Linking critical patches of sloth bear *Melursus ursinus* for their conservation in Meghamalai hills, Western Ghats, India

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The study examines the distribution and factors regulating the sloth bear in a fragmented hills of Meghamalai in Western Ghats through occupancy framework. Indirect evidences were sought over 133 grids of 4 sq. km size between December 2011 and December 2012. Indirect evidences were recorded in 58 of 133 sampled grids that estimated naïve occupancy of 0.43 ($p = 0.3180$). Understorey cover negatively affected the detection of indirect evidences. The parsimonious model contained three covariates, viz. tree height, grass cover and anthropogenic disturbance. Overall occupancy of bear was 0.54, which is 25% higher than the naïve occupancy estimate. The study predicted higher proportion of evergreen forests with intermediate grass cover and less extent of disturbance determines the occupancy of bear in these hills. The 'critical link' connecting Periyar–Agastiyamalai hills and Anamalai hills is still active and supports high suitable sites for bears. It is suggested that Ammagajam–Upper Manalar Contiguity and Critical Link needs to be protected by appending with Meghamalai Wildlife Sanctuary.

Keywords: Conservation, critical patches, sloth bear, surrogate species.

SLOTH bear (*Melursus ursinus*) is one of the four species of bears found in India (the others being sun bear *Helarctos malayanus*, brown bear *Ursus arctos isabellinus* and Asiatic black bear *U. thibetanus*)[1,2]. High depiction in the country, four out of eight bears of the world, is attributed to India's geographic location at the junction of the Palaearctic and Indo-Malayan biogeographic zones[1]. The reportedly stable estimated population of 6000–11,000 adult bears is spread over in 174 Protected Areas (PAs) in India[3]. However, populations that persist outside the PAs are alleged to be highly vulnerable to human pressure[4]. In addition to the reduction in its habitat, the bear faces severe anthropogenic pressure due to poaching for its gall bladder, fat, meat and skin[5]. Crop raiding and conflict with humans by bears are attributed to loss of their habitat across their range[6]. Considering the rapid disappearance of their natural habitat, the IUCN has categorized sloth bears as 'Vulnerable'[5]. Among the large carnivores, sloth bear has relatively high density in the southern Western Ghats and occupies a wide array of natural forests. Sloth bear, being a large omnivorous animal showing a high adaptability to live in all the altitudinal gradients and vegetation types in the Western Ghats[7], is the best surrogate species to address the conservation issues.

In the southern Western Ghats, the Periyar–Agastiyamalai and Anamalai corridors have been degraded due to heavy exploitation of forests. However, both corridors are connected with Meghamalai hills through a narrow strip of forest, which has been considered as a 'critical link' by Critical Ecosystem Partnership Fund-Western Ghats profile[8]. A portion of the Meghamalai hills was declared as a PA, and the remaining area in the hills was not assessed properly for conservation. Further, high density of humans, developmental activities and croplands make this mountain range more vulnerable. In this context, the sloth bear can act as a surrogate species for the conservation of this hill and the critical link. The present study explores the factors that determine the occurrence of sloth bear in Meghamalai hills and usage of the critical link, which would help in prioritizing the area for conservation.

Meghamalai is located in the Theni Forest Division of Tamil Nadu (Figure 1). A wide range of altitudinal gradients (220–2000 m amsl) and varied rainfall pattern form an array of vegetation types ranging from dry forests (thorn, deciduous and savannah forests) to wet forests (evergreen and shola grasslands). Composition and configuration of the hills support diverse species of vertebrates, viz. 18 species of fishes[9], 35 amphibians[10], 90 reptiles[11], 254 birds[12] and 63 mammals. The mean annual rainfall of the lower and higher elevations of the study site is 1500 and 2161 mm respectively. Major rivers originating from these hills are the Vaigai and the Suruliar, on which five dams operate, viz. High Wavys, Manalar, Venniyar, Eravangalar and Shanmuganathi dams for producing electricity and for irrigation. The southern part of Meghamalai is a fragmented unit of the Periyar–Agastiyamalai corridor, connecting the PAs of Periyar Tiger Reserve in the west and Grizzled Squirrel Wildlife Sanctuary in the south, whereas the northern part of the forest division is connected to the Anamalai corridor.

