

Habitat occupancy of sloth bear *Melursus ursinus* in Chitwan National Park, Nepal

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Abstract

Mammals around the world face serious threats and experience massive decline in their populations and geographic ranges. The sloth bear has become extinct from two of five range countries and the existing population face serious conservation threats. Despite being endangered in Nepal, decades of conservation obliviousness have hindered their conservation and management. We assessed the distribution and habitat use by sloth bears in relation to landscape, environmental, and anthropogenic factors in Chitwan National Park, Nepal. We conducted a sign survey from March-June 2020 in 4*4 km² grids (n=45) in a checkerboard approach. An observation was spatially replicated four times by recording information in four continuous search trails of 1 km each. We recorded presence/absence of sloth bears, termites, fruits and disturbance in the field and extracted information on tree cover, terrain ruggedness and vegetation index from remotely sensed image of the study area. The data was analyzed using single species-single season occupancy method in PRESENCE software. By using repeated observations these models account for imperfect detectability of species to provide robust estimates of species occupancy. Averaged habitat occupancy estimate obtained from the best models was $= 0.53 \pm 0.04SE$ with detection probability $p = 0.44 \pm 0.1SE$. Selection of variable based on summed AIC weight from the top models (AIC<2) showed that presence of termites ($W_i=0.66$) significantly influenced sloth bear habitat occupancy. Habitat occupancy was positively influenced by termites followed by fruits, disturbance, terrain ruggedness and vegetation productivity, whereas, it was negatively influenced by tree cover. We suggest that future conservation interventions and action plans aimed at sloth bear management must adequately consider these requirements and issues.

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Abstract:

Mammals around the world face serious threats and experience massive decline in their populations and geographic ranges. The sloth bear has become extinct from two of five range countries and the existing population face serious conservation threats. Despite being endangered in Nepal, decades of conservation obliviousness have hindered their conservation and management. We assessed the distribution and habitat use by sloth bears in relation to landscape, environmental, and anthropogenic factors in Chitwan National Park, Nepal. We conducted a sign survey from March-June 2020 in 4*4 km² grids (n=45) in a checkerboard approach. An observation was spatially replicated four times by recording information in four continuous search trails of 1 km each. We recorded presence/absence of sloth bears, termites, fruits and disturbance

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Keywords:

Sloth bear, Occupancy, Nepal, Wildlife Conservation

Introduction :

Large mammals around the world face serious threats and experience massive decline in their populations and geographic ranges (Ceballos et al. 2015, 2017; Ripple et al. 2014; Karanth, 2009; Ceballos & Ehrlich 2002). Protected areas (PAs) have become the last refuge of many threatened mammals and have contributed to conservation of some flagship species yet their effectiveness to halt decline of other sympatric species remains questioned (UNEP-WCMC & IUCN, 2021; CBD, 2020; Li et al. 2020; Geldmann et al. 2019; Schulze et al. 2018; Barnes et al. 2016; Ceballos et al. 2015; Geldmann et al. 2013; Hoffmann et al. 2010). Increasing pressure on the environment has compromised the intactness of natural habitat and species ability to procreate and persist in a healthy population (Crooks et al. 2017; Wilson et al. 2016). Extinction risk of mammals in small, degraded, and isolated habitats increase in long run through population decline and loss of genetic diversity (Frankham et al. 2002, 2010).

The sloth bear *Melursus ursinus* is an endemic mammal of the Indian sub-continent occurring in a wide range of habitats including dry or moist forest, savannah, scrublands and grasslands (Dhariya et al. 2020; Garshelis et al. 1998). However, their populations have declined by almost 50 % over the last three decades and are categorized as “vulnerable” in IUCN Red List (Dhariya et al. 2020). They have become extinct from entire country in Bangladesh (Islam et al. 2013) and possibly from Bhutan and locally from different habitat patches of India and Nepal (Dhariya et al. 2020; Garshelis et al. 1998). They were once present along continuous strip of forest and grasslands in the southern Nepal until 1950s when expansion of human settlement and agriculture confined them primarily in few protected areas (Amin et al. 2018; Jnawali et al. 2011). While distribution, habitat use, population and conservation ecology of sympatric co-predators’ tiger and leopard is well explored (Subedi et al. 2021; Thapa et al. 2021; Lamichhane et al. 2019, 2017; Dhungana et al. 2019, 2018; Kafley et al. 2019; Pokheral et al. 2019; Karki et al. 2015; Barber-Meyer et al. 2013; Bhattarai et al. 2012; Carter et al. 2012; Smith 1984), similar studies for sloth bears are limited (Lamichhane et al. 2016; Laurie & Seidensticker, 1977; Garshelis et al. 1999; Joshi et al. 1995, 1997, 1999) to from a conclusive view on its current conservation status.

