Landscape associations of Asiatic black bears in Kashmir Himalaya, Pakistan

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Abstract: The Asiatic black bear (*Ursus thibetanus*) is threatened throughout its range and assessed as nationally vulnerable in Pakistan. Habitat degradation and loss, illegal exploitation, and human–bear conflict are key threats to the species, but there is a lack of empirical knowledge regarding its occurrence in Pakistan. In 2012, we conducted a sign survey study to classify Asiatic black bear presence in a little studied and isolated region of the Kashmiri Mountains in Azad, Jammu and Kashmir, north Pakistan. We compared bear presence in 5 habitat types (agriculture, forest, pasture, plantation, and scrubland) across an elevational range of 910 to 2,990 m. We used hierarchical logistic regression analysis to identify whether elevation, habitat and/or the interaction between the two explained bear presence in the region. Type of bear sign was significantly associated with some habitats, although claw marks were not associated with any habitat type. The strongest positive predictor of bear presence was the interaction between elevation and forest habitat, with greater presence (37.5%) in forest habitat at higher elevations between 1,890 and 2,855 m. The predicted likelihood of bears occurring in agriculture, plantation, and scrubland habitats was always <10%, regardless of elevation, and >30% in forest habitat. Our findings contribute to the national understanding of black bear presence and we provide recommendations for actions that support effective conservation management of the species in Pakistan.

Key words: Asiatic black bear, Azad Jammu and Kashmir, elevation, habitat use, hierarchical logistic regression, Pakistan, sign surveys, *Ursus thibetanus*

DOI: 10.2192/URSUS-D-20-00017.2 ***Ursus 32:article e1 (2021)***

The Asiatic black bear (*Ursus thibetanus;* hereafter, black bear) is a globally threatened species classified as Vulnerable, and, mainly due to illegal exploitation, habitat degradation and loss, and human–bear conflict, is also a species of conservation concern in 5 of its 18 range countries (Garshelis and Steinmetz 2016). The global population has declined by 30–40% over the past 30+ years, although national declines deduced from indirect surveys are as severe as >60% (in Bangladesh and Vietnam; Garshelis and Steinmetz 2016). Evidence-based measures of abundance informing population trends are lacking; current best estimates suggest that Asiatic black bear populations are decreasing in 13 of its range countries, including Pakistan (Garshelis and Steinmetz 2016), where it is assessed as nationally vulnerable (Sheikh and Molur 2004) with a previously estimated population of <1,000 individuals (Sheikh 2006). The Pakistan Wildlife Ordinance of 1970 protects the species nationally, and state-issued wildlife acts afford protection at the local level (Awan et al. 2016).

Historically, black bears occurred throughout the montane forests of Pakistan (Khan et al. 2012). However, northern Pakistan now potentially contains up to 45 populations arranged in 6 metapopulations, although only 2 of these are estimated to hold >50 individuals (284–351 individuals in Kohistan–Batagram–Mansehra; 95–124 individuals in Diamir–Astore; Abbas et al. 2015). The range and occupancy of black bear in Pakistan has declined by 33% in the past 30–40 years (Abbas et al. 2015). These declines are attributed to increasing human settlement, habitat loss through logging and livestock grazing, illegal trade in bears and their parts, and human–bear conflict in areas where bears raid crops and kill livestock

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(Sheikh 2006, Ghadirian et al. 2012, Khan et al. 2012, Charoo 2013, Ali et al. 2015, Awan et al. 2016). The live capture of bears for baiting with dogs appears to be declining (Abbas et al. 2015). Despite this, there is an absence of baseline information on distribution (Abbas et al. 2015) and systematic monitoring of, and landscape management for, the species at the national level (Awan et al. 2016).

