Population estimation of Asiatic black bear in the Himalayan Region of India using camera traps

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Abstract: Robust population estimation of rare or elusive threatened species lacking distinct identifiable features poses a challenge in the field of conservation and management. The Asiatic black bear (*Ursus thibetanus*) is one such species. Methodological frameworks—such as radiotelemetry, genetic sampling, and camera-trapping—though crucial and advantageous, sometimes require additional information through invasive methods for individual identification. In this study, we estimated the population density of Asiatic black bear in 2 protected areas in the Indian Himalayan Region without information on individual identification. We conducted the study through a spatial capture–recapture framework using camera traps in the summer during May–July 2018 in Daranghati Wildlife Sanctuary (WLS) and May–July 2019 in Rupi Bhaba WLS. Using the recently developed Spatial Presence–Absence model, we estimated g_0 (detection probability), σ (scale or movement parameter related to home range of the species), and *N* (population size) of Asiatic black bears from the camera-trap data using a Bayesian framework. We estimated a population density of 2.5 individuals/100 km^2 (95% Credible Interval = 1.42–9.63 individuals/100 km^2) from Daranghati WLS and 0.3 individuals/100 km^2 (95% Credible Interval = 0.2–0.7 individuals/100 km^2) from Rupi Bhaba WLS. Abundance estimates produced by extrapolating these densities were 11 Asiatic black bear individuals (95% Credible Interval = 4–27) from Daranghati WLS and 2 Asiatic black bear individuals (95% Credible Interval = 1–3) from Rupi Bhaba WLS. This is the first population estimate of Asiatic black bear from the Indian Himalaya without individual identification. We recommend that this method, which provides minimal sampling bias and ease of sampling, can be replicated in other mountainous landscapes for a robust density estimation of this species.

Key words: Asiatic black bear, Bayesian framework, capture–recapture, density, Himachal Pradesh, individual identification, spatial presence–absence, *Ursus thibetanus*

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Conservation and management of rare or threatened species require quantified ecological data, along with baseline information, such as distribution and habitat assessments (Ngoprasert et al. 2012). Population estimation is less challenging when individuals of the species are uniquely identifiable through physical features, such as stripes for tigers (*Panthera tigris;* Karanth and Nichols 1998) or rosettes for leopards (*P. pardus*) and jaguars (*P. onca;* Silver et al. 2004, Harihar et al. 2009). Population estimation of species lacking uniquely identifiable features poses major challenges. To overcome such limitations, radiotelemetry, camera-trapping (Burton et al. 2015), or genetic sampling (Latham et al. 2012) techniques are crucial sampling frameworks for increasing the number of spatial and temporal observations of such species. However, when such species are long-ranging and reside in rugged terrains, where systematic sampling is logistically demanding, collecting samples for individual identification becomes challenging. One such species is the Asiatic black bear (*Ursus thibetanus*), a large carnivore distributed through southern and eastern Asia from the Himalayan landscapes to the Russian Far East (Mallon 1991, Garshelis and Steinmetz 2016). The species inhabits habitat types ranging from tropical forests to cold and high mountainous areas such as the alpine zones (Fahimi et al. 2011, Sunar et al. 2012, Garshelis and Steinmetz 2016).

The Asiatic black bear is distributed continuously throughout the Indian Himalayan Region (IHR), which supports one of the largest populations of the species

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(Sathyakumar 2001). The species occurs in 83 Protected Areas in India, spread across 5 States and 2 Union Territories. The species inhabits an altitudinal range of 1,200–3,300 m (Prater 1980), which may extend up to 4,300 m (e.g., beyond the tree line [Sunar et al. 2012]). Although the species is distributed all across the Indian Himalaya, ecological studies have been limited to a few protected areas (e.g., Dachigam National Park in Jammu and Kashmir, Kanchendzonga National Park in Sikkim) and the studies were focused on distribution (Sathyakumar 1999, Sathyakumar and Chaudhury 2007, Bashir et al. 2018), ranging (Sathyakumar et al. 2013), food habits (Sathyakuamar and Viswanath 2003), and other ecological aspects (Charoo et al. 2011, Sunar et al. 2012). Although the aforementioned studies are important, population and demographic parameters were not the focus of those studies. Thus, several countries within the species' range have proposed tentative population and density estimates for the Asiatic black bear (Sunar et al. 2012). In India, it was estimated as 7,000–9,000 individuals (Sathyakumar 2006, Steinmetz and Garshelis 2008).