Information on the species spatial distribution pattern in the wild and factors that influence this pattern are critical for setting conservation priorities and site-specific management actions for securing these population over time. Primarily, species distribution and habitat use are determined by the availability and spatial variation of food resources and the extent of natural and anthropogenic threats (Ceballos & Ehrlich, 2002; Schipper et al. 2008). Unlike other carnivores, bears exhibit a different set of morphological specializations for diet (Sacco et al. 2004). Sloth bears are specially adapted for myrmecophagy with the composition of diet varying with temporal and spatial availability of the food resources particularly termites and fruits (Philip et al. 2021; Palei et al. 2014, 2020; Rather et al. 2020; Mewada et al. 2019, 2015; Baskaran et al. 2015; Khanal & Thapa, 2014; Sukhadiya et al. 2013; Baskaran & Desai. 2010; Bargali et al. 2004; Joshi et al. 1997;

Laurie & Seidensticker,1977). In fruit rich areas, sloth bears play important role in the dispersal of seed and regeneration of fruit plants (Sreekumar & Balakrishnan, 2002) thus playing important role in maintenance of forest structure and composition. They largely prefer habitats away from human disturbance (Joshi et al. 1999; Babu et.al 2015, Ghimire & Thapa,2014; Ratnayeke et.al.2007) but they have also been reported to tolerate some degree of disturbance in human-dominated landscapes (Puri et.al 2015, Bargali et al. 2012; Akhtar et al.2004, 2007). Prevalence of human-sloth bear conflict in India (Rajpurohit & Kruasman, 2000; Debata et al. 2012,2017; Garcia et al. 2016; Dhamorikar et al. 2017; Bargali et al. 2005; Ratnayeke et al 2014; Ahmed et al.2012; Sharp et al.2020; Ketting et al.2020) and Nepal (Pokharel et al. 2020; Ruda et al. 2020; Silwal et al. 2019; Lamichhane et al. 2018; Acharya et al.2016) is one of the threats to its survival. Additionally, removal of the individuals through poaching or live capture for use as ‘dancing bears’ is not common but can be detrimental enough for a population that is already small, isolated and threatened.

Direct observation of sloth bears is difficult because of their rare, elusive, and aggressive nature. We use occupancy analysis which is widely used in recent years and have evolved as a strong, flexible, and viable method for estimating species distribution and occupancy dynamics while accounting for possible non-detection as well as incorporating predictor variables measured remotely or during the observation process in field (MacKenzie et al.2002,2003, 2004, 2017; Bailey et al. 2014; MacKenzie & Nichols 2004; MacKenzie & Royle, 2005). We employed single-season occupancy model for understanding the distribution and occupancy dynamics of the sloth bears and its ecological, environmental, and anthropogenic determinants.

METHODOLOGY

Study Area: The study was conducted in Chitwan National Park (27°16.56'- 27°42.14'N, 83°50.23'- 84°46.25'E), the first national park situated in south central Nepal covering 953 sq. km. It is a designated Ramsar site and UNESCO world heritage site. The park landscape consists of alluvial plain and mountain range of the outer Himalaya known as Churiya hills. Seasonal and perennial rivers originate in the Churiya and cascade down to the lowlands before being drained by three major river systems. The East Rapti River runs along the northern boundary of park, Reu river runs along the southern boundary of the park, both the rivers mix before being drained to the Ganges by the Narayani river that forms the western boundary of the park. In the east, the park is contiguous with the boundary of Parsa National Park . The study area lies in the Indomalaya biogeographic realm and consists of tropical moist forest vegetation dominated by deciduous forest of *Shorea robusta* (70%) followed by grassland (10%), riverine forest (7%), mixed forest (7%) and wetlands (4%). The successional gradient of the park is formed of ten grasslands and three forest associations (Lehmkuhl J.F.1999). The area has hot and humid summer monsoon from mid-May to late-September when 90% of the 2,400mm of rain falls. The monsoon causes dramatic floods which alter the courses and character of the rivers and thus plays important role in shaping park's landscape particularly creating and maintaining different successional stages of habitats. Temperatures reach a maximum of 38degC during wet summer and drop to a minimum of 6degC in dry winter. The matrix of different habitat conditions and climate makes this area a hotspot of biodiversity harbouring the largest population of rhinos, tigers and sloth bears and many other threatened flora and fauna in Nepal. The core park area is surrounded by a 750 sq.km buffer zone, which consists of forests, settlements and agriculture lands. The park and the local people jointly initiate community development activities and manage natural resources in the buffer zone. Thirty-to-fifty percent of the park revenue particularly from tourism activities is provided to these buffer zone communities for community development and natural resource management activities. The buffer zone community is socially mixed of indigenous fishing community and immigrated hill communities relying mostly on subsistence agriculture.