Asiatic black bears occur in the dry and moist temperate forests and in the tropical pine (*Pinus roxburghii*) forests in the northern part of Pakistan and autonomous state of Azad Jammu and Kashmir (AJ&K, Sheikh and Molur 2004, Dar 2006, Khan et al. 2012). Bears may utilize different habitats temporally (Izumiyama and Shiraishi 2004), undertaking altitudinal migrations in response to food availability and quality (Izumiyama and Shiraishi 2004, Hwang et al. 2010). Black bears exhibit a dietary shift from more succulent vegetation in the spring months to hard mast resources in the winter (e.g., oak acorns [*Quercus incana*]; Reid et al. 1991, Hashimoto 2002, Hwang et al. 2002, Huygens et al. 2003, Charoo et al. 2009, Koike 2010). In Kashmir, bears may utilize croplands more when there is a shortage of fruits (Charoo 2013). These temporal shifts in resource utilization and potential use of agricultural crops increase the challenges of effective landscape management when assessing the bear's habitat requirements remains a primary conservation action in Pakistan (Sheikh and Molur 2004).

Given its current national and global conservation status, the increasing threats (Sheikh and Molur 2004, Garshelis and Steinmetz 2016), and the potential impact of climate change on the availability of suitable habitat and population connectivity (e.g., Aryal et al. 2012), it is increasingly important to understand how black bears use such anthropogenically affected landscapes in the region. Here we use field data from plot-based sign surveys (Steinmetz and Garshelis 2010, Lee et al. 2019) to present the probability of occurrence of black bears relative to broad habitat type and elevation in an important, yet understudied landscape in the Kashmir Mountains, Pakistan. We believe the outcomes of this will assist national conservation and landscape managers in applying adaptive management approaches that help reduce human–bear conflict and habitat degradation and loss in this part of the western Himalaya.

Study area

The study area of the Pir-Chinasi–Pir-Hasimar mountains (34°22–12′N, 73°30–47′E) covers 406 km^2 in the state of Azad Jammu and Kashmir (AJ&K), Pakistan, and falls within the Western Himalayan biodiversity hotspot (Myers et al. 2000; Fig. 1). It is also at the western limit of the bear's contiguous extant distribution (Garshelis and Steinmetz 2016). Elevation ranges from 900 to around 3,500 m (AJ&K Bureau of Statistics 2018). The climate is subtropical with an average annual rainfall of 1,280 mm (Dar 2006). Most rainfall occurs during March and April, May is the driest month, and there is heavy winter snowfall (Choudry 1975, Mir 1999). The lower reaches of the predominantly south-facing slopes are thickly distributed with human settlements, interconnected by roads or tracks, which are steadily increasing and affecting the natural resources of the area (AJ&K Bureau of Statistics 2018).

Subtropical chir pine forest, mixed coniferous forests, and subalpine–alpine pastures characterize the vegetation zonation of the study area (Choudry 1975, Mir 1999). *Pinus roxburghii* dominates chir pine forest found between 760 to 1,525 m, with blue pine (*P. wallichiana*) present in the upper reaches of this elevational range. Other tree species include *Punica granatum* and members of the genera *Berberis, Ficus, Grewia,* and *Quercus.* Mixed coniferous forest replaces chir pine forest above 1,525 m, with blue pine the dominant species. Above 2,950 m, subalpine–alpine pastures replace forest habitat, with species of *Juniperus* and *Salix* the main vegetation components (Choudry 1975, Mir 1999). The people who live near forest areas also used forest resources for different purposes, such as gathering raw vegetables, timber, and firewood, and grazing livestock. The area also has potential to grow fruits such as apples, apricot, peaches, etc., but this does not occur on a commercial scale yet (Awan 2014).

Methods

We divided the study area into 17, 5 × 5-km grid cells using ArcGIS and randomly established 10 survey plots of 50-m radius within each cell. Our plots covered an elevational range of 915 to 2,991 m; there is no forest habitat above this elevation in the study landscape. We conducted surveys of Asiatic black bear sign in each plot from June to September 2012. We visited each survey plot once and searched it thoroughly, recording any sign of feeding, footprints, claw marks on trees, and feces as positive indication of bear activity within a plot (Steinmetz and Garshelis 2010, Lee et al. 2019). We only included bear sign we classified as fresh (<3 months old; Ali et al. 2017) to ensure sign ages were commensurate with the temporal framework of the study. The distribution of black bear may overlap with that of brown bear