Globally, a common method for population estimation of bears is the application of mark–recapture techniques through systematically collected hair samples (Poole et al. 2001, Kendall et al. 2008, Gardner et al. 2010). However, this method is expensive because the samples need to be individually identified first through genetic analysis before mark–recapture analysis can be carried out for population estimation. Although Asiatic black bears can be identified individually through their chest pattern (white V mark on the chest), the pattern is visible only when the animal is in an erect position on its hind legs (Ngoprasert et al. 2012, Sunar et al. 2012). Thus, it is difficult to identify Asiatic black bears through sampling methodologies such as camera-trapping and direct sightings. However, in a study in Thailand, an attempt was made by aligning 3 cameras in a triangular manner and positioning a bait in between to photo-capture the chest pattern when the animal attempts to grab the bait in a vertical position (Ngoprasert et al. 2012). Although it is a novel methodology for identification of Asiatic black bears, such a setup is logistically difficult in mountainous landscapes for population estimation of the species and difficult to replicate at a landscape level. This is because the bears are difficult to observe, often inhabiting densely vegetated and remote habitats, and are mostly nocturnal. Again, in addition to the difficulty of individual identification, the species has large home ranges and occurs naturally at low densities (Hazumi and Maruyama 1986, Reid et al. 1991).

In this regard, the analytical frameworks (Gilbert et al. 2020) available for population estimation of unmarked species are more feasible methods for estimating Asiatic black bear populations. One of the recent methodological developments in this framework is the spatial count (Chandler and Royle 2013) and spatial presence–absence (SPA) model (Ramsey et al. 2015), which provide a robust analytical framework for estimating the density of species without individual identification.

It has been suggested that, for many biological applications, density estimates are more valuable than population estimation because differences in density are likely to reflect corresponding differences in habitat suitability or anthropogenic effects (Miller et al. 1987). Further, density derived from a small study area can be extrapolated to obtain population estimates for a larger area of conservation importance. Recent advances in density estimators in the spatial capture–recapture framework can account for the bias caused by detection heterogeneity (Royle et al. 2014). We estimated the population density of Asiatic black bear in 2 protected areas of the IHR using camera traps and the spatial count model (Chandler and Royle 2013) using the Bayesian framework. This model used a hierarchical approach, which has been developed for count data with spatial and temporal correlations, excessive zeroes, uneven sampling intensities, and inference on missing spots (Agarwal et al. 2002, Wang et al. 2015). The hierarchical statistical approach estimates both systematic and stochastic parameters; it thus accommodates clustered or correlated spatial data and incorporates uncertainty in the analysis (Thogmartin et al. 2006). The Bayesian framework allows the incorporation of prior knowledge using previous ecological information of the species known as "informative prior" (Christensen and Waagepetersen 2002). Furthermore, we used an extension of the recently developed spatial count model (Chandler and Royle 2013) known as the SPA model (Ramsey et al. 2015), which allows density estimation of unmarked populations by incorporating spatially correlated detections in neighboring devices tied with supplementary information on home range size (Chatterjee et al. 2020a, b). Methods used to determine the population status of Asiatic black bears in India have been limited to questionnaires, sign surveys, and genetic sampling using hair samples (Sathyakumar 2001, Sathyakumar et al. 2013). Our study was the first attempt to estimate the population density of Asiatic black bears in the IHR without individual identification. This method can be replicated in other protected areas in mountainous landscapes with minimal sampling bias, ease of sampling, and robust density estimation.

Study area

We conducted the study in 2 protected wildlife sanctuaries (WLS) of Himachal Pradesh in India, Daranghati WLS and Rupi Bhaba WLS (Fig. 1). They are about 80 km apart and both have subtropical conditions in the lower altitudes and temperate, subalpine, and alpine conditions toward the higher altitudes.