Survey Design: We overlaid grids of 4*4 km over the map of study area (**Figure 1**). With a random start we surveyed in grids at a systematic spacing of 4 km. This checkerboard sampling design minimizes autocorrelation between sampling grids, facilitates concentration of survey efforts, even coverage of large and hostile study area and is suitable for studying medium to large mammals with relatively ease. It has been used to study elephants (Thapa et al. 2019), tigers (Thapa & Kelly, 2017) and antelope (Krishna et al. 2008). This resulted in a total of 45 grids which covered 720 sq.km (43% coverage of park area).

Our grid size is comparable to the home range of sloth bears which is estimated as 9 and 14 sq.km for male and female sloth bears respectively (Joshi et.al 1995). Studies on sloth bears in India have shown that the spatial replicates produce occupancy estimates similar to the temporal replicates and thus are useful for distribution assessments of species when field resources are limited or logistic challenges preclude traditional survey approaches that yield temporally replicated data (Srivathsa et al.2017). We used four spatial replicates of one km length in each grid.

Field Methods: We carried out sign surveys within the selected 45 grids with a sampling effort of four km in each grid. Two observers walked in the grid and recorded both direct sightings and indirect signs such as scat and footprint found within the visible width of the search trail. We divided this search trails or replicates into equal distanced segments of 200 m. A segment was recorded as occupied ‘1’ if we made a direct visual sighting or if we detected the footprint or scat of sloth bears. Sloth bears are often found to defecate in open areas along the road, over the bridges and on the ‘machans’ wildlife view towers and other exposed surfaces. Absence of black bears, sun bears or other species of similar size and habit in the study area enabled us in unambiguous identification of the sloth bear signs in the field. To standardize the detection process, avoid biases that may arise from misidentification and decay of signs and adhere to the closure assumption in occupancy studies, we only included fresh sloth bear signs – direct sighting, footprints, and scat along sample trails (Putman R.J. 1984; Morin et al.2016; Rota et al. 2009; Laing et al. 2003). Field surveys were carried out between March and June of 2020. Within the segments, we collected sloth bear presence/absence data and associated ecological, environmental and anthropogenic variables. When the signs and covariates were detected in the segment it was recorded as ‘1’ and ‘0’ otherwise. If the sampling could not be done because of logistic reasons, outside park jurisdiction or under intense human use, the segment was treated as a missing observation.

Co-variate Selection:

We selected a mix of six plausible remotely sensed and ground-based variables that reflected characteristics of landscape, condition of habitat, persistent anthropogenic pressures, and availability of major food resources based on the review of available literature. For small study area with few sample sites model loses power of explanation and unwanted errors increase as the number of variables are increased in a model. It is generally advised to use one variable per ten sites in occupancy model. Thus, following the principles of parsimony, we included three site co-variates and three sample covariates (**See Table 1**). We selected termites, fruits and disturbance as sample covariates and measured them in the field. Tree cover, terrain ruggedness index (TRI) and enhanced vegetation index (EVI) were site level covariates that were obtained from remotely sensed images. Termites and fruits were selected as variables as they represent the dominant food resource for sloth bears (Khanal & Thapa, 2014; Sukhadiya et al. 2013; Bargali et al. 2012; Joshi et al.1997). Studies in India have shown that sloth bears were positively associated with the topographic ruggedness (Puri et al. 2015; Srivathsa et al. 2017) and forest cover (Srivathsa et.al. 2017). Sloth bears have been reported to avoid human and livestock disturbance (Babu et al. 2015; Puri et al. 2015) but they have also been reported from human dominated landscapes with degraded habitats (Bargali et al. 2012). We combined human disturbance, livestock disturbance and fire in our search trails as a measure of disturbance. They are thought to prefer relatively dry habitats as indicated by the negative relationship between habitat occupancy and vegetation productivity (Srivathsa et al. 2017). We chose EVI rather than normalized difference vegetation index (NDVI) to measure vegetation productivity in our study as EVI has improved sensitivity. In Nepal, it was found that sloth bears move to grasslands during the dry season and prefer to remain in forests during the wet season (Joshi et al. 1995). We used the tree cover data prepared by Hansen et al (2013) as a proxy of habitat condition, higher cover indicating forested habitat and lower cover indicating grassland habitat. Covariates were first checked for collinearity (**Figure 2**), and then z transformed before running occupancy models (Kirshna et al. 2008; Panthi et al. 2017). We hypothesized that *ceteris paribus* 1) sloth bear occupancy will increase with increasing termites, fruits and heterogeneity in the terrain and, 2) sloth bear occupancy will decrease with increasing tree cover, EVI and disturbance.