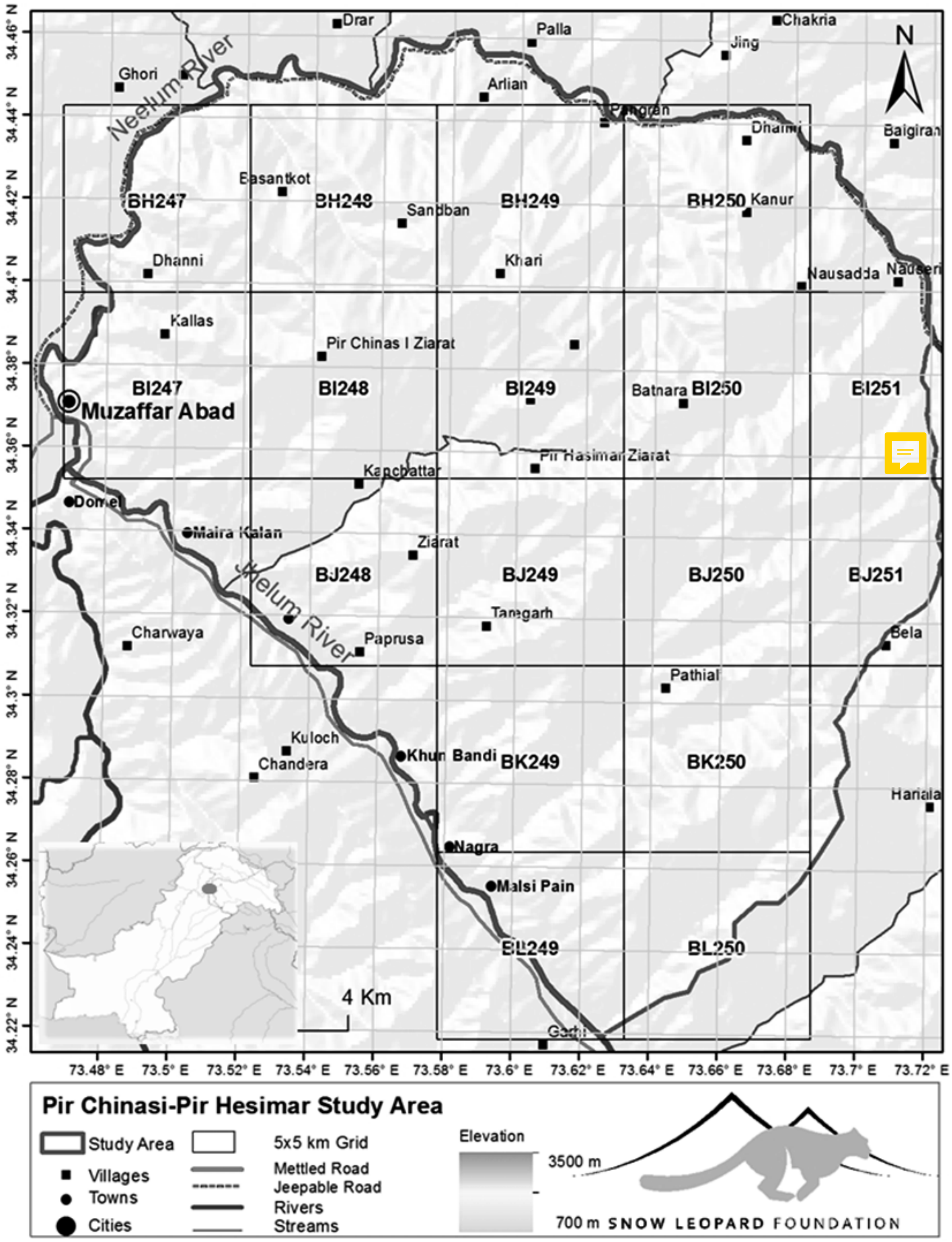

Fig. 1. Location of the Pir Chinasi–Pir Hasimar mountains study area, Azad Jammu and Kashmir, Pakistan, where we conducted a sign survey study to classify Asiatic black bear (*Ursus thibetanus*) presence during 2012. The image includes the 5 $\times$ 5-km survey grid cells.

Table 1. Number of plots surveyed during 2012 in each habitat in the Pir Chinasi and Pir Hasimar mountains study area, Azad Jammu and Kashmir, Pakistan, with the proportion of those with new Asiatic black bear (*Ursus thibetanus*) sign, and the naïve occupancy for each site (±SE). Habitat codes: A (Agriculture), F (Forest), Pa (Pasture), Pl (Plantation), S (Scrubland). For ease of interpretation, plots in bold highlight where bears were recorded as present. '-' Indicates no plots in that habitat at that site. We have ordered sites by increasing elevation.