Daranghati Wildlife Sanctuary

Daranghati WLS (31°22′–28′N; 77°47′–51′E) is situated in the Rampur Bushahr Division of Shimla District. It is a former game reserve of the Bushahr Dynasty and was notified as a sanctuary in 1962 and then renotified in 1974. The sanctuary is divided into Daranghati WLS I and II. These two discontinuous units lie on either side of the Dhauladhar Range, which forms a part of the Middle Himalaya. The total notified area of the sanctuary, including both the parts, is 168 km^2. The altitude varies between 1,900 m and 5,400 m and there are 5 main forest types: moist cedar forest, western mixed coniferous forest, moist temperate deciduous forest, Kharsu oak (*Quercus semecarpifolia*) forest, and West Himalayan subalpine forest (Pandey 1990). The sanctuary harbors mammalian fauna such as the common leopard, Asiatic black bear, Himalayan brown bear (*U. arctos*), Himalayan musk deer (*Moschus chrysogaster*), Himalayan serow (*Capricornis thar*), Himalayan tahr (*Hemitragus jemlahicus*), blue sheep (*Pseudois nayaur*), and Himalayan goral (*Naemorhedus goral*). Moreover, the sanctuary has been selected as an Important Bird Area (IBA; Criteria: A1, A2; http://datazone.birdlife.org/site/factsheet/daranghati-wildlife-sanctuary-iba-india, Accessed 2 May 2022), based on the presence of the globally threatened western tragopan (*Tragopan melanocephalus*).

Rupi Bhaba Wildlife Sanctuary

Rupi Bhaba WLS (31°3553N, 77°5213”E) is situated in the Nichar Subdivision of the Kinnaur District and covers an area of 503 km^2. It forms a part of the Shrikhand Mountains of the Dhauladhar Range in the Greater Himalaya. The altitudinal range of the sanctuary is between 2,100 m and 5,900 m and the area is characterized by glaciers, deep river gorges, and steep slopes. The Pin Valley National Park and Great Himalayan National Park form its northern and western boundaries, respectively. The sanctuary includes 5 forest types: alpine pastures, dry temperate coniferous forests, dry broadleaf and coniferous forests, Kharsu oak forest, and lower Western Himalayan temperate forest (Champion and Seth 1968). Such a wide variation in altitude supports a diversity of mammalian fauna, including snow leopard (*Panthera uncia*), Himalayan ibex (*Capra sibirica*), Himalayan musk deer, Himalayan black bear, Himalayan serow, Himalayan tahr, Himalayan goral, and Indian muntjac (*Muntiacus muntjak*). This sanctuary also is an important habitat for the western tragopan and has been listed as an IBA (Criteria: A1, A2, A3; http://datazone.birdlife.org/site/factsheet/18164, Accessed 2 May 2022).

Methods

Field methods

We conducted the field study in the summer during May–July 2018 in Daranghati WLS and May–July 2019 in Rupi Bhaba WLS. We conducted camera-trap sampling in both the sanctuaries, and rapidly assessed the study areas through sampling pre-existing trails (3–10 km) and sign surveys prior to selecting appropriate sites for placement of camera traps. We deployed 87 camera traps in the study areas—44 in Daranghati WLS and 43 in Rupi Bhaba WLS—for a session of 35 days in each sanctuary (Fig. 1 B and C). We initially deployed cameras focusing on the terrestrial mammal community of the study areas and placed them at a height of 30–40 cm from the ground. Parts of the study areas could not be covered because of snow cover and inaccessibility of terrain, and thus, instead of a grid-based approach, we placed the camera traps based on the sign surveys following a sampling design that maintained a minimum distance of 1.5 km between them. This distance included the minimum average daily movement distance (Garland 1983) of the focus mammal species to maintain an optimal distance between spatial replicates and thus avoid spatial autocorrelation. We collected information regarding Global Positioning System location of camera trap, elevation, broad habitat type, presence of water body, and presence of indirect evidence from each camera-trap location. We identified mammal species photo-captured in camera traps using the “Field guide of mammals for Indian Subcontinent” (Prater 1980). We defined each day (24 hr) as a sampling occasion, and multiple detections within a day were combined as a single capture.