Occupancy estimation and modelling the effects of covariates:

Studies have demonstrated that spatial replication can serve as a good surrogate for temporal replication in occupancy studies of sloth bears (Srivathsa et.al.2017). For our grids we considered 1 km search trail as one spatial replicate. We employed an equal search effort of 4 km in each grid, thus maintaining four spatial replicates in each grid. Detection histories were constructed for each grid, where ‘1’ indicates detection of species and ‘0’ indicates non-detection and ‘.’ indicates a missing observation. For example a detection history of ‘010-’ indicates that the sloth bear or its sign was not detected in first and third search trail, detected in the second search trail and the sampling was not done in the fourth search trail. For each covariate, data recorded in each segment along the search trail were pooled to obtain an single average covariate score. We ran single-species single season occupancy analysis using a maximum likelihood-based approach in the PRESENCE software 2.12.31 to derive calculated occupancy (Hines, 2006). We followed a two-step process to estimate probability of detection and probability of bear occurrence. First, we modelled detection (p) keeping constant structure for occupancy model as ψ (.). We hypothesized that three ground based covariates 1) Termite 2) Fruit and 3) Disturbance Index would affect our probability of detecting sloth bears and its signs along the search trail, so we used them in the first step for modelling detection probability. We hypothesized that sloth bear signs detection will be higher in areas with termite mounds and fruits and they will be lower in areas with high disturbance. We modelled different combinations of the detectability (p) covariates and selected the best model based on minimum AIC, keeping the ψ fixed.

In the second step, we modelled probability of occupancy (ψ) keeping the top detection model from step one as a constant structure for detection model (Srivathsa et al. 2017; Panthi et al. 2017; Doherty et al. 2012). We constructed a set of 27 priori candidate models, each representing a different ecological hypothesis. These models included either single or additive effects of two or more covariates to investigate the influence of covariates on occurrence. Model fit was assessed using the parametric bootstrap procedure (MacKenzie & Bailey, 2004). The covariate models were compared and ranked using an information theoretic approach, relying on Akaike Information Criterion (AIC) for testing relative model fits. Models with ΔAIC of <2 were strongly supported by the data. Due to inherent advantage of model averaging (Burnham & Anderson, 1998), the final occupancy estimates and associated standard error were averaged across the model set. To infer relative influence of covariates on occurrence, we summed the computed model weights of all the model containing the particular covariate. Additionally, we used the estimated β -coefficients to assess the strength of association of each covariate with occupancy probability.

RESULTS:

Occupancy and Detection:

The estimated sloth bear detection probability was $0.44 \pm 0.1_{SE}$. The top model with lowest AIC value that influenced detection probability included termites, fruits and disturbance (**Table 2**). Among them, termite was the most influential covariate that had significant effect on detection probability ($W_i = 0.81$, $\beta = 1.80 \pm 0.53_{SE}$) of sloth bears. We used this top model for detectability in subsequent analyses to model occupancy probability. Occupancy results are presented in **Table 3**. Among the set of candidate occupancy models, the model including termites ($\beta_T = 0.80 \pm 0.40_{SE}$, $W_i = 0.12$) and fruits ($\beta_F = 0.58 \pm 0.42_{SE}$, $W_i = 0.12$) was the best occupancy model. Since, a single model did not fully explain the observed data and because of the inherent advantages of model averaging (Burnham & Anderson, 1998) we obtained average occupancy estimates, and the associated standard errors from the most competitive models ($\Delta AIC < 2$). The model averaged occupancy estimate for our study area was $0.53 \pm 0.04_{SE}$.

Influence of Covariates:

The null model that did not include any covariates for detection or occupancy performed poorly and ranked the lowest (AIC=175.48). Model performance improved after we included the covariates alone or in combination according to our priori hypothesis. Summed AIC weight of covariates from the most competitive models was highest for termite followed by fruit, disturbance, tree cover and equal for EVI $W_i = 0.12$ and TRI (**Figure 3**). Average model specific β -coefficient value from the top competitive models for termites, fruit, disturbance, terrain ruggedness and vegetation productivity indicated their positive influence on sloth

bear occupancy whereas negative beta coefficient for tree cover indicated its negative association with sloth bear habitat occupancy (**Figure 4**) .

Discussion:

Occupancy and Detection:

This study provides the first ever occupancy estimate for sloth bears from Nepal. Sloth bears were elusive species with less than a half ($p = 0.44$) probability of detection. Their signs were detected in 21 out of the sampled 45 grids, giving a naïve occupancy of 0.46. By explicitly incorporating the imperfect detection of animals into the occupancy estimate, the proportion of area occupied by sloth bear in Chitwan national park substantially increased ($= 0.53$). An increase in habitat occupancy by 15% over the naïve estimate highlights the importance of considering the imperfect detection when studying sloth bears.

