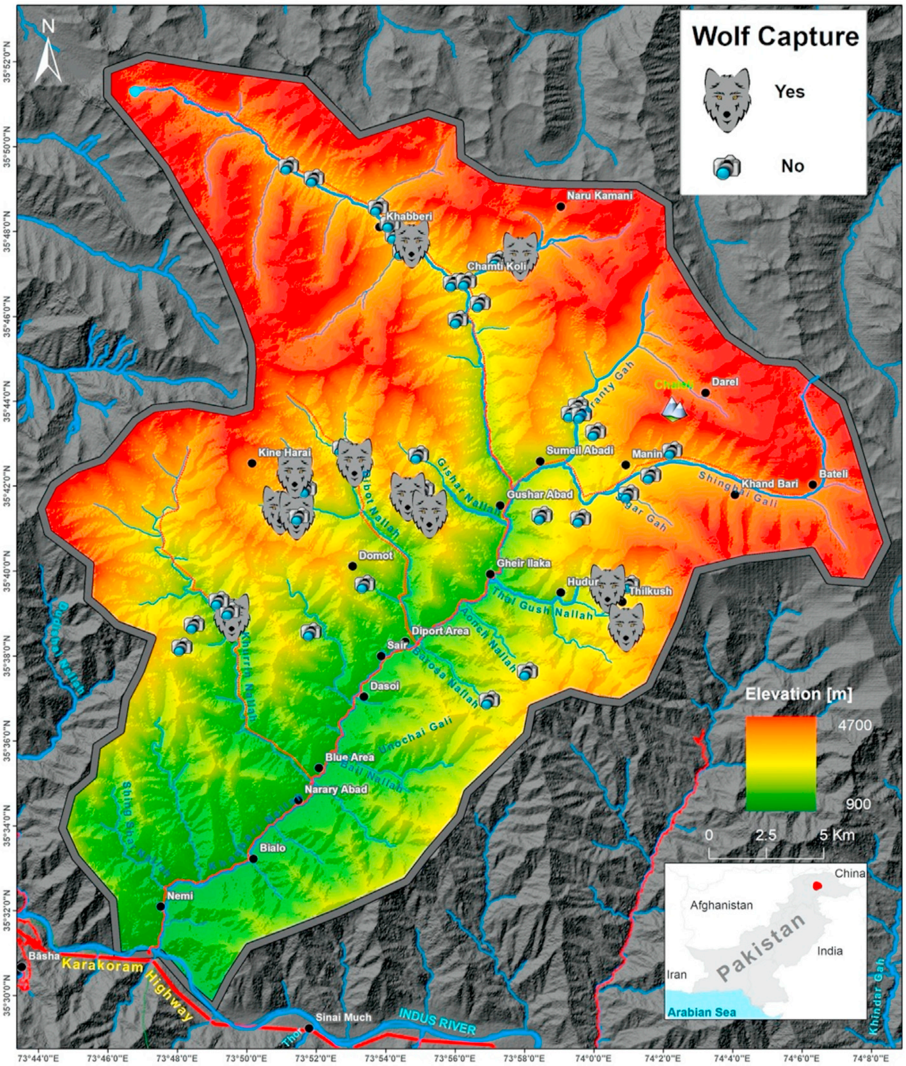

Fig. 1. Layout map of camera-trap distribution in Khanbari Valley, Diamer District Gilgit-Baltistan.

2.2. Survey techniques

Two types of survey techniques were used in the current study including camera trapping and questionnaire survey.

2.2.1. Camera trapping

Camera trapping is frequently applied for monitoring elusive, cryptic, and rare species of wildlife (Jackson et al., 2006). It is a proven technique for estimation of density, habitat suitability, occupancy, and diversity of wildlife species (Ahmad et al., 2016; Kabir et al., 2017; Karanth and Nichols, 1998). A camera trapping study was conducted in Khanbari Valley from 5th December 2014 to 11th January 2015. The whole study area was defined into blocks of comparable size based on natural watershed demarcations. A total of 47 motion-sensitive (PC900 HyperFire™ and HC500 HyperFire™ Reconyx, Holmen, WI, USA) cameras were installed at various sites in different watersheds across the study area encompassing an area of 810 km^2 (Fig. 1). A literature review of 81 studies in central and south Asia indicates that the number of cameras used in population and occupancy studies of snow leopards ranged between 20 and 50 per study area in uniform grids of various sizes ranging between 5 and 10 square kilometers (Khan, 2019).

In each watershed, locations for camera installation were selected based on the presence of scats, pugmarks, or other signs of the wolf (Ahmad et al., 2016; Kabir et al., 2017), and confluence point of multiple trails were preferred. A minimum distance of 1 km between camera stations was ensured in the majority of cameras but inaccessibility due to rough terrain, non-availability of tracks, and chances of avalanches and rockfall in knee-deep snow obstructed this exercise in few watersheds. All cameras were erected on metal poles with an approximate height of 50 cm from the ground. To eliminate the chance of false photos triggered by sunlight, cameras were fixed either northwards or southwards. All the vegetation was removed from the viewshed of the camera to avoid motion-triggered unwanted photos (Jackson et al., 2006). Castor-based lures were applied to improve the chances of capture probability and enhance the photo-capture of both flanks of animals (Bischof et al., 2014; Guil et al., 2010). All the cameras were set with the same set of triggering: three consecutive photos in one second along with recording the time and day of capture. All the relevant topographical information i.e. habitat, elevation, terrain features, etc. were documented in specific sheets given as **Annexure A of Supplementary materials**. The coordinates and elevation of every camera were obtained through the Global Positioning System (GPSMAP 62s Garmin, GARMIN Ltd, USA).

2.2.2. Questionnaire survey

Questionnaire surveys are an effective tool for evaluating human attitude, level of tolerance, and the perception of people towards wildlife (Ahmad et al., 2016). The patchy and sporadic spread of human settlements across the valley was the main obstacle to collect systematic sampling based on the proportion size of entire households in each village. Thus, interviews of 57 randomly selected respondents from villages viz. Khanbari (11 households), Bailo (08), Dasoi (09), Dobot (06), Khurran (04), Narrary (05), Naimay(07), and Saire (07) were conducted and attendance of local elders and local wildlife guard was ensured to avoid false information. A semi-structured questionnaire was utilized covering information regarding the status of predators, livestock demography, depredations, and attitude of locals to the wolf. Each section contained further questions to elaborate on the details. Color photographs of the grey wolf were displayed to the respondents to obtain reliable information in the interview session.