Analytical methods

Spatial autocorrelation. Prior to density estimation, we evaluated spatial autocorrelation in the Asiatic black bear captures to ensure that the captures were not clustered because this could lead to potential bias in population estimation (Moqanaki et al. 2021). We modelled the

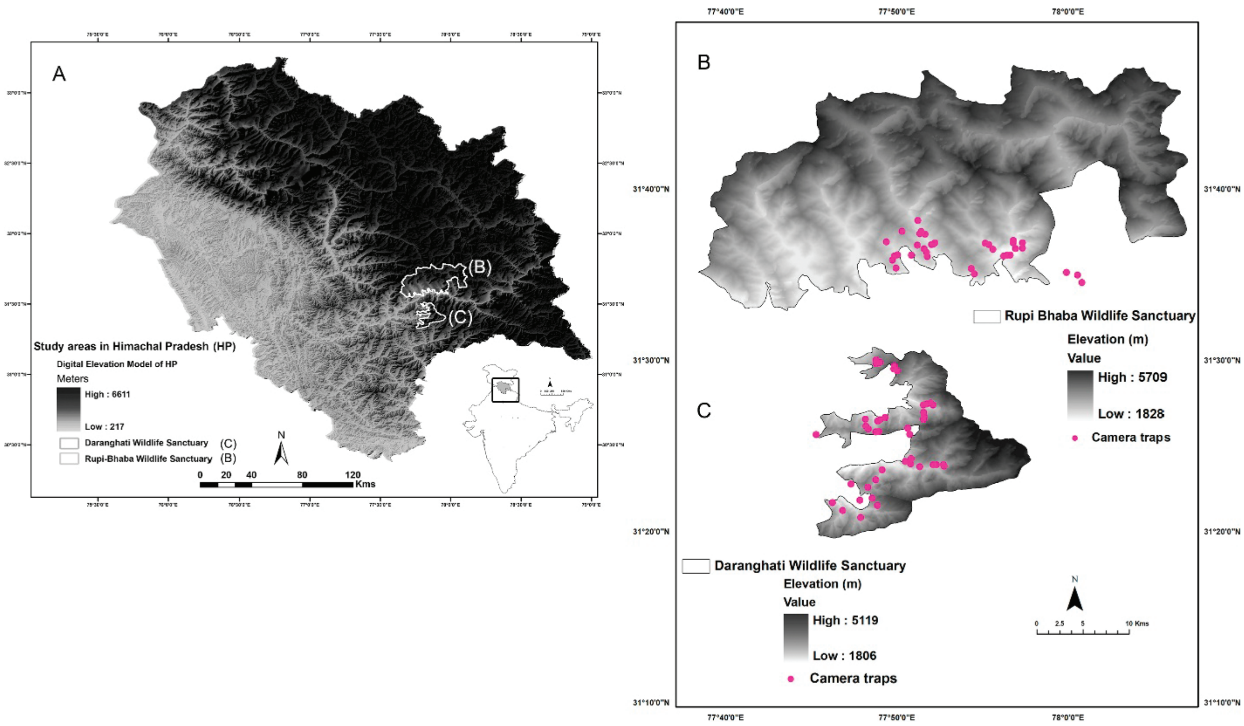

Fig. 1. Map of study areas showing (A) location of study sites in the state of Himachal Pradesh, India, where we estimated Asiatic black bear (*Ursus thibetanus*) population density via camera-trap captures made during summers of 2018 and 2019; Digital elevation model along with camera-trap placement locations of (B) Rupi Bhaba and (C) Daranghati wildlife sanctuaries.

total number of captures using the latitude–longitude of the respective camera-trap site and used Moran's I statistics (Moran 1950) to estimate spatial autocorrelation. We carried out the analysis in the "ape" package in Program R 3.4 (R Core Team 2017).

Density estimates. We estimated population density using spatial presence–absence (SPA; Ramsey et al. 2015), which is an extension of the spatial count model of Chandler and Royle (2013). Spatial presence–absence models are structurally similar to spatial capture–recapture (SCR) models (Efford 2004). Spatial count models the latent encounters of individuals that are spatially referenced via sampling devices using data augmentation and Markov chain Monte Carlo (MCMC) sampling in a Bayesian framework (Ramsey et al. 2015). Unlike the likelihood-based point estimates, Bayesian frameworks estimate the posterior distribution of the parameter. Similar to SCR models, SPA models estimate g_0 (detection probability), σ (scale or movement parameter related to home-range of the species), and *N* (population size; Ramsey et al. 2015).