Our estimates are comparable to earlier studies on sloth bears outside Nepal (**See Table 4**). Habitat occupancy estimates for the sloth bear have varied between 0.54 to 0.83 in India. This difference might be because of difference in the home range of the species. The home range for sloth bears in Nepal is estimated at 9-14 sq.km in Chitwan (Joshi et al. 1995) which is lower than in India estimated at 12 sq. km for a female and 85 sq. km for a male (Yoganand et al. 2005) and higher than that estimated for sub-species *Melursus ursinus ornatus* at 2.2 and 3.8 sq.km in Srilanka (Ratnayeke et al. 2007, 2021) respectively for female and male sloth bears. Additionally, most of the reported studies of sloth bear occupancy in India are from the Western ghats that has one of the largest blocks of contiguous forest cover and diversity of habitat conditions consisting of semi-evergreen, tropical moist, dry deciduous, thorny forest and scrub interspersed with agricultural area and rocky outcrops while our study area is relatively homogenous with small grasslands patches interspersed in a deciduous forest habitat. The occupancy-abundance relationship of species tends to be linked (Gaston et al. 2002; Zukerberg et al. 2008) particularly at the small and homogenous areas (Hui et al. 2009). Considering our occupancy estimate of 0.53 obtained from our sampling of the study area, the suitable habitat inside the park is ~500 sq.km and the population around ~100-150 individuals. It indicates that sloth bears have fairly wide distribution throughout the park, with relatively higher occupancy ($\psi > 0.53$) areas along the northern boundary of the park (**Figure 5**) . Both Laurie & Seidensticker (1977) and Garshelis et al (1999) recognize that there is uneven distribution of sloth bears with high density in the alluvial floodplains along the bank of Rapti river in north part of the park and relatively lower density on rest of the park dominated by upland Sal forest.

Influence of Covariates:

Summed AIC weight from the most competitive ($\Delta AIC < 2$) eight models showed that termites are most important covariates followed by fruit, disturbance, tree cover, TRI and EVI (**Figure 2**) . The averaged strength of positive influence of covariates in habitat occupancy was higher for termites followed by fruit, disturbance, TRI and EVI while it was negative for tree cover. The 95% confidence interval (CI) of averaged beta coefficients occupancy covariates overlapped zero except for termites indicating high confidence on the magnitude and direction of influence by termites but less confidence on similar influence by other variables (**Figure 3**) .

Food resources of sloth bears particularly termites followed by fruits had relatively strong influence on sloth bear occupancy. This is expected because sloth bears are opportunistic omnivores specialized for myrmecophagous diet particularly termites. Studies on feeding ecology also shows that termites are most frequent in diet throughout year while fruits dominate according to seasonal availability (Yoganand et al. 2005; Palei et al. 2014, 2020; Bargali et al. 2004; Ramesh et al. 2012; Rather et al. 2020; Philip et al. 2021). In Chitwan, fruits are available for short duration from April-August while termites increasingly dominate the sloth bear's occurring in 52% of scats in 1970s (Laurie and Seidensticker, 1977), 81% during 1990s (Joshi et al. 1997) and 92% in 2010s (Khanal and Thapa 2014). Sloth bears had negative association with tree cover indicating its preference for open grassland habitat. During the dry season, the soil in upland Sal forest habitat becomes stiff (Mall & Karki, 2016) and termites excavate deeper into the ground to keep up with lowering water table (Mugendi D.G 2020; Ahmed et al. 2018; Kalumanga, 2016; Dangerfield

et.al.1998). While water table is relatively higher in alluvium grasslands and the soil is relatively loose making it favourable for sloth bears to obtain termites. Correlation analysis with tree cover indicated that not termites mounds ($r=0.02$) but fruits were more abundant in grasslands ($r= -0.28$) during this period. Axelsson and Andersson E.P. 2012 and Chakraborty and Singh 2020 also observed that termite mounds were higher in forested areas compared to edge or open habitats. However, Garshelis et al (1999) also showed that mound digging by sloth bears was higher in grasslands despite high density of mounds in the forest. They also reported high ratio of diggings to obtain underground colonies of termites during the dry season. Thus, the preference for habitats with open tree cover during the dry season may be due to the better accessibility of food resources.

We expected that disturbance would have negative influence on habitat occupancy by sloth bears but in contrast the averaged beta coefficient for the covariate indicated otherwise. Understanding effects and impact of disturbance on species is challenging as it is driven by multiple factors such as individual behavior, evolutionary history as well as the frequency, duration and scale of disturbance events (Graham et al.2021; Iwasaki & Noda, 2018; Sousa W.P. 1984). In relatively intact landscape such as in western ghats, India, sloth bears have shown to avoid disturbance (Das et al. 2014; Puri et al. 2015; Babu et al. 2015) while in human dominated landscapes they have been reported to tolerate some degree of disturbance (Bargali et al. 2012) often consuming cultivated crops (Palei et al. 2019), human food waste (Prajapati et al. 2021) and causing conflicts with humans (Debata et al. 2017; Dhamorikar et al. 2017). Human-sloth bear conflict is common throughout the year in chitwan national park suggesting that sloth bears perceive humans as threats (Acharya et al.2016; Silwal et al.2016; Lamichhane et al. 2018). However, sloth bears might be using disturbed habitat in moderation for requirements such as food, water and shelter as suggested by weak but positive correlation of disturbance with terrain ruggedness, vegetation productivity and termites (**Figure 2**). Rugged terrain provides sloth bears with resting and denning refuge (Baskaran et al. 2015; Bargali et al. 2012; Akhtar et al. 2007) sites and cover to hide their cubs from potential predators like tigers. We used coefficient of variation in terrain ruggedness and enhanced vegetation productivity across our grids as it better represented the heterogeneity in the habitat. They were positively related but did not have enough variation to produce significant effect on the sloth bear occupancy. The weak association of covariate might be because our study was more localized while these variables are more adequately captured at a larger scale (Rather et al. 2021; Srivathsa et al. 2017).