2.3. Analytical approach

For occupancy analysis, the photographs were thoroughly examined for wolf photos and the capture date was documented in a tabulated form for the target species. Based on capture events, an electronic sheet of trap history was formed, which included the details of when the species was trapped in cameras; “1” was assigned to the days on which the photo of the species was recorded while “0” was given to the days without capture while “−“ indicated days when the camera was not operational. Thus, the trap history revealed the detection and non-detection history of the grey wolf.

Site covariates including Normalized Difference Vegetation Index (NDVI), elevation, slope, the density of roads, and ruggedness were extracted around a buffer of 500m radius of each camera station using Spatial Analyst Tools in ArcGIS 10.3. Each camera-trap, which constitutes point sampling, represents the proportion of habitat occupied within a wolf home range during a one-month sampling period (Efford and Dawson, 2012; Neilson et al., 2018). MacKenzie et al. (2002) was followed to estimate site occupancy and detection probability for species, detection, and non-detection in Program PRESENCE by applying the single-season occupancy model (Hines, 2006; Nichols et al., 2008). Camera trapping data of wolf encounters was arranged on weekly basis to get consistent outputs. The correlation of various sites and survey covariates were checked, and to eliminate confounding effects during the analysis, some variables were dropped. Different sets of sites and survey covariates were tried to get the model that effectively described the variation in model outputs. The best model was chosen based on Akaike Information Criteria (AIC) with a minimum value that signifies a balance between fit (likelihood) and the least number of parameters (Akaike, 1974; Burnham and Anderson, 2002). To derive the final parameter estimates, top models were selected and their model averaging was carried out (Nichols et al., 2008).

In order to understand the prey selection of wolf among the available livestock from questionnaire data, we calculated selection ratio indices for prey preferences (Manly et al., 2007). Furthermore, to derive statistical inference from data, mostly the choice of the model depends on the type of response variables. Since we were interested in modeling the predation counts i.e. the response variable, we used Poisson regression. Model selection based on AIC was made through stepwise backward elimination using p-value $= 0.05$ and effects were plotted using package “effects” in R.

The predation count was modeled with explanatory factors including habitat, prey type, prey age, time, and season. Based on local knowledge, habitat was categorized into two levels: forest and pasture. There was one observation in the village and therefore it was merged into the pasture. The prey type had sub-categories like goat, sheep, and others. Others included cattle, horses, and donkeys. Prey age was classified into two-level young and adults—young were of age up to two years while more than two years were considered as adults. Time was classified as day and night. The season had subclasses as spring, summer. There was no observation for winter, and a single observation for autumn was merged with summer.

The format used in this study for the collection of data and script of the Poisson Regression model in the program “R” is given as **Annexure B of Supplementary material**.

3. Results

3.1. Camera trapping

Overall, forty-seven motion-triggered cameras were installed in various watersheds of the study area. These cameras kept on operational for a total of 1428 trap nights and obtained 30,855 photographs. Grey wolf individuals were captured at 11 camera stations at 12 different capture events (Fig. 2). A total of 276 wolf photographs were obtained. The photo-capture rate obtained for the grey wolf was 0.77 while the percentage of wolf captures was calculated at 0.89.

Fig. 2. First photographic evidence of black wolf in Khanbari Valley, Diamer District, GB.

3.2. Occupancy of himalayan wolf

Naïve occupancy estimated for grey wolf was 0.23 in Khanbari Valley during the survey. To test the impact of various environmental factors, 16 models were run in the PRESENCE program, including site and survey covariates in multiple combinations (**provided in Supplementary Material C**). No single model stood out to be the best in terms of AIC (Akaike Information Criteria), therefore model averaging of models with delta AIC<2 was conducted to obtain estimates at the site level (Table 1). The average occupancy after model averaging was estimated at 0.37 ± 0.22 S.E. and detection probability was 0.29 ± 0.19 S.E. The variables retained in the averaged models were: NDVI, Roads, Slope, and Ruggedness. All these variables had a positive effect on occupancy, suggesting that wolf preferred areas with denser vegetation, higher ruggedness, steeper slopes, and away from roads (Table 2).

3.3. Human-wolf conflict

3.3.1. Livelihood system in study area

The livelihood source in the study area, like the rest of northern Pakistan, is mainly constituted of an agro-pastoral lifestyle, where livestock is a main source of revenue. In Khanbari Valley, about 5% of households (n = 57) raised a total of 9,169 livestock with herd size averaging 161 (range 6–635) per household. Goats constituting 84.8%, followed by sheep 7.5% while cattle and others made up 5.4% and 2.2% of the herd respectively. During the year 2014, the 57 respondents sold a total of 450 livestock for USD 60,539 which resulted in an average income of USD 1,062 per household annually.

3.3.2. Public sighting and status

Interviews of 57 respondents were conducted in the 8 villages of Khanbari Valley in 2014 to assess the sightings of large carnivores; snow leopard, common leopard, grey wolf, brown bear, Asiatic black bear, and lynx present in the area

Table 1
Top Models tested for the grey wolf and their AIC weightage and values, likelihood, and number of parameters.

Model	AIC	Delta AIC	AIC weight	Model Likelihood	No. Parameters	−2*Log Like
Ψ(NDVI), p(.)	95.44	0	0.1821	1	3	89.44
Ψ(NDVI + Roads.), p(.)	95.86	0.42	0.1476	0.8106	4	87.86
Ψ(NDVI + Slope.), p(.)	96.11	0.67	0.1303	0.7153	4	88.11
Ψ(Ruggedness), p(.)	97.43	1.99	0.0673	0.3697	3	91.43

Ψ = occupancy, and p = detection probability.

Table 2
Parameter estimates of covariates retained in the top occupancy models of grey wolf.