Site	Average elevation (range; m)	Overall site occurrence (0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0)	Habitat (plots with bear sign/total plots)				
			Pl	S	A	Pa	F
BL249	1,189 (930–1,570)		-	0/5	0/5	-	-
BK249	1,520 (1,114–2,130)		0/2	0/7	0/1	-	-
BJ248	1,528 (1,037–2,080)		-	0/4	0/4	-	0/2
BH247	1,586 (1,006–2,076)		0/6	0/2	0/1	-	0/1
BI247	1,593 (91[illegible]–2,221)		0/2	0/1	0/3	-	0/4
BL250	1,624 (1,088–2,126)		0/5	0/3	0/2	-	-
BH250	1,933 (1,250–2,523)		-	0/4	-	-	**5/6**
BI251	1,934 (1,430–2,260)		-	0/2	-	-	**2/8**
BH248	2,057 (1,230–2,542)		-	0/2	-	-	**4/8**
BI248	2,069 (1,437–2,587)		-	0/3	0/3	-	0/4
BH249	2,216 (1,618–2,855)		-	**1/1**	-	-	**5/9**
BK250	2,222 (1,674–2,572)		-	0/1	0/2	-	**3/7**
BJ249	2,245 (1,790–2,616)		0/1	-	0/1	-	**5/8**
BJ251	2,355 (1,861–2,795)		-	0/1	-	-	**1/9**
BJ250	2,396 (1,944–2,784)		-	0/1	0/1	0/1	**1/7**
BI250	2,472 (1,970–2,950)		-	-	**1/1**	**1/3**	**3/6**
BI249	2,555 (1,971–2,991)		-	-	-	0/1	**4/9**
Overall		0.21 ± 0.06	0.00± 0.00	0.07 ± 0.07	0.09 ± 0.09	0.11 ± 0.11	0.31 ± 0.07

(*Ursus arctos*) above 2,500 m in Pakistan (Nawaz 2007), although perhaps more typically over 3,000 m elevation (Garshelis and Steinmetz 2016), but there are no records of brown bear in this landscape, so we are confident that all sign was attributable to black bear. We categorized the habitat (or land use) at each plot as either agriculture, forest, pasture, plantation, or scrubland and recorded elevations using Global Positioning System. Plantations include all planted forests in the mountains, irrigated areas, riverbanks, and trees planted in barren areas and on homesteads and farmlands. Whereas scrubland is landscape comprising a plant community characterized by vegetation dominated by shrubs, it often also including grasses herbs.

Agriculture predominantly consists of corn (*Zea mays*), which is the only crop of the area. Fruit trees, such as peach, apple, walnuts, etc., are found in study area. Feeding signs were primarily found in corn fields, whereas feces also were recorded as evidence of presence along with other signs.

We combined all sign data into one category for bear presence or absence, and used a Fisher's exact test to investigate any associations between sign occurrence and habitat type. Presence–absence count data fulfilled the test's assumption of expected frequencies (Howell 2012; all expected counts were >1). We used the standardized residuals to identify the direction and significance of combinations of sign type and habitat categories.

We ran an initial hierarchical logistic regression analysis using 3 potential predictors of bear presence (binomial response variable): elevation, habitat, and the interaction between elevation and habitat. We determined the model of best fit from these predictors using block and model chi-square statistics. We then repeated the analysis using the model of best fit to identify any sources of bias, and checked for multicolinearity and logit linearity. We assessed overall, final model fit using a Hosmer–Lemeshow goodness-of-fit test (Hosmer and Lemeshow 2000).

Results

We classified 88 of the 170 plots (51.8%) as forest, 37 (21.8%) as scrub, 24 (14.1%) as agriculture, 16 (9.4%) as plantation, and 5 (2.9%) as pasture (Table 1; Fig. 2). We detected fresh bear sign (<3 months old) in 36 of the 170 plots (21.2%). In these plots, we recorded 4 types of sign: bear scat in 15 of the 36 plots (41.7% of all sign), claw marks in 6 plots (16.7%), feeding sign in 5 plots (13.9%), tracks in 4 plots (11.1%), and scat and tracks together in 6 plots (16.7%). Site-based occurrence of bears based on fresh sign ranged from 0.0 to 0.6 (n = 10/site), with a mean of 0.21 ± 0.06 (Table 1).