Conservation Implications

We show that sloth bears are widespread but elusive in CNP whose detection and occupancy is influenced by a range of variables. Landscape features like ruggedness change over decades, however, habitat variables like tree cover, vegetation productivity as well as the availability of fruits and insects change over short time periods. While generalist species may adapt to such changes, specific feeding and habitat requirements of sloth bears make it more vulnerable. Changes particularly loss and fragmentation of habitat can have long-term genetic consequences through loss of genetic diversity and population decline (Murphy et al.2017; Thatte et al. 2020; Dutta et al. 2015). Furthermore, studies have shown decline of sympatric carnivores where conservation are focused on revival of single species such as tigers (Jhala et al. 2020; Li et al. 2020). Tigers and sloth bear co-occur in Nepal where the former's population has almost doubled since 2009 (DNPWC & DFSC, 2018) Direct threats on its population through predation by tigers (Joshi et al. 1999) might be low, however indirect consequences of habitat alteration due to tiger focused management can be expected. Grassland habitat in the park is shrinking due to proliferation of shrub, woody vegetation as well as invasive alien plants which is already impacting grassland dependent species (Subedi et al. 2017; Murphy et al. 2013). Intactness of the habitat and species' abilities to survive and reproduce is further challenged by anthropogenic pressure which is exacerbated by the increasing impacts of climate changes (Pant et al. 2020). The fate of this unique ursid, therefore, not only relies on how it responds to the changing availability of insects, fruits and habitat but also on how park managers respond through management actions/inactions. Our study can serve as a general guidance to parks and wildlife conservation authorities towards departure from incidental conservation to active management of sloth bear population. Management actions should be geared towards creation of suitable habitat such as through creation of habitat mosaics with grasslands and patches of wild

fruits that enable sloth bears to access their main food throughout the year and successfully reproduce. We suggest empirical multi-season assessments of disturbance intensity and relative cost and benefits that these disturbed and undisturbed habitats might provide for sloth bears to enhance our understanding of sloth bear distribution and habitat use. Furthermore, investigations on abundance of sloth bear as well as ground dwelling and mound building termites, fruit trees and other insects is required for a deeper understanding of ecological interactions and behavioural responses of the sloth bear. Our findings when combined with future knowledge generated from long-term experimental research and monitoring of sloth bear can serve as a valuable baseline for formulation of sloth bear conservation strategy and management plan.

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Data Accessibility : The data used to generate analysis is presented in the table and appendices and will be archived in publicly accessible repository Dryad.

Author's Contribution: RPP, RK, NS conceptualized the research; RPP lead the data collection, curation, formal analysis and wrote the original draft; RK supported analysis, funding acquisition, writing-review and editing; BRL supported in formal analysis, methodology, writing-review and editing, MSh supported writing-review and editing; TT supervised the study (lead); NS, MSh, MS supervised the study (Equal).

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Table 1. Description of covariates and hypothesized response on occupancy(Psi) and detection (P) of sloth bear. ‘+’ signifies a positive effect on the response variable, ‘-’ signifies a negative effect on the response variable and ‘*’ signifies that the covariate has no effect on the response variable.

Covariate	Description	Psi	P
Enhanced Vegetation Index (EVI)	EVI (2018) was obtained from SRTM vegetation index available at https://earthexplorer.usgs.gov .	-	*
Tree Cover (TC)	Prepared by Hansen et al. 2013, downloaded from the Global Forest Change website. (http://earthenginepartners.appspot.com/science-2013-global-forest).	+	*
Terrain Ruggedness Index (TRI)	Calculated in ArcGIS using 30 m resolution Digital Elevation Model (DEM) layer from the U.S. Geological Survey (USGS) website (https://earthexplorer.usgs.gov/)	+	*
Disturbance (D)	Presence absence (P/A) score of human, livestock and fire disturbance recorded in field and pooled to obtain an average score for each grid.	-	-
Fruit (F)	Presence absence of fruit plants most frequently consumed during the dry season in Chitwan (Khanal & Thapa, 2014 was pooled to obtain an average fruit score for each grid.	+	+

Covariate	Description	Psi	P
Termite (T)	Presence absence of termites recorded in field and single score for each grid obtained by averaging scores across four replicates.	+	+

Table 2. Summary of model selection process (Step 1) for factors affecting detection probability of Sloth bear