Coefficients	β	SE
ψ (NDVI)	0.49	0.29
ψ (Roads)	0.21	0.14
ψ (Slope)	0.18	0.13
ψ (Ruggedness)	0.25	0.19

documented in the last five years. The Asiatic black bear was the most sighted species followed by grey wolf and snow leopard. The majority of respondents had few sighting for brown bear and common leopard (Table 3).

To determine the status of the carnivores, people were asked to categorize them as common, rare, or absent. A large number of respondents viewed three species; Asiatic black bear (60% respondents), grey wolf (56%), and lynx (54%) to be common in the area. About 77% of locals thought snow leopard was rare, while the majority of locals (93%) considered brown bear and common leopard were absent (Fig. 3).

3.3.3. Livestock predation and economic assessment of loss

The respondents had lost 166 livestock to wolf's predation in the last five years in Khanbari Valley. There was no significant difference in predation losses across the sampled sites (Chi-square = 0.89, p = 0.989).

The selection ratio index indicates that predation of goat though highest in proportion is predated as per availability. However, sheep predation indicates selection for this animal, because predation is much higher (2.33) than availability. Cattle and other were also predated as per availability and account for the least part of the livestock loss (Table 4).

The described figure of 166 livestock losses constituted a monetary loss of USD 17,047 (USD 299) per household) to 57 households during the last 05 years. This economic loss constitutes 28% of the overall income generated from the sale of livestock per annum. The greater economic loss occurred in the form of goat depredation, followed by cattle, sheep, and others (Table 4).

3.3.4. Factors affecting livestock predations

The top poisson regression model (AIC 172.22), retained four variables: habitat, prey type, prey age, and time of predation (Table 5, Fig. 4). The full model with variables was:

$$lmer(Predation\tilde{}\ Season + Habitat + Prey.Type + Prey.Age + Prey.Sex + Time + (1|Year), family = poisson)$$

The final selected model through stepwise backward elimination was:

$$lmer(Predation\tilde{}\ Habitat + Prey.Type + Prey.Age + Time, family = poisson)$$

The parameter estimates indicated that predation in pastures was 1.5 times higher than the forest. Among prey types, predation was highest in goats, followed by sheep. Taking other livestock (cattle, donkey, and horse), the predation rate for goat and sheep is 5 and 4 times, respectively. Similarly, wolf attacks were 2.2 times higher in adults than in the young group. The timing of predation appeared to be predictable, as predation at night was 2.4 times higher than that during day time.

3.3.5. Perceived danger of grey wolf

Wolf is perceived to be a high risk for their livestock, and a major threat to the livelihood of local communities. On a rank of 1–4 (1 = most dangerous, while 4 = least dangerous), the majority of respondents (81%) placed wolf in Rank 2 followed by Rank 3 (12%), Rank 4 (5%), and Rank 1 (2%).

4. Discussion

This study is the first to employ the use of camera traps to estimate the grey wolf's occupancy in Pakistan. Camera trapping is more dependable than sign-based or secondary studies for elusive species like grey wolf in remote and little-studied areas

Table 3
Reported sightings for carnivore species in Khanbari Valley in last five years.

Species	Total annual sighting	Average annual sighting
Snow Leopard	273	5
Common Leopard	42	1
Grey wolf	515	9
Brown Bear	42	1
Black Bear	832	15
Lynx	558	10

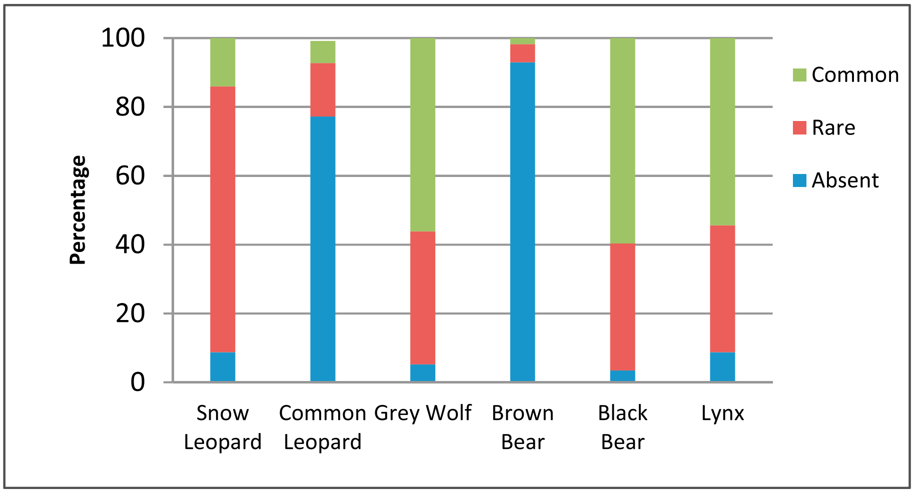

Fig. 3. Status of different carnivores in the study area based on public information.

such as northern Pakistan. This effort was aimed at bridging the information gaps in ecological data about the species here in this part of the world. This technique has been used to document elusive and wide-ranging species like the grey wolf across the word (Ilemin, 2014; Kabir et al., 2017; Subba et al., 2017).

According to Roberts and d'Olanda (1977), the northern areas are a promising homeland for the grey wolf, though empirical evidence for their occurrence is limited. The occupancy estimates obtained were 0.37 ± 0.22 S.E. comparable to one reported from other parts of the Himalaya (0.32 ± 0.12 S.E.) with similar habitat conditions (Suryawanshi et al., 2013). The high variance in the estimate is likely due to the small data set, low encounter rate, and design flaws (close installation of camera stations in comparison to home range size, partial coverage of the whole area due to inaccessibility along with harsh weather conditions). Sparse and imprecise data in large carnivore's research is common, yet invaluable to inform management measures. For example, photo-graphic evidence of species occurrence and occupancy pattern across survey sites provides first-ever empirical evidence to policymakers for targeting conservation efforts for this threatened species. Detection probability was low (0.29 ± 0.19 S.E.) than reported by Suryawanshi et al. (2013, 0.45, SE = 0.15) from India. Lack of covariate's effect on detection is probably due to short survey duration and less heterogeneous habitat.