The highest proportion of plots with fresh bear sign detected in them was in forest habitat (33 of 88 plots (37.5% of forest plots); Table 1). Forest plots covered an elevational range of 1,390 to 2,970 m, with bear sign recorded between 1,890 and 2,855 m (Table 2). Of the remaining plots with bear sign, we recorded one each in pasture (at 2,190 m; 20.0% of pasture plots; range of 2,190–2,991 m), agriculture (at 2,093 m; 4.2%; range of 915–2,093 m), and scrubland (at 1,618 m; 2.7%; range of 1,028–2,618 m) habitats (Tables 1, 2). We did not detect any bear sign in plantations or below 1,618 m elevation. Overall, we recorded 88.9% of all sign (weighted by sampling effort per 100-m elevation band) between 2,000 and 2,700 m.

The presence of bear sign was significantly associated with habitat (Fisher's = 44.073, P < 0.001), and the size of the effect of habitat type on sign presence was significant (Cramer's V = 0.496, P < 0.001). Bear sign was positively associated with forest (z = 3.785, P < 0.001; 25.3% of counts) and negatively associated with agriculture (z = −2.188, P < 0.01), plantation (z = −2.103, P < 0.01), and scrubland (z = −2.573, P < 0.01). When considering type of sign, footprints and feces were positively associated with forest (z = 3.439, P < 0.001; 15.7% of counts) and negatively associated with scrubland (z = −2.426, P < 0.01; Fisher's = 39.308, P < 0.001; Cramer's V = 0.305, P < 0.001). Feeding sign was positively associated with pasture (z = 2.465, P < 0.01), but claw marks were not associated with any habitat type.

The logistic regression model of best fit included all 3 effects: elevation (χ^2 = 23.623, P < 0.001), habitat (χ^2_{Block} = 18.688, P = 0.001; χ^2_{Model} = 42.311, P < 0.001), and an interaction term between elevation and habitat (χ^2_{Block} = 13.305, P = 0.010; χ^2_{Model} = 55.616, P < 0.001). The predictor variables fitted the data adequately in the final logistic regression model (Hosmer–Lemeshow test: χ^2_7 = 14.008, P = 0.051). The elevation–habitat interaction (Z^2_4 = 19.400, P = 0.001) and, specifically, the interaction between elevation and forest habitat (ß = 0.001, Z^2_1 = 9.901, P = 0.002) was a significant positive predictor of bear presence (Fig. 3). The interaction between elevation and forest had an odds ratio of 1.001 (95% confidence interval = 1.000–1.002), indicating that, as this interaction increases, so too does the likelihood of bears being present.

Discussion

Understanding patterns of species' occurrence and habitat association are fundamental for effective conservation management where natural habitats of the species have already been fragmented by human encroachment, economic development, and unsustainable land-use practices (Visconti et al. 2011, Awan et al. 2016, Bista et al. 2018). Protected area planning and management increasingly use models of species occurrence to advance such conservation initiatives (Cocks and Baird 1989, Araújo and Williams 2000, Williams and Araújo 2000, Polasky and Solow 2001, Johnson et al. 2004). We hope our findings contribute to effective conservation management of Asiatic black bear in this portion of its range.