Model	AIC	ΔAIC	W_i	ML	K
psi(.),p(T+F+D)	161.81	0.00	0.54	1.00	5.00
psi(.),p(T+F)	163.22	1.41	0.27	0.49	4.00
psi(.),p(T+D)	164.42	2.61	0.15	0.27	4.00
psi(.),p(T)	167.27	5.46	0.04	0.07	3.00
psi(.),p(F+D)	171.00	9.19	0.01	0.01	4.00
psi(.),p(D)	171.12	9.31	0.01	0.01	3.00
psi(.),p(F)	174.12	12.31	0.00	0.00	3.00
psi(.),p(.)	175.48	13.67	0.00	0.00	2.00

AIC- Akaike's information criterion , ΔAIC - difference in the AIC values between each model and the model with the lowest AIC, W_i - AIC model weight, K- Number of parameters estimated by the model, T-Termite, F- Fruit D- Disturbance

Table 3. Summary of model selection process (Step 2) for Sloth bear occupancy . Coefficient of variation was used for TRI , EVI and the disturbance index was developed using resource collection, fire and grazing

Model	AIC	ΔAIC	W_i	ML	K
psi(T+F),p(T+F+D)	159.02	0.00	0.12	1.00	7.00
psi(T), p(T+F+D)	159.06	0.04	0.12	0.98	6.00
psi(T+F+D), p(T+F+D)	159.28	0.26	0.11	0.88	8.00
psi(T+D), p(T+F+D)	160.11	1.09	0.07	0.58	7.00
psi(T+TC), p(T+F+D)	160.20	1.18	0.07	0.55	7.00
psi(T+F+TRI), p(T+F+D)	160.47	1.45	0.06	0.48	8.00
psi(T+F+TC), p(T+F+D)	160.49	1.47	0.06	0.48	8.00
psi(T+F+EVI), p(T+F+D)	160.58	1.56	0.06	0.46	8.00
psi(TC+T+F+D), p(T+F+D)	161.28	2.26	0.04	0.32	9.00
psi(F), p(T+F+D)	161.58	2.56	0.03	0.28	6.00
psi(.),p(T+F+D)	161.81	2.79	0.03	0.25	5.00
psi(TC+D+T), p(T+F+D)	161.89	2.87	0.03	0.24	8.00
psi(TC+T+F+TRI), p(T+F+D)	162.05	3.03	0.03	0.22	9.00
psi(F+D), p(T+F+D)	162.22	3.20	0.02	0.20	7.00
psi(TC+T+F+EVI), p(T+F+D)	162.37	3.35	0.02	0.19	9.00
psi(TRI), p(T+F+D)	162.93	3.91	0.02	0.14	6.00
psi(EVI), p(T+F+D)	162.94	3.92	0.02	0.14	6.00
psi(TC), p(T+F+D)	163.03	4.01	0.02	0.13	6.00
psi(D), p(T+F+D)	163.15	4.13	0.02	0.13	6.00
psi(F+TC), p(T+F+D)	163.40	4.38	0.01	0.11	7.00

Model	AIC	Δ AIC	Wi	ML	K
psi(TC+TRI+EVI+T), p(T+F+D)	163.88	4.86	0.01	0.09	9.00
psi(TC+TRI), p(T+F+D)	164.12	5.10	0.01	0.08	7.00
psi(TC+D+F), p(T+F+D)	164.20	5.18	0.01	0.08	8.00
psi(TC+EVI), p(T+F+D)	164.57	5.55	0.01	0.06	7.00
psi(TC+D), p(T+F+D)	164.75	5.73	0.01	0.06	7.00
psi(TC+TRI+EVI+T+F+D), p(T+F+D)	164.96	5.94	0.01	0.05	11.00
psi(TC+TRI+EVI), p(T+F+D)	165.87	6.85	0.00	0.03	8.00
psi(TC+TRI+EVI+F), p(T+F+D)	166.23	7.21	0.00	0.03	9.00
psi(.),p(.)	175.48	16.46	0.00	0.00	2.00

AIC- Akaike's information criterion , Δ AIC- difference in the AIC values between each model and the model with the lowest AIC, W_i - AIC model weight, K- Number of parameters estimated by the model, T-Termite, F- Fruit plants, D- Disturbance Index, TC-Tree Cover, EVI-Enhanced Vegetation Index, TRI-Terrain Ruggedness Index

Table 4: Comparison of occupancy and detection estimates, top occupancy model, associated covariates, and their influence on sloth bear occupancy.