The present study identified NDVI with a strong positive effect, suggesting that occupancy within a wolf home range was higher where vegetation is denser. According to Din et al. (2013), the grey wolf prefers alpine and sub-alpine meadows avoiding rocky hills and rugged barren mountains across the District Chitral of Hindukush landscape. The cape hare, the major prey-base in the study area, was also abundant in the densely vegetated meadows of the valley. Jedrzejewski et al. (2008) reported that the grey wolf preferred forest cover as the dominant habitat in Poland. Nowak et al. (2008) also documented wolf utilization of forests for shelter.

The occupancy was higher at locations distant from the roads suggesting that the species avoids disturbed areas. Wydeven et al. (2001) and Whittington et al. (2005) observed that a grey wolf pack selected areas located away from active roads, and trails and showed a tendency towards low-use roads and trails. Potvin et al. (2005) and Oakleaf et al. 2006 also reported that wolves avoid localities with a high density of roads to minimize encounters with humans.

Terrain features like slope, ruggedness, and elevation influenced occupancy of wolf. As affirmation from literature, Kaczensky et al. (2008) reports wolves prefer mountainous terrain over flat steppe in Mongolia through GPS data. Wild ungulates, the main prey-base of large carnivores, prefer broken and rugged terrain to avoid predators and to ensure theirsurvival and are subsequently followed by them (Schaller, 1976). Since predators follow the prey, topographic features become important for habitat use and occupancy (Rich et al., 2013).

There have been several camera trap studies carried out within the grey wolf range across northern Pakistan in the past five years; Din et al. (2013) in Chitral, Bischof et al. (2014) in Qurumbur National Park and Khunjerab National Park, Wang et al. (2014) in Khunjerab National Park, Gilgit Baltistan, Pakistan. However, a large black male was photo-captured for the first time during the current study, and we assume it is an alpha male.

The utmost prevalent factor of human-wildlife conflict across the globe is the predation of livestock by carnivores and is largely confined to the developing countries (Treves and Karanth, 2003). In the Himalayas and Hindukush ranges, increased killing of livestock by the wolf is correlated with the increase in livestock numbers (Din et al., 2013; Khan et al., 2019). The average annual livestock loss (0.58 animal/household) by wolf estimated during the current study is lower than the predation rate documented from other areas of Pakistan (1.09 per household/year) (Din et al., 2013). Globally, decline in densities of its natural prey-base is a vital factor triggering wolf predation on livestock (Meriggi and Lovari, 1996; Vos, 2000), and the same is

Table 4
Reported livestock losses by the wolf in Khanbari Valley, during the last five years (2009–2014).

	Goat	Sheep	Cattle	others	Total
Reported livestock losses	126	31	6	3	166
Proportion by type of animal (A)	0.76	0.19	0.04	0.02	1.00
Proportion of livestock holdings in the community (B)	0.85	0.08	0.05	0.02	1.00
Selection ratio (w = A/B)	0.89	2.33	0.72	0.90	4.85
Average loss of animal per household	2.2	0.5	0.1	0.05	2.85
Economic losses of livestock (USD)	10,962	1,768	3,156	1,161	17047

Table 5
Parameter estimates of Poisson regression, tested on predation by the grey wolf in Khanbari Valley, GB.

Factors	Levels	Odds Ratio	Estimate	Std. Error	z value	P-value
Intercept		0.244	−1.409	0.467	−3.016	0.003
Habitat	Forest	Reference				
	Pasture	1.486	0.396	0.175	2.262	0.024
Prey Type	Other	Reference				
	Goat	5.014	1.612	0.346	4.662	0.035
	Sheep	3.991	1.384	0.384	3.603	0.042
Prey Age	Young	Reference				
	Adult	2.242	0.807	0.293	2.756	0.006
Time	Day	Reference				
	Night	2.403	0.877	0.175	5.013	0.005

true for Gilgit-Baltistan of Pakistan, where populations of wild ungulates are on the decline in many areas (Abbas et al., 2013). This is evident from no photo-captures of wild ungulates in the study area.

Depredation of livestock causes high economic losses among pastoralists whose sole livelihood is livestock. In Khanbari Valley, the overall economic loss caused by grey wolf predation was USD 17,046 (USD 299 per household). This loss is higher than previously documented by Din et al. (2013) (USD114 per household), Ahmad et al. (2016) (USD 21), Din et al. (2017) (USD 110) but lower than Khan et al. (2019) (USD 424. 8 per household) from Pakistan. Such huge economic losses serve stimulus for hostile behavior and leading to retaliatory actions by pastoralists (Conforti and De Azevedo, 2003; Oli et al., 1994). Some 66 to 85 wolves were killed in the 2005–2006 period using firearms in retribution for attacks on livestock in Gilgit Baltistan of Northern Pakistan (Abbas et al., 2013).

The current study revealed that grey wolf depredation was higher in pastures, followed by forests and negligible in villages. A large number of depredations in pasture and forest is because of the uphill movement of the locals to their summer huts in open meadows along with their livestock which makes them prone to depredation (Ahmad et al., 2016). This study reported that goats and sheep were more susceptible than others. Khan et al. (2014) reported grey wolf killed more goats and sheep than cattle and others in Karakoram-Pamir Mountains in Gilgit Baltistan while a similar trend in the Hindukush range observed by Khan et al. (2019). It is convenient for large carnivores to kill livestock of medium size and shift them to shelter due to their lighter weight (Dar et al., 2009). This study documented that wolf depredation of adult livestock was far higher than young ones. Ahmad et al. (2016) reported that livestock herds are mostly composed of adults, while young ones are kept at home to minimize their predation risk in open meadows. The higher frequency of attacks on livestock during the night is consistent with the findings of Patterson et al. (2004) as they documented more attacks after dark.

The majority of people declared the grey wolf as dangerous carnivores, it is because of the heavy predations caused by large packs roaming in the area (Ahmad et al., 2016). The other factor to consider is the fear of attacks on humans (Behdarvand and Kaboli, 2015). Din et al. (2013) also reported that the wolf is considered the most dangerous carnivore owing to its high predation. Khan et al. (2014) reported lower predation rate of livestock by wolf than that by snow leopards. But since wolf predates on more economically valuable species like yak, it recives greater hatred. Xu et al. (2015) reported that the negative perception of wolves was directly correlated to the predation rate and the number of livestock owned by people in western China.