We assumed a half-normal detection function to model the probability of detection for this analysis because the sensitivity of the camera to detect an individual decreases monotonically with increasing distance. For each camera-trap site, we recorded the detection or nondetection of an Asiatic black bear for each 24-hour sampling interval. The state space (S) consisted of the sampled area and a surrounding buffer area that was large enough to include all individuals potentially exposed to sampling. We estimated the movement parameter (σ) using a telemetry study on home ranges of Asiatic black bears conducted by Sathyakumar et al. (2013) in Dachigam National Park in the IHR. The home range was estimated as 48 ± 20 km^2 (Sathyakumar et al. 2013), which would be equivalent to a home-range radius varying from 3 km to 5 km. We converted the radius to σ with the equation given by Sun et al. (2014) and incorporated the information into the model using an informative Gamma prior with a scale parameter 20 and rate parameter 5. An informative prior utilizes the parameter's available information, whereas an uninformative prior assumes an unweighted distribution

Table 1. Parameter estimates (with 95% credible interval) of the spatial presence–absence model with an informative gamma prior (20, 5) for Asiatic black bear (*Ursus thibetanus*) population density estimated via camera-trap captures made during May–July 2018 in Daranghati Wildlife Sanctuary (WLS) and May–July 2019 in Rupi Bhaba WLS in Himachal Pradesh in the Indian Himalayan region.

Parameter	Daranghati WLS	Rupi Bhaba WLS
Density/100 km^2	2.50 (1.42–6.77)	0.3 (0.2–0.7)
σ	2.25 (1.49–3.38)	2.86 (2.09–3.31)
g_0	0.10 (0.02–0.24)	0.09 (0.001–0.32)
Estimated $\hat{N}$	11 (4–27)	2 (1–3)

with no previous knowledge. We also used an uninformative uniform prior U (0, 10) to model sigma and to compare the model fitting and convergence with the informative gamma prior. We placed a uniform prior, U (−10, 10), on the logit of g_0. We used 50,000 MCMC iterations (with the initial burn-in of 5,000) and fixed the thinning rate of the chains as 1. We estimated the parameters in a Bayesian framework following iterations, so it was necessary to check the convergence of chains. We used Geweke diagnostic scores (Geweke 1991) to test the convergence of the MCMC chains using the "coda" package (Plummer et al. 2006) in Program R 3.4 (R Core Team 2017). A Geweke score of <1.6 indicated convergence of the estimated parameters in the chain.

Results

Eleven of 44 camera traps deployed in Daranghati WLS, and 9 of 43 in Rupi Bhaba WLS, were lost or stolen. We obtained 38 captures of Asiatic black bears in 33 camera traps in Daranghati WLS in 1,155 total trap-nights (Fig. S1, Supplemental Material) and 20 captures of Asiatic black bears in 34 camera traps in Rupi-Bhaba WLS in 1,190 total trap-nights (Fig. S1). Significant spatial autocorrelation (Moran's $I = 0.16$, $P < 0.001$) was detected in captures of Rupi Bhaba WLS, but not in Daranghati WLS (Moran's $I = -0.0001$, $P = 0.51$; Fig. 2).

The SPA model estimated a population density of 2.50 individuals/100 km^2 (95% Credible Interval = 1.42–6.77 individuals/100 km^2) from Daranghati WLS and a movement parameter of 2.25 km (95% Credible Interval = 1.49–3.38; Fig. 3, Table 1). The posterior distribution of the parameters (population estimate $\hat{N}$ and movement parameter σ) from the SPA model are presented in Figure 3. Detection probability from the area was estimated as 0.10 (95% Credible Interval = 0.02–0.24; Table 1). We estimated the population density from Rupi Bhaba WLS as 0.3 individuals/100 km^2 (95% Credible Interval = 0.2–0.7 individuals/100 km^2), the movement parameter as 2.86 km (95% CI = 2.09–3.31), and the detection probability as 0.09 (95% Credible Interval = 0.001–0.32; Table 1). Extrapolating the densities for the trapping areas produced abundance estimates of 11 individuals (95% CI = 4–27) in Daranghati WLS and 2 individuals (95% CI = 1–3) in the Rupi Bhaba WLS (Table 1).