Author	Study Area	Psi	P	Best Model & influence of covariates
This Study	Nepal- Chitwan National Park	0.53	0.44	Termite (+) & Fruit (+)
Srivathsa et.al 2017	India- Bhadra Tiger Reserve	0.57	0.39	NDVI (-); Forest cover (+) & Ruggedness (+)
Puri et.al 2015	India	0.61	0.40	Forest cover (+) Ruggedness (+) Mean annual precipitation (-)
Babu et.al 2015	India- Meghamalai Hills	0.54	0.33	Grass cover (+), Tree height (+) & Disturbance (-)
Das et.al 2014	India- Northeastern Karnataka	0.79	0.47	Termite (+) & Fruit Trees (+)
Ramesh et al 2012	India- Mudumalai Tiger Reserve	0.83	0.23	Null model
Ratnayake et.al 2007	Srilanka	0.48	NA	Monsoon forest (+), Road density (-), Elevation (-)

Appendix 1 : Combined list of occupancy and detection models ranked according to AIC

Model	AIC	Δ AIC	Wi	ML	K
psi(T+F), p(T+F+D)	159.02	0.00	0.12	1.00	7.00
psi(T), p(T+F+D)	159.06	0.04	0.12	0.98	6.00
psi(T+F+D), p(T+F+D)	159.28	0.26	0.10	0.88	8.00
psi(T+D), p(T+F+D)	160.11	1.09	0.07	0.58	7.00
psi(T+TC), p(T+F+D)	160.20	1.18	0.07	0.55	7.00
psi(T+F+TRI), p(T+F+D)	160.47	1.45	0.06	0.48	8.00
psi(T+F+TC), p(T+F+D)	160.49	1.47	0.06	0.48	8.00
psi(T+F+EVI), p(T+F+D)	160.58	1.56	0.05	0.46	8.00
psi(TC+T+F+DI), p(T+F+D)	161.28	2.26	0.04	0.32	9.00
psi(F), p(T+F+D)	161.58	2.56	0.03	0.28	6.00
psi(.),p(T+F+D)	161.81	2.79	0.03	0.25	5.00
psi(TC+D+T), p(T+F+D)	161.89	2.87	0.03	0.24	8.00
psi(TC+T+F+TRI), p(T+F+D)	162.05	3.03	0.03	0.22	9.00
psi(F+D), p(T+F+D)	162.22	3.20	0.02	0.20	7.00
psi(TC+T+F+EVI),p p(T+F+D)	162.37	3.35	0.02	0.19	9.00
psi(TRI), p(T+F+D)	162.93	3.91	0.02	0.14	6.00
psi(EVI), p(T+F+D)	162.94	3.92	0.02	0.14	6.00
psi(TC), p(T+F+D)	163.03	4.01	0.02	0.13	6.00

Model	AIC	Δ AIC	Wi	ML	K
psi(D), p(T+F+D)	163.15	4.13	0.02	0.13	6.00
psi(.),p(T+F+D)	163.22	4.20	0.01	0.12	4.00
psi(F+TC), p(T+F+D)	163.40	4.38	0.01	0.11	7.00
psi(TC+TRI+EVI+T), p(T+F+D)	163.88	4.86	0.01	0.09	9.00
psi(TC+TRI),p p(T+F+D)	164.12	5.10	0.01	0.08	7.00
psi(TC+D+F), p(T+F+D)	164.20	5.18	0.01	0.08	8.00
psi(.),p(T+D)	164.42	5.40	0.01	0.07	4.00
psi(TC+EVI), p(T+F+D)	164.57	5.55	0.01	0.06	7.00
psi(TC+D), p(T+F+D)	164.75	5.73	0.01	0.06	7.00
psi(TC+TRI+EVI+T+F+D),p(T+F+D)	164.96	5.94	0.01	0.05	11.00
psi(TC+TRI+EVI),p p(T+F+D)	165.87	6.85	0.00	0.03	8.00
psi(TC+TRI+EVI+F), p(T+F+D)	166.23	7.21	0.00	0.03	9.00
psi(.),p(T)	167.27	8.25	0.00	0.02	3.00
psi(.),p(F+D)	171.00	11.98	0.00	0.00	4.00
psi(.),p(D)	171.12	12.10	0.00	0.00	3.00
psi(.),p(F)	174.12	15.10	0.00	0.00	3.00
psi(.),p(.)	175.48	16.46	0.00	0.00	2.00

Appendix 2: Covariates influencing Sloth bear occupancy inferred from top model (Δ AIC <2), ranked on the basis of summed model weights with averaged β co-efficients and associated standard error.

Estimate	Variable	AIC_Weight	Beta	SE	LCI	UCI
Occupancy	T	0.66	0.84	0.41	0.03	1.65
	F	0.40	0.62	0.44	-0.25	1.48
	D	0.18	0.61	0.55	-0.47	1.69
	TRI	0.06	0.28	0.41	-0.52	1.09
	EVI	0.06	0.25	0.38	-0.50	0.99
	TC	0.13	-0.33	0.41	-1.14	0.48
Detection	T	0.81	1.80	0.53	0.76	2.83
	F	0.53	0.88	0.39	0.12	1.65
	D	0.70	-0.59	0.33	-1.22	0.05