Occupancy framework was followed to elucidate the factors that influence the occurrence of sloth bear in the study site. The estimated home range size of sloth bear in central India is reported to be 12 sq. km for a female and 85 sq. km for a male[7]; however, home range size for bears is not available for the Western Ghats. To accommodate the grids in the narrow patches of the forests in the critical link, we selected 4 sq. km as a minimum sampling unit to assess the occurrence of sloth bear on spatial scale. These spatial grids were overlaid on the base map

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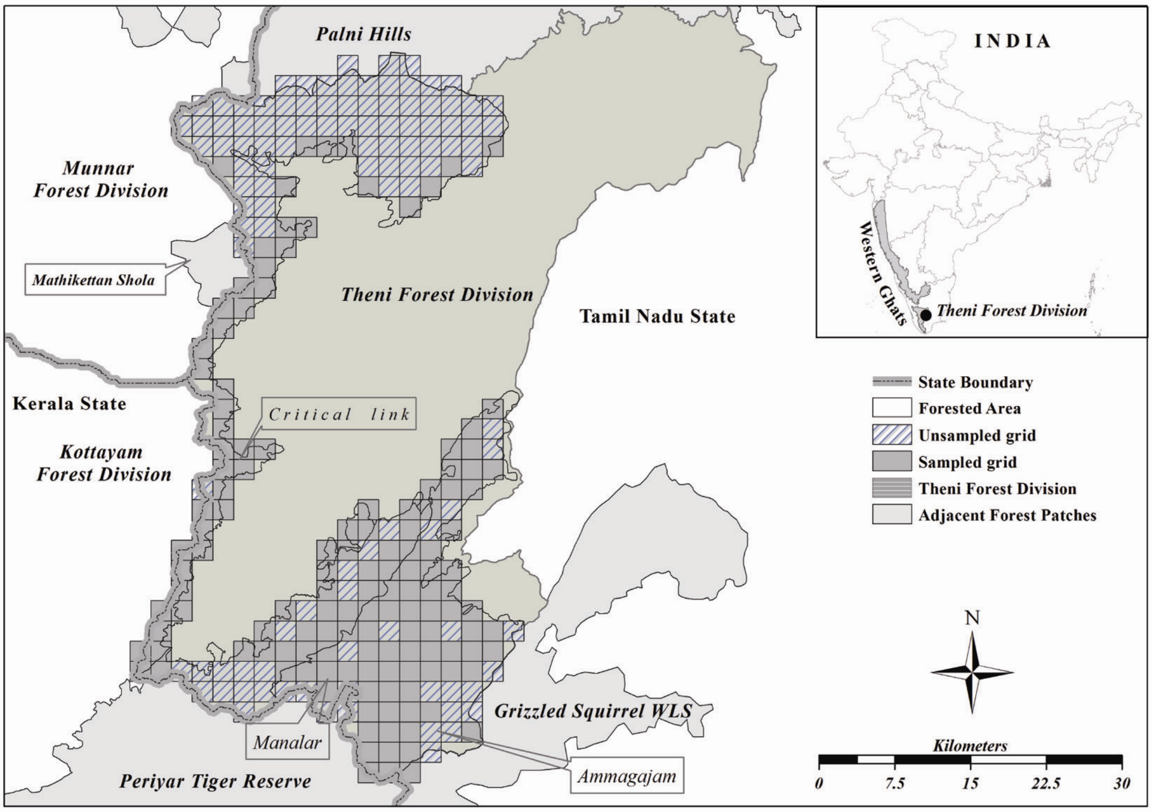

Figure 1. Map showing Meghamalai hills in the southern Western Ghats and design of sampling framework.

Table 1. Hypothetical assumption on the effect of each covariate on detection and occupancy of sloth bear

Covariates	ψ	P
Grass height	+	–
Grass cover	+	–
Weed cover	–	–
Weed height	–	–
Understorey cover	0	–
Understorey height	0	–
Tree height	+	0
CV_NDVI	–	0
Disturbance	–	0
Altitude	+	0
Slope	–	0

Positive and negative signs indicate positive and negative influences on the occupancy and detection probability respectively; 0 indicates no influence.

of Meghamalai hills. A total of 250 grid cells were established, of which we selected all 'complete' (more than 75% of the grid falls within the forest boundary) grid cells for sampling, i.e. 230 grid cells. However, due to inaccessible terrain in some of the grids, only 133 grid cells covering 532 sq. km (>70% of the total area) were sampled for the occurrence of bears. In each grid, existing trails or bearing fixed routes were used such that they represented all the habitat types of the entire grid. A minimum of 2.5 km was considered as sampling distance to cover the entire grid. Spatial replicate was followed to estimate the detection probability and occupancy[13]. Every 500 m length of walk in the grid was considered as a spatial replicate and thereby a minimum of five spatial replicates were undertaken in each grid. In each spatial replicate, every 100 m length of replicate was considered as a segment, where covariates for sampling were recorded. Occurrence of bear and other covariates was noted in all segments and replicates in a grid. Sloth bears are crepuscular/nocturnal in their activity; thus, their direct sightings are difficult during the day sampling. Therefore, the bear droppings were considered as an evidence of occurrence. To record the bear droppings, 2 m on both sides along the trail was considered as sampling area. During the walk, presence of bear droppings within the sampling area was recorded for each 100 m segment to construct the detection history. The sampling was done during December 2010–May 2011 and December 2011–May 2012.