The Geweke diagnostic scores showed convergence of all parameters of the SPA models for both the areas—the Z-statistic values were <1.6. Also, the Geweke scores of each parameter were significantly different from $Z = 1.6$ for all the parameters. The Geweke scores (P-values in parentheses) of Asiatic black bear from Daranghati WLS were $\sigma = 1.2$ (0.89), $g_0 = -0.52$ (0.3), $\psi = -0.04$ (0.48), and $N = -0.12$ (0.5); while the Geweke scores of Asiatic black bear from Rupi Bhaba WLS were $\sigma = 0.46$ (0.68), $g_0 = 1.21$ (0.89), $\psi = -1.11$ (0.13), and $N = -1.13$ (0.13). All the parameters from both study areas converged when an informative gamma prior was used for the movement parameter (σ). When the uninformative uniform prior to model sigma was used, the parameters did not converge, and the model produced no ecologically meaningful estimates.

Discussion

In this study, we estimated the number of Asiatic black bears (without individual identification) in 2 protected areas in the IHR using noninvasive sampling methodology. Our study was focused on providing a robust estimation of Asiatic black bear numbers using camera-trap sampling that can be replicated over other areas for rigorous density estimation. We also demonstrated the applicability of the SPA model (Ramsey et al. 2015) for unmarked density estimation.

Of the 2 sampling locations, only Daranghati WLS produced meaningful density estimates. In Rupi Bhaba WLS, capture numbers of Asiatic black bear were low and the captures were clustered in 13 camera traps of the 34 sampling locations. The occurrence of spatial autocorrelation was expected because the camera-trapping array in Rupi Bhaba WLS was concentrated in the low elevations, whereas in Daranghati WLS the effort was spread across a larger area of the sanctuary. This disparity in effort was primarily caused by the inaccessibility of a major portion of Rupi Bhaba WLS because of the terrain complexity, which was also reflected in the low estimated population density of Asiatic black bears. Both WLS, however, have