5. Conclusions

The results of this study confirmed the presence of the grey wolf, particularly in areas away from human activities, and documented its conflict with local people in the study area. Local people incurred formidable financial losses owing to its depredation on livestock and subsequently it was considered to be a dangerous species. The predation incidents were frequent in pastures where livestock are left for free grazing. Thus, conflict mitigation measures are vital for promoting wolf-human co-existence, which can be achieved through initiatives like compensation for economic losses, improving watch and ward practices by recruiting more wildlife staff from the same valley, construction of proper predator-proof corrals in pastures, and awareness campaigns in the local community.

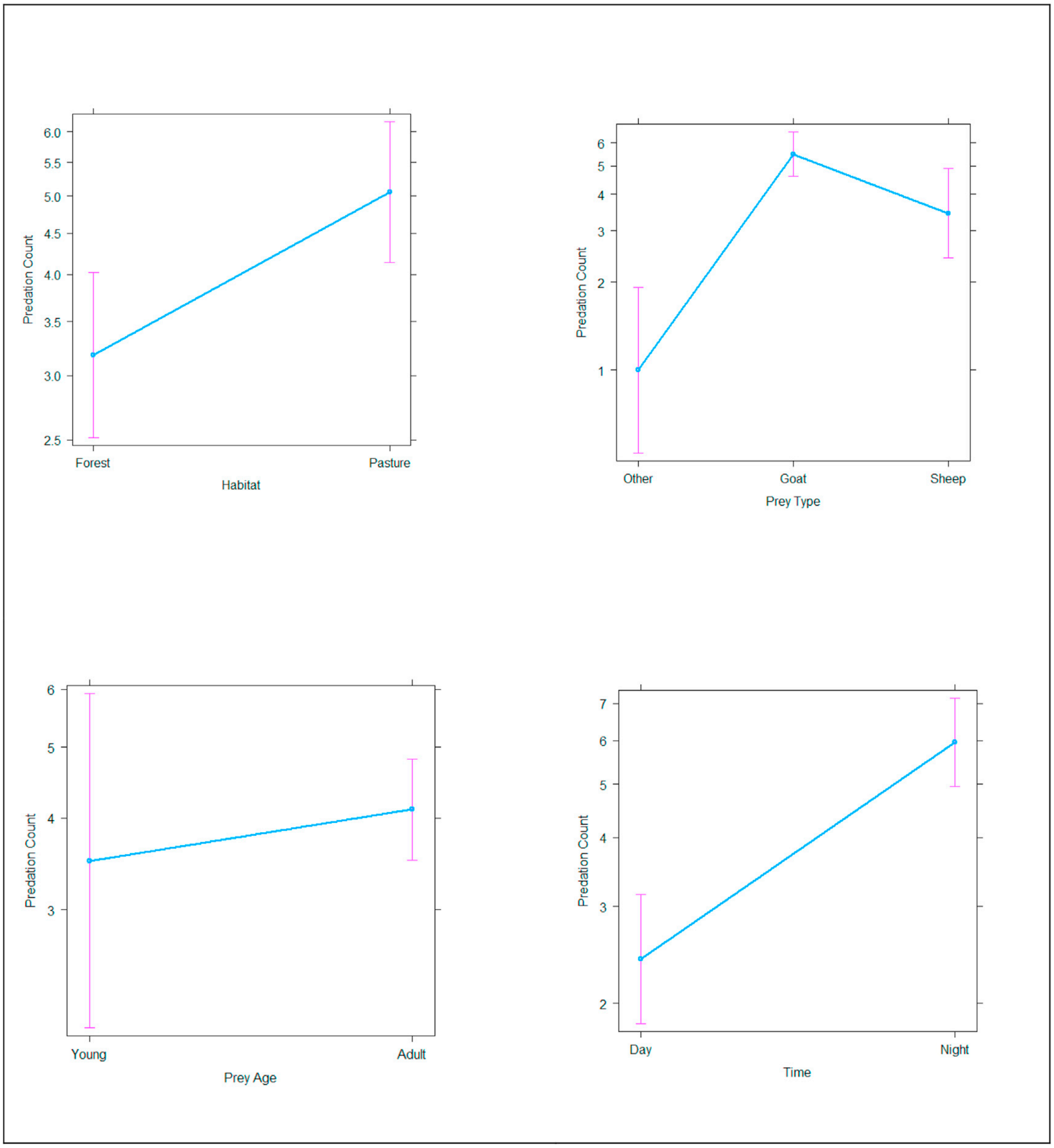

Fig. 4. Effect of different variables on predation of the wolf in Khanbari Valley, GB.

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.

Acknowledgments

We are extremely thankful to the Parks and Wildlife Department of GB for facilitating this study. The financial support of Panthera and logistic support from the Snow Leopard Foundation (SLF), Pakistan made all this possible. Mr. Siraj Khan, Field Assistant, Snow Leopard Foundation (SLF), Pakistan played a crucial role in managing the base-camps during this fieldwork. The support extended by the staff of Wildlife Conservation Society (WCS), Pakistan especially by Mr. Mayoor Khan has been pivotal in conducting this whole research on the ground. The intellectual support and guidance provided by Dr. Koustubh Sharma, Senior Ecologist, Snow Leopard Trust (SLT) in the analysis of this study were very helpful. Mr. Tauheed Ullah Khan, Mr. Fathul Bari, and Mr. Romaan Hayat Khattak helped in the analysis and provided helpful comments on initial drafts. The authors are indebted to Ms. Celesta Von Chamier for her extensive review to improve the English language.

Open Access funding provided by the Qatar National Library.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2020.e01402.

References

Abbas, F., Rooney, T.P., Mian, A., 2013. Grey wolf in Gilgit-Baltistan, Pakistan: distribution, abundance and persecution. Canid Biol. Conserv.

Aggarwal, R.K., Kivisild, T., Ramadevi, J., Singh, L., 2007. Mitochondrial DNA coding region sequences support the phylogenetic distinction of two Indian wolf species. J. Zool. Syst. Evol. Res. https://doi.org/10.1111/j.1439-0469.2006.00400.x.