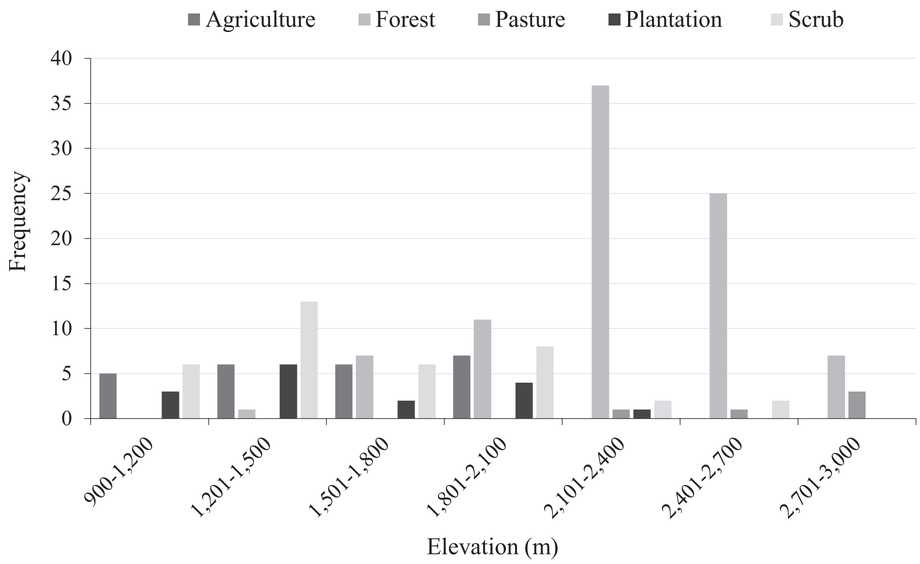

Fig. 2. Frequency of sign survey plots surveyed during 2012 to classify Asiatic black bear (*Ursus thibetanus*) presence in each habitat across all elevations in the Pir Chinasi and Pir Hasimar mountains study area, Azad Jammu and Kashmir, Pakistan.

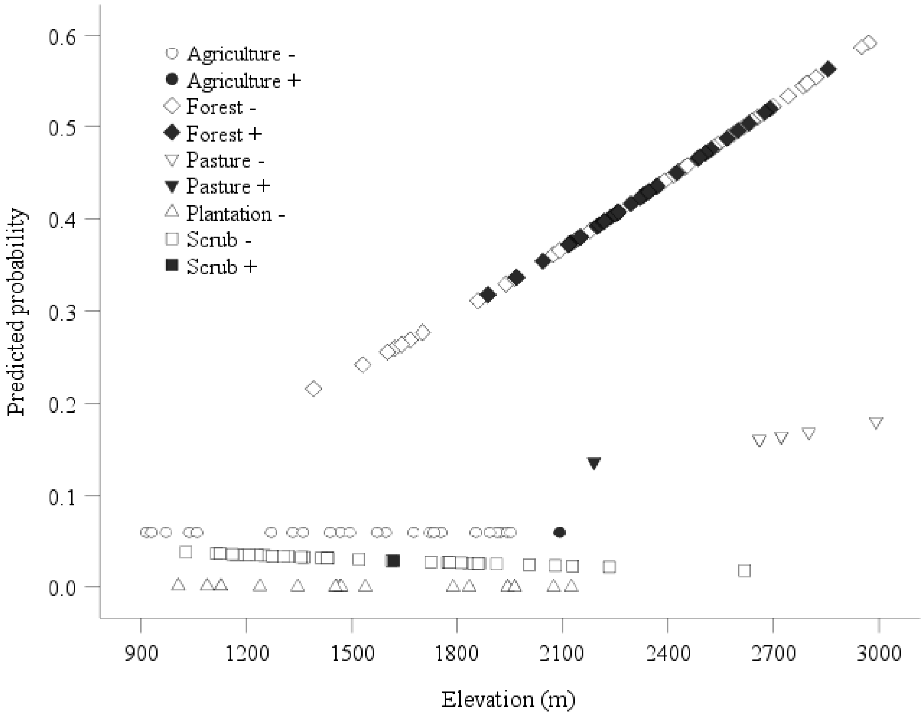

Fig. 3. Predicted probability of Asiatic black bear (*Ursus thibetanus*) presence in relation to elevation and habitat, with positive records of bears (derived from a sign survey study to classify bear presence in 2012) included as filled symbols, in the Pir Chinasi and Pir Hasimar mountains study area, Azad Jammu and Kashmir, Pakistan.

Table 2. Elevation range surveyed during 2012 to classify Asiatic black bear (*Ursus thibetanus*) presence in each habitat type in the Pir Chinasi and Pir Hasimar mountains study area, Azad Jammu and Kashmir, Pakistan. Asiatic black bear presence ('1' in bold) or absence ('0') is assigned to 100-m bands. An absence of any survey plots within an elevation band is indicated by '-'. Arrows represent the range of elevations at which each habitat type was recorded.