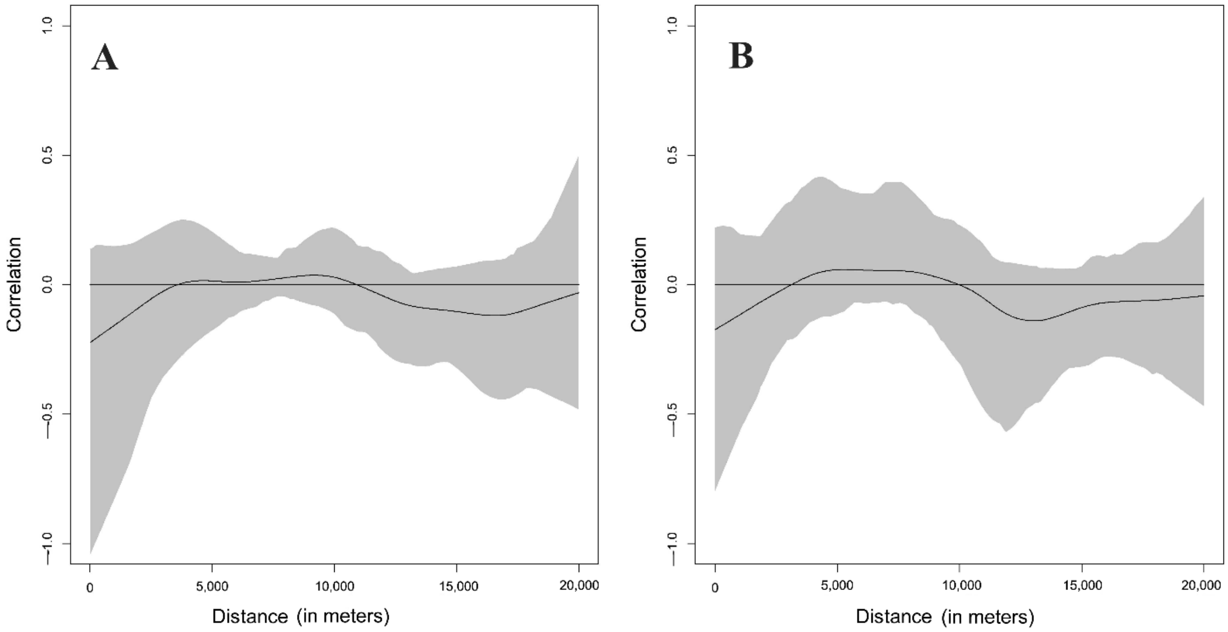

Fig. 2. Moran's I correlation coefficient variogram with geographic distance (meters) between camera-trap captures of Asiatic black bears (*Ursus thibetanus*) from (A) Daranghati and (B) Rupi Bhaba wildlife sanctuaries in Himachal Pradesh, India, during summers of 2018 and 2019. Although the credible interval overlapped zero, Asiatic black bear captures in Rupi Bhaba WLS had significant spatial autocorrelation.

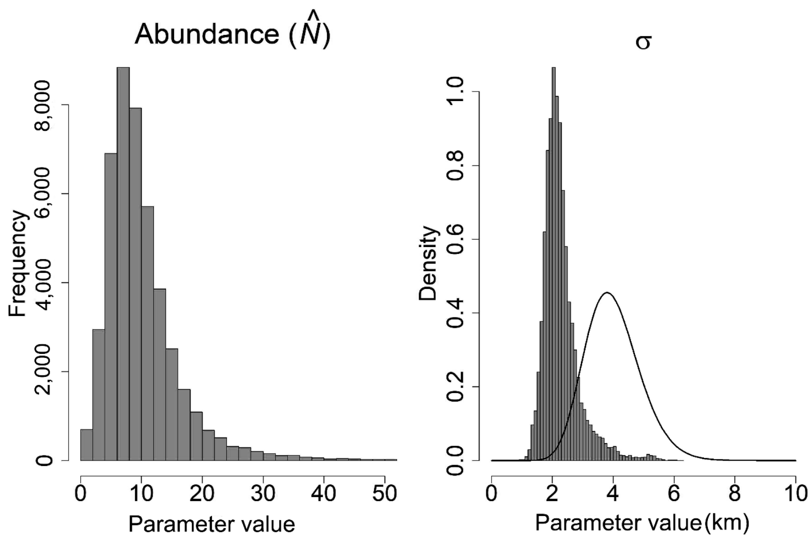

Fig. 3. Plot showing the estimated abundance ($\hat{N}$) and movement parameter (σ) of Asiatic black bear (*Ursus thibetanus*) camera-trap captures from Daranghati wildlife sanctuary, Himachal Pradesh, India, during summers 2018 and 2019. We used a gamma (20, 5) prior to model the movement parameter. The bars represent the histogram of the posterior distribution of model parameters (population and movement parameter). The line denotes the prior distribution used to model the movement parameter.

suitable habitats to harbor good populations of Asiatic black bear (Sathyakumar 2001; Sathyakumar and Chaudhury 2007). Thus, there is a possibility of underestimation of Asiatic black bear population from this WLS as a result of lack of sampling.

Previous studies from India (Saberwal 1989, Sathyakumar 1999, Sathyakumar et al. 2013) tentatively estimated the density of Asiatic black bear as "1.3 to 1.8 per km^2" through questionnaire surveys and genetic analysis through hair sample collection, which was available only from Dachigam National Park, Jammu, and Kashmir. Another study in Senchal WLS, West Bengal, estimated the tentative density of the species as "1/3.55 km^2" (Sunar et al. 2012). Ngoprasert et al. (2012) estimated the population density of Asiatic black bear from 2 evergreen forests in Thailand as 8 ± 3.04 individuals/100 km^2 and 5.8 ± 2.31 individuals/100 km^2 using spatial capture–recapture models with unique chest marks. This was a more refined estimate than previous population studies of the species. The population density estimates in our study were lower than those of Ngoprasert et al. (2012) and the range of the credible interval of our study was larger than the range of confidence interval of Ngoprasert et al. (2012). The reason was that the detection probability (g_0) had a large variation in our study (Credible Interval = 0.02–0.24 and 0.001–0.32 for Daranghati and Rupi Bhaba WLS, respectively). However, the credible interval of our study overlapped with Ngoprasert et al. (2012), showing that, without individual identification, our study could produce quite precise estimates. The variability of the parameter could be reduced by deploying cameras for a longer duration and joining or pooling sampling occasions (Kays et al. 2020), which in turn can produce more precise density estimates. This was demonstrated in another mammalian community study from the IHR by Pal et al. (2021), where the photo-capture rate of Asiatic black bears was 3.43 ± 1.50, which was significantly higher than our capture rates (Rupi Bhaba: 1.45 ± 2.26; Daranghati: 2.63 ± 0.75). Nonetheless, the movement parameter (σ) estimate from our study was 2.25 km (95% Credible Interval = 1.49–3.38 km) and 2.86 km (95% Credible Interval = 2.09–3.31 km), which were not substantially different from the estimates of 2.60 km (95% CI = 1.81–3.74 km) and 2.57 km (95% CI = 1.80–3.66 km) from Ngoprasert et al. (2012). This comparable robustness with overlapping movement parameters showed that camera-trap–based unmarked models can be replicated for density estimation in other areas. Moreover, telemetry studies from Dachigam National Park (Sathyakumar et al. 2013) showed the average home range of the Asiatic black bear was 47.88 ± 20.12 km^2 (95% kernel density). Home ranges calculated using the movement parameter estimate of our study (35.6 ± 3.48 km^2) were also not substantially different from the radiotelemetry home-range estimates of Sathyakumar et al. (2013).