Ahmad, S., Hameed, S., Ali, H., Khan, T.U., Mehmood, T., Nawaz, M.A., 2016. Carnivores' diversity and conflicts with humans in Musk deer national Park, azad Jammu and Kashmir, Pakistan. Eur. J. Wildl. Res. https://doi.org/10.1007/s10344-016-1029-6.

Akaike, H., 1974. A new look at the statistical model identification. IEEE Trans. Automat. Contr. https://doi.org/10.1109/TAC.1974.1100705.

Akbar, M., Khan, H., Hussain, A., Hyder, S., Begum, F., Khan, M., Ali, A., Hussian, S.A., Khan, G.R.S.W., Abbas, Q., Ali, S., 2014. Present status and future trend of chilghoza forest in Goharabad, District Diamer, Gilgit-Baltistan, Pakistan. J. Biodivers. Environ. Sci. (JBES).

Behdarvand, N., Kaboli, M., 2015. Characteristics of gray wolf attacks on humans in an altered landscape in the west of Iran. Hum. Dimens. Wildl. https://doi.org/10.1080/10871209.2015.963747.

Bischof, R., Hameed, S., Ali, H., Kabir, M., Younas, M., Shah, K.A., Din, J.U., Nawaz, M.A., 2014. Using time-to-event analysis to complement hierarchical methods when assessing determinants of photographic detectability during camera trapping. Methods Ecol. Evol. 5 https://doi.org/10.1111/2041-210X.12115.

Buckland, S.T., Goudie, I.B.J., Borchers, D.L., 2000. Wildlife Population Assessment: Past Developments and Future Directions. Biometrics. https://doi.org/10.1111/j.0006-341X.2000.00001.x.

Burnham, K.P., Anderson, D.R., 2002. A Practical Information-Theoretic Approach, Model Selection and Inference.

Conforti, V.A., De Azevedo, F.C.C., 2003. Local perceptions of jaguars (Panthera onca) and pumas (Puma concolor) in the Iguaçu National Park area, south Brazil. Biol. Conserv. https://doi.org/10.1016/S0006-3207(02)00277-X.

Cunningham, P., Wronski, T., 2010. Arabian Wolf Distribution Update from Saudi Arabia. Canid News.

Dar, N.I., Minhas, R.A., Zaman, Q., Linkie, M., 2009. Predicting the patterns, perceptions and causes of human-carnivore conflict in and around Machiara National Park, Pakistan. Biol. Conserv. https://doi.org/10.1016/j.biocon.2009.04.003.

Din, J.U., Hameed, S., Shah, K.A., Khan, M.A., Khan, S., Ali, M., Nawaz, M.A., 2013. Assessment of canid abundance and conflict with humans in the hindu kush mountain range of Pakistan. Wildl. Biol. Pract. https://doi.org/10.2461/wbp.2013.9.5.

Din, U.J., Ali, H., Ali, A., Younus, M., Mehmood, T., Norma-Rashid, Y., Ali Nawaz, M., 2017. Pastoralist-predator interaction at the roof of the world: conflict dynamics and implications for conservation. Ecol. Soc. https://doi.org/10.5751/ES-09348-220232.

Distefano, E., 2005. Human-wildlife Conflict Worldwide: A Collection of Case Studies, Analysis of Management Strategies and Good Practices. FAO, Rome.

Efford, M.G., Dawson, D.K., 2012. Occupancy in continuous habitat. Ecosphere. https://doi.org/10.1890/es11-00308.1.

Fleishman, E., Mac Nally, R., Fay, J.P., Murphy, D.D., 2001. Modeling and predicting species occurrence using broad-scale environmental variables: an example with butterflies of the great basin. Conserv. Biol. https://doi.org/10.1046/j.1523-1739.2001.00053.x.

Frank, K.T., Petrie, B., Choi, J.S., Leggett, W.C., 2005. Ecology: trophic cascades in a formerly cod-dominated ecosystem. Science 80–. https://doi.org/10.1126/science.1113075.

Fritts, S.H., Bangs, E.E., Fontaine, J.A., Johnson, M.R., Phillips, M.K., Koch, E.D., Gunson, J.R., 1997. Planning and implementing a reintroduction of wolves to Yellowstone National Park and central Idaho. Restor. Ecol. https://doi.org/10.1046/j.1526-100x.1997.09702.x.

Guil, F., Agudín, S., El-Khadir, N., Fernandez-Olalla, M., Figueredo, J., Domínguez, F.G., Garzon, P., Gonzalez, G., Muñoz-Igualada, J., Oria, J., Silvestre, F., 2010. Factors conditioning the camera-trapping efficiency for the Iberian lynx (Lynx pardinus). Eur. J. Wildl. Res. https://doi.org/10.1007/s10344-009-0353-5.

Hines, J.E., 2006. PRESENCE2- Software to Estimate Patch Occupancy and Related Parameters. USGS-PWRC. http://w2ww.mbr-pwr.usgs.gov/software/presence.html.

Ilemin, Y., 2014. A camera trapping survey reveals a melanistic Grey Wolf (Canis lupus) in an unusual habitat in Turkey (Mammalia: carnivora). Zool. Middle East. https://doi.org/10.1080/09397140.2014.892299.

Jackson, R.M., Roe, J.D., Wangchuk, R., Hunter, D.O., 2006. Estimating snow leopard population abundance using photography and capture-recapture techniques. Wildl. Soc. Bull. 34, 772–781.

Jedrzejewski, W., Jedrzejewska, B., Zawadzka, B., Borowik, T., Nowak, S., Mysłajek, R.W., 2008. Habitat suitability model for Polish wolves based on long-term national census. Anim. Conserv. https://doi.org/10.1111/j.1469-1795.2008.00193.x.

Jhala, Y., 2003. Status, ecology and conservation of the Indian wolf Canis lupus pallipes sykes. J. Bombay Nat. Hist. Soc.