Covariates that influence the detection and occupancy of bears were included as sampling and site covariates respectively. We hypothesized that increase in grass, weed and understorey cover would negatively influence the detection of bear droppings (Table 1). Tree density, tree height, tree cover, canopy contiguity, disturbance

Table 2. Details of habitat covariates used in modelling, occupancy, their mode of assessment, unit of measurement and scale of measure

Parameters	Mode of assessment	Unit of measurement	Scale	
			P	ψ
Altitude	GIS	Metres	–	Mean/grid
Slope	GIS	Degrees	–	Mean/grid
CV_NDVI	GIS	Variance	–	Mean/grid
Tree height	Visual	Metres	–	Mean/grid
Understorey height	Visual	Metres	Mean/replicate	Mean/grid
Understorey cover	Visual	Percentage	Mean/replicate	Mean/grid
Grass height	Visual	Metres	Mean/replicate	Mean/grid
Grass cover	Visual	Percentage	Mean/replicate	Mean/grid
Weed cover	Visual	Percentage	Mean/replicate	Mean/grid
Disturbance	Visual	Gradient	–	Mean/grid

CV_NDVI, Coefficient of variance of normalized difference vegetation index; GIS, Geographical information system.

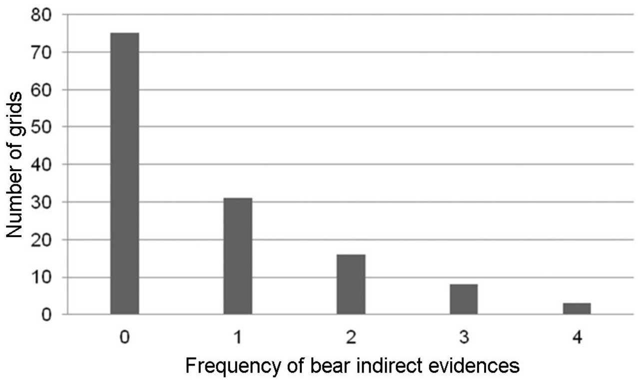

Figure 2. Frequency distribution of observed instances of indirect evidences of sloth bear in grids of Meghamalai hills.

index, altitude, slope, normalized difference in vegetation index (NDVI), and coefficient of variance of NDVI (CV_NDVI) were considered as site covariates.

A sampling point at every 100 m of replicate, thus five sampling points per replicate, was established to assess the habitat and sampling covariates. Point-centred quarter method[14] was followed to quantify tree characteristics. Distances of four nearest trees from four quarters with greater than 20 cm girth at breast height (GBH) were measured to estimate tree density. Remaining tree covariates (tree height, cover, contiguity) were measured qualitatively (Table 2). Five metre radius circular plot was established to quantify understorey characteristics. Tree height was measured in metres and tree and shrub cover as percentage. Disturbance in each replicate was coded in a gradient, ranging from 1 to 10 scoring for low to high anthropogenic disturbance. The presence of threats such as livestock grazing, illegal hunting, conflict with wild animals, non-timber forest produce (NTFP) collection, fuel wood, fodder extraction and presence of human settlements in each segment and the grids was coded as 1 and absence of the same as 0. We summed all values to get the overall anthropogenic pressure in each grid. SRTM images were used to extract altitude and slope values for each grid, while multi-dated satellite data of SPOT-VEGETATION were used for extracting NDVI and CV_NDVI. Mean NDVI was highly correlated with vegetation-related parameters and CV_NDVI, which indicate the degree of variation in NDVI, viz. low for evergreen forests and high for dry forests.

Bear droppings contributed to detection histories for each replicate, where '1' indicated detection of the animal, '0' indicated non-detection and '–' indicated a missing observation. We constructed detection histories for all the sampled grids. The two model parameters – probability that a grid is occupied by the species (ψ) and detection probability (p) were estimated using likelihood functions[15]. The program PRESENCE ver. 3.0 was used to derive maximum likelihood estimates of the model parameters. We cross-correlated these covariates to remove all the auto-correlated variables and correlation coefficient above 0.50 was set as the cut-off value for removing correlated variable. Thereby we retained ten uncorrelated covariates for further analysis (Table 1). Ground variables such as understorey, grass and weed were built-in into the model to estimate detection probability, while tree, remotely sensed covariates, understorey and disturbance variables were included for modelling occupancy. Considering previous publications regarding the covariates[4–7], 10 a priori models were developed to assess the relative influence of covariates on detection and occupancy of bear in each grid. Model selection, computation of model weights, and averaging of parameters followed the framework of Burnham and Anderson[16]. The effect of each covariate on occupancy and detection probability was evaluated using logistic model with logit link function. We calculated the model-averaged parameters using Akaike weights for proportion of sites used and detection probabilities. To infer the relative influence of each covariate on occurrence, model weights were

Table 3. Summary of factors affecting the detection of indirect evidences of sloth bear

Model	*P*	AIC	ΔAIC	w_i	K
ψ (.), *p* (USC)	0.3329	502.09	0.00	0.6068	2
ψ (.), *p* (.)	0.3180	503.05	0.96	0.3755	2
ψ (.), *p* (USH)	0.3663	509.20	7.11	0.0173	2
ψ (