Compared with the spatial capture–recapture method used by Ngoprasert et al. (2012), we did not use a sex-specific covariate to explain spatial heterogeneity, because accurate sex identification was not possible from the camera-trap data. We were able to use the informative prior for the SPA model because there were home range estimates available for the species from previous studies (Sathyakumar et al. 2013). Uninformative priors provided no ecologically meaningful population estimate compared with informative priors in this case. Other studies utilizing the spatial count model also highlighted varying estimates with informative and uninformative priors (Burgar et al. 2018). Future studies with additional information (e.g., partial individual identity, radiotelemetry) can be used to increase the precision of the density estimates further. We speculate that use of baited camera traps (Ngoprasert et al. 2012) and hair trap stations (Sathyakumar et al. 2013) possibly can alter the behavior and movement of the species. This may lead to underestimation in the movement parameter and overestimation in the density estimate. In contrast, our study used a noninvasive method (camera traps) with minimal chance of behavioral change and an enhanced scope for density estimation of unmarked individuals.

Our results come with certain caveats. The geographic coverage was inadequate in one sampling site (Rupi Bhaba WLS) for such a far-ranging species as the Asiatic black bear. Further, as shown in simulation studies by Chandler and Royle (2013), the accuracy of the model estimate improves with identifiable individuals. Radiotelemetry studies and marked individuals along with this method can aid in further reducing the credible intervals, thus improving statistical robustness. Also, an increase in sampling effort along with simulation for estimation of optimal sampling effort could improve the precision of the density estimates.

The current population density from this study is an improvement from previous studies in India. This study showed the potential of the SPA model (Ramsey et al. 2015) to be replicated in other landscapes for a robust population estimation of Asiatic black bears without individual identification. Moreover, this method can provide a better allocation of effort and cost as compared with radiotelemetry and genetic capture–recapture studies. The Asiatic black bear has been categorized as Vulnerable (Garshelis and Steinmetz 2016) under the International Union for Conservation of Nature Red List of

Threatened Species and is also listed under Appendix I of CITES (1992; https://cites.org/eng/app/appendices.php) and Schedule I of the Indian Wildlife (Protection) Act, 1972 (amended 2003; MOEF 2003). Moreover, it is one of the large carnivore species having negative interactions with humans in the IHR (Charoo et al. 2011, Bashir et al. 2018). Estimates from this model can be extrapolated to a larger area to understand large-scale population status. Accurate and reliable estimates from such models can help managers to build conservation and monitoring strategies. This will provide a roadmap to manage and mitigate negative interactions in future, as well as monitor the demography, population trend, and status of Asiatic black bears in the IHR.

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Supplemental material

Fig. S1. Map showing Asiatic black bear (*Ursus thibetanus*) detections in different vegetation types of (A) Rupi Bhaba and (B) Daranghati wildlife sanctuaries, Himachal Pradesh, India.

Data availability statement

Data used for the analysis is available on Dryad data repository (https://datadryad.org).

Archived Material in Dryad: https://doi.org/10.5061/dryad.fxpnvx0tp.