Joshi, B.D., Lyngdoh, S., Singh, S.K., Sharma, R., Kumar, V., Prakash, T.V., Dar, S.A., Maheswari, A., Pal, R., Bashir, T., Reshamwala, H.S., Shrotriya, S., Sathyakumar, S., Habib, B., Kvist, L., Goyal, S.P., 2020. Revisiting the Woolly Wolf (Canis lupus chanco) phylogeny in Himalaya: addressing taxonomy, spatial extent and distribution of an ancient lineage in Asia. PloS One. https://doi.org/10.1371/journal.pone.0231621.

Kabir, M., Hameed, S., Ali, H., Bosso, L., Din, J.U., Bischof, R., Redpath, S., Nawaz, M.A., 2017. Habitat suitability and movement corridors of grey wolf (Canis lupus) in Northern Pakistan. PloS One. https://doi.org/10.1371/journal.pone.0187027.

Kaczensky, P., Enkhsaikhan, N., Ganbaatar, O., Walzer, C., 2008. The great gobi b strictly protected area in Mongolia - refuge or sink for wolves cards lupus in the Gobi? Wildl. Biol. https://doi.org/10.2981/0909-6396-14.4.444.

Karanth, K.U., Nichols, J.D., 1998. Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79, 2852–2862. https://doi.org/10.1890/0012-9658(1998)079[2852:EOTDII]2.0.CO;2.

Khan, B., Ablimit, A., Nawaz, M.A., Ali, R., Khan, M.Z., Jaffaruddin, R.K., 2014. Pastoralist experience and tolerance of snow leopard, wolf and lynx predation in Karakoram Pamir Mountains. J. Biodivers. Environ. Sci. (JBES) 4, 214–229.

Khan, B.U., 2019. Effect of Study Design on Density Estimates of Large Ranging Species. Quaid-i-Azam University.

Khan, T.U., Xiaofeng, L., Ahmad, S., Mannan, A., Khan, W., Khan, A.A., Khan, B.U., Din, E.U., Bhattarai, S., Shah, S., Saeed, S., Amara, U., 2019. Status and magnitude of grey wolf conflict with pastoral communities in the foothills of the Hindu Kush Region of Pakistan. Animals. https://doi.org/10.3390/ani9100787.

Krithivasan, R., Athreya, V., Odden, M., 2009. Human-wolf conflict in human dominated landscapes of ahmednagar District, Maharashtra. Rufford small grants found. Nat. Conserv. 1–53.

MacKenzie, D.I., Nichols, J.D., 2004. Occupancy as a surrogate for abundance estimation. Anim. Biodivers. Conserv.

MacKenzie, D.I., Nichols, J.D., Lachman, G.B., Droege, S., Royle, A.A., Langtimm, C.A., 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology. https://doi.org/10.1890/0012-9658(2002)083[2248:ESORWD]2.0.CO;2.

Manly, B.F.L., McDonald, L., Thomas, D.L., McDonald, T.L., Erickson, W.P., 2007. Resource Selection by Animals: Statistical Design and Analysis for Field Studies. Springer Science & Business Media, pp. 83–118.