Habitat	Elevation (m)																				
	900	1,000	1,100	1,200	1,300	1,400	1,500	1,600	1,700	1,800	1,900	2,000	2,100	2,200	2,300	2,400	2,500	2,600	2,700	2,800	2,900
Agriculture	0	0	-	0	0	0	0	0	0	0	0	**1**									
Plantation		0	0	0	0	0	0	-	0	0	0	0									
Scrubland		0	0	0	0	0	0	**1**	0	0	0	0	0	0	-	-	0				
Pasture													**1**	-	-	-	-	0	0	0	0
Forest					0	0	0	0	0	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	0	**1**	

Generally considered a forest species (Garshelis and Steinmetz 2016), Asiatic black bears tend to be found in areas with a more closed canopy and little human disturbance (Charoo et al. 2009). We also recorded the highest frequency of bear sign in forest habitat, a proxy for undisturbed areas, followed by pasture, agriculture, and scrubland, with no sign of bears found in plantations. The likelihood of detecting bear sign was also greater in forest than in other habitats, indicating a preference for this habitat (Garshelis and Steinmetz 2016). Although we did record bear sign in human-modified habitats, there was no statistical relationship between these and bear presence. This supports the reasoning that bears do not preferentially select these habitats, but utilize them intermittently (Huygens et al. 2003, Garshelis and Steinmetz 2016), perhaps to minimize human interaction at least during our study period (Jun–Sep).

Driven by the demands of a growing human population (Awan et al. 2016), forest loss continues to threaten the conservation status of Asiatic black bears in Pakistan: from 1990 to 2010, Pakistan lost 33.2% of its tree cover and an additional 12.7% to 2015 (FAO 2015). This is indicative of wider concerns, with ≥10% of the potential global distributional area for black bears now not suitable, owing to human encroachment (Escobar et al. 2015). Nevertheless, perhaps an encouraging basis for future conservation management in the region is that AJ&K state gained 231 ha of tree cover from 2001 to 2012 (Global Forest Watch 2014). This is the second highest regional gain and more than twice the regional average during this period; 15% of the state remains forested, which is the highest level of tree cover in Pakistan (Global Forest Watch 2014).

Our records of bear presence are consistent with the altitudinal range reported for black bears in Pakistan (Ali et al. 2017), and with similar studies elsewhere in the western Himalayas (Sathyakumar and Choudhury 2007, Charoo et al. 2009, Aryal et al. 2012). We did not record bear presence from 915 m to ~1,620m, irrespective of habitat type, but detected the majority of bear sign at mid- to upper elevations, which is similarly reported in Nepal, even when lower and higher elevations were surveyed (Bista and Aryal 2013). Although nonforest habitat dominated lower elevations in our study area, the lack of records may suggest an absence of occurrence in lower elevations based on food availability in the area (Izumiyama and Shiraishi 2004, Hwang et al. 2010), particularly fruits (at least during the time of the year of our study [Jun–Sep]). Equally, at other times of the year (Reid et al. 1991, Hashimoto 2002, Hwang et al. 2002, Huygens et al. 2003, Charoo et al. 2009, Koike 2010), or during periods when there is a shortage of fruits (Charoo 2013), bears may range into agricultural landscapes (Charoo et al. 2009). Consequently, this may then drive seasonal fluctuations in human–bear conflict in this landscape. In addition to temporal shifts in habitat use, this increases the challenge of effective conservation management for bears in Pakistan (Sheikh and Molur 2004).