Marnewick, K., Funston, P.J., Karanth, K.U., 2008. Evaluating camera trapping as a method for estimating cheetah abundance in ranching areas. African J. Wildl. Res. https://doi.org/10.3957/0379-4369-38.1.59.
Meriggi, A., Lovari, S., 1996. A review of wolf predation in southern europe: does the wolf prefer wild prey to livestock? J. Appl. Ecol. https://doi.org/10.2307/2404794.
Mishra, C., 1997. Livestock depredation by large carnivores in the Indian trans-Himalaya: conflict perceptions and conservation prospects. Environ. Conserv. https://doi.org/10.1017/S0376892997000441.
Neilson, E.W., Avgar, T., Cole Burton, A., Broadley, K., Boutin, S., 2018. Animal movement affects interpretation of occupancy models from camera-trap surveys of unmarked animals. Ecosphere. https://doi.org/10.1002/ecs2.2092.
Nichols, J.D., Bailey, L.L., O'Connell, A.F., Talancy, N.W., Campbell Grant, E.H., Gilbert, A.T., Annand, E.M., Husband, T.P., Hines, J.E., 2008. Multi-scale occupancy estimation and modelling using multiple detection methods. J. Appl. Ecol. https://doi.org/10.1111/j.1365-2664.2008.01509.x.
Nowak, S., Mysłajek, R.W., Jędrzejewska, B., 2008. Density and demography of wolf, Canis lupus population in the western-most part of the Polish Carpathian Mountains, 1996-2003. Folia Zool.
Oakleaf, J.K., Murray, D.L., Oakleaf, J.R., Bangs, E.E., Mack, C.M., Smith, D.W., Fontaine, J.A., Jimenez, M.D., Meier, T.J., Niemeyer, C.C., 2006. Habitat selection by recolonizing wolves in the northern rocky mountains of the United States. J. Wildl. Manag. https://doi.org/10.2193/0022-541x(2006)70[554:hsbrwi]2.0.co;2.
Oberosler, V., Groff, C., Iemma, A., Pedrini, P., Rovero, F., 2017. The influence of human disturbance on occupancy and activity patterns of mammals in the Italian Alps from systematic camera trapping. Mamm. Biol. https://doi.org/10.1016/j.mambio.2017.05.005.
O'Connell, A.F., Talancy, N.W., Bailey, L.L., Sauer, J.R., Cook, R., Gilbert, A.T., 2006. Estimating site occupancy and detection probability parameters for meso- and large mammals in a coastal ecosystem. J. Wildl. Manag. https://doi.org/10.2193/0022-541x(2006)70[1625:esoadp]2.0.co;2.
Oli, M.K., Taylor, I.R., Rogers, M.E., 1994. Snow leopard Panthera uncia predation of livestock: an assessment of local perceptions in the Annapurna Conservation Area, Nepal. Biol. Conserv. https://doi.org/10.1016/0006-3207(94)90547-9.
Patterson, B.D., Kasiki, S.M., Selempo, E., Kays, R.W., 2004. Livestock predation by lions (Panthera leo) and other carnivores on ranches neighboring Tsavo National Parks, Kenya. Biol. Conserv. https://doi.org/10.1016/j.biocon.2004.01.013.
Pollock, K.H., Nichols, J.D., Simons, T.R., Farnsworth, G.L., Bailey, L.L., Sauer, J.R., 2002. Large scale wildlife monitoring studies: statistical methods for design and analysis. Environmetrics. https://doi.org/10.1002/env.514.
Potvin, M.J., Drummer, T.D., Vucetich, J.A., Beyer, D.E., Peterson, R.O., Hammill, J.H., 2005. Monitoring and habitat analysis for wolves IN upper Michigan. J. Wildl. Manag. https://doi.org/10.2193/0022-541x(2005)69[1660:mahafw]2.0.co;2.
Rich, L.N., Russell, R.E., Glenn, E.M., Mitchell, M.S., Gude, J.A., Podruzny, K.M., Sime, C.A., Laudon, K., Ausband, D.E., Nichols, J.D., 2013. Estimating occupancy and predicting numbers of gray wolf packs in Montana using hunter surveys. J. Wildl. Manag. https://doi.org/10.1002/jwmg.562.
Ripple, W.J., Beschta, R.L., 2012. Trophic cascades in Yellowstone: the first 15years after wolf reintroduction. Biol. Conserv. https://doi.org/10.1016/j.biocon.2011.11.005.
Roberts, T.J., d'Olanda, B., (principe, 1977. The Mammals of Pakistan.
Royle, J.A., Nichols, J.D., 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology. https://doi.org/10.1890/0012-9658(2003)084[0777:EAFRPA]2.0.CO;2.
Schaller, G.B., 1976. Mountain Mammals in Pakistan. Oryx. https://doi.org/10.1017/S0030605300014071.
Shahi, S.P., 1982. Status of the grey wold (Canis lupus pallipes) in India: a preliminary survey. J. Bombay Nat. Hist. Soc.
Sharma, D.K., Maldonado, J.E., Jhala, Y.V., Fleischer, R.C., 2004. Ancient wolf lineages in India. Proc. R. Soc. B Biol. Sci. https://doi.org/10.1098/rsbl.2003.0071.
Sheikh, K., Molur, S., 2005. Status and Red List of Pakistan's Mammals, Based on Conservation Assessment and Management Plan for Mammals. IUCN, Pakistan, p. 344.
Shrotriya, S., Lyngdoh, S., Habib, B., 2012. Wolves in Trans-Himalayas: 165 Years of taxonomic confusion. Curr. Sci.
Sillero-zubiri, C., Switzer, D., 2004. Management of Wild Canids in Human-Dominated Landscapes. Canids Foxes, Wolves, Jackals Dogs. Status Surv. Conserv. Action Plan, second ed.
Stevens, K., Dehgan, A., Karlstetter, M., Rawan, F., Tawhid, M.I., Ostrowski, S., Ali, J.M., Ali, R., 2011. Large Mammals Surviving Conflict in the Eastern Forests of Afghanistan. ORYX. https://doi.org/10.1017/S0030605310000517.
Subba, S.A., Shrestha, A.K., Thapa, K., Malla, S., Thapa, G.J., Shrestha, Sujeet, Shrestha, Shrota, Subedi, N., Bhattarai, G.P., Ottvall, R., 2017. Distribution of Grey Wolves Canis lupus Lupus in the Nepalese Himalaya: Implications for Conservation Management. ORYX. https://doi.org/10.1017/S0030605316000296.
Suryawanshi, K.R., Bhatnagar, Y.V., Redpath, S., Mishra, C., 2013. People, predators and perceptions: patterns of livestock depredation by snow leopards and wolves. J. Appl. Ecol. https://doi.org/10.1111/1365-2664.12061.
Treves, A., Karanth, K.U., 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology. https://doi.org/10.1111/j.1523-1739.2003.00059.x.
Vos, J., 2000. Food habits and livestock depredation of two Iberian wolf packs (Canis lupus signatus) in the north of Portugal. J. Zool. https://doi.org/10.1017/S0952836900008050.
Wang, Yun, Wang, Yudi, Tao, S., Chen, X., Kong, Y., Shah, A., Ye, C., Pang, M., 2014. Using infra-red camera trapping technology to monitor mammals along Karakorum Highway in Khunjerab National Park, Pakistan. Pakistan J. Zool.
Werhahn, G., Liu, Y., Meng, Y., Cheng, C., Lu, Z., Atzeni, L., Deng, Z., Kun, S., Shao, X., Lu, Q., Joshi, J., Man Sherchan, A., Karmacharya, D., Kumari Chaudhary, H., Kusi, N., Weckworth, B., Kachel, S., Rosen, T., Kubanychbekov, Z., Karimov, K., Kaden, J., Ghazali, M., Macdonald, D.W., Sillero-Zubiri, C., Senn, H., 2020. Himalayan wolf distribution and admixture based on multiple genetic markers. J. Biogeogr. https://doi.org/10.1111/jbi.13824.
Werhahn, G., Senn, H., Ghazali, M., Karmacharya, D., Sherchan, A.M., Joshi, J., Kusi, N., López-Bao, J.V., Rosen, T., Kachel, S., Sillero-Zubiri, C., Macdonald, D.W., 2018. The unique genetic adaptation of the Himalayan wolf to high-altitudes and consequences for conservation. Glob. Ecol. Conserv. https://doi.org/10.1016/j.gecco.2018.e00455.
Whittington, J., St Clair, C.C., Mercer, G., 2005. Spatial responses of wolves to roads and trails in mountain valleys. Ecol. Appl. https://doi.org/10.1890/03-5317.
Wydeven, A.P., Mladenoff, D.J., Sickley, T.a., Kohn, B.E., Thiel, R.P., Hansen, J.L., 2001. Road density as a factor in habitat selection by wolves and other carnivores in the Great Lakes Region. Endanger. Species.
Xu, Y., Yang, B., Dou, L., 2015. Local villagers' perception s of wolves in Jiuzhaigou County, western China. PeerJ. https://doi.org/10.7717/peerj.982.
Zarei, F., Kafaei, S., Esmaeili, H.R., 2019. Annotated checklist and conservation status of mammals of Fars Province, southern Iran. J. Threat. Taxa. https://doi.org/10.11609/jott.4231.11.1.13087-13113.