Our findings indicate that bears are more likely to be present at higher elevations, where forest habitat is more prevalent, with habitats of lower altitudes indicative of human activity, generally. Undoubtedly, bear conservation requires better retention of forest habitat in this landscape, especially when increasing costs associated with human–bear conflict and crop raiding are attributable to forest loss and bears shifting habitat utilization and resource use (Huygens et al. 2003, Hwang and Garshelis 2006, Bista and Aryal 2013, Skripova 2013, Ali et al. 2015). However, although consideration and action for regenerating and restoring forest habitat at lower elevations, which is the favorable approach to take in these study landscapes, may be societally and economically limited in the short term, we recommend a land-use management strategy that helps mitigate for human–bear conflict. In the western Himalayas, ~60% of human–bear conflicts occur within 250 m of forested habitat, only 1–2% of conflicts occur beyond 1 km from forest, and the majority of this conflict occurs in agricultural landscapes (Charoo et al. 2009). Within the same landscape, Awan et al. (2016) reported crop damage as a major conflict between humans and bears, which increased during the past few years and mostly occurred very close to the forest areas (i.e., <250 m; Kruskal–Wallis $H = 8.311$, 2 df, $P < 0.05$). Awan et al. (2016) further reported an increasing trend in the number of bears killed in the same landscape, with 13 bears reported killed between 2008 and 2012. We encourage a land use approach that leaves scrubland habitat as a buffer between agricultural land and plantations, where the likelihood of bears being present is <10%, and forest habitat, where there is >30% chance of bears occurring, to help reduce human–bear conflict in this landscape. Such scrubland habitats may then provide a source for natural regeneration or active habitat restoration in the longer term.

An additional consideration here is traditional pastoralism in the landscape, where community members move to alpine meadows for 3–5 months in the summer to graze livestock and utilize natural resources (Awan 2014). This practice means they and their livestock move through habitat and elevations where bears are most likely present. They tend to resolve any attacks on their livestock by shooting the bear, while also directly affecting habitat quality (Awan 2014). Documenting these impacts is important in understanding conflict history, status, and future conservation planning.

The Pir-Chinasi–Pir-Hasimar mountains have no protected area status nor dedicated wildlife protection staff, despite the presence of a number of red-listed species (Sheikh and Molur 2004). Consequently, there is little enforcement of wildlife law or, indeed, engagement with communities about wildlife conservation and sustainable utilization of natural resources. Implementing a community awareness program could be effective in conserving black bear and forest habitats in these mountains, and best served by close collaboration with the communities that depend upon this landscape. However, this needs to allay any existing negative views these communities may hold toward bears (Awan 2014), which are driven by anthropogenic demands on the landscape and competition with bears for natural resources (Awan et al. 2016).

Robust information on species presence is essential in effective conservation planning (Rondinini and Boitani 2007) and we acknowledge the limitations of our single-season field data. That said, our results provide a relative baseline for monitoring bear occurrence and conservation planning for the species, and coupled with remote sensing data, understanding spatio-temporal patterns and the broad impacts of further habitat degradation or loss to the population in this landscape (Yoccoz et al. 2001). Extrapolating our snapshot of landscape use by black bears broadly indicates that they are found in ~21% of the Pir-Chinasi–Pir-Hasimar mountains (~85.3 km^2 of 406 km^2), and ~31% of forest habitats, although we did not survey above 2,991 m and to the highest elevation of 3,500 m. Therefore, it remains important that additional, systematic fieldwork is conducted to more accurately understand the distribution of Asiatic black bears in the state of AJ&K (Awan 2014). At the very least, with suitable forest habitat found at the highest elevations in the Pir-Chinasi–Pir-Hasimar mountains, we recommend that future monitoring activities include surveys above 2,990 m to capture fully the distribution of black bears in this landscape. Incorporating camera traps is an effective approach to monitoring large mammals in mountainous regions (Jackson et al. 2005), and would help identify wider landscape use by bears, including temporal patterns, and help mitigate human–bear conflict (Awan et al. 2016). Integrating these approaches with surveys elsewhere in Pakistan would provide a cohesive approach to understanding the status, and supporting the conservation management of black bears nationally.

Acknowledgments

We would like to thank the State Wildlife Department for granting the appropriate research permits and their wildlife field staff, particularly M. Altaf, for assisting in the fieldwork. We are grateful to the Snow Leopard Foundation for their help with mapping and Geographic Information System analysis. We are also thankful to the Himalayan Nature Conservation Foundation for providing field equipment for this study. We also thank the Associate Editor and anonymous reviewers, who helped to improve the quality of this manuscript.

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Received: May 28, 2020
Accepted: February 2, 2021
Associate Editor: K. Yamazaki

Authors Queries

Journal: **URSUS**
Paper: **URSU-32-01-21_1XO**
Title: **Landscape associations of Asiatic black bears in Kashmir Himalaya, Pakistan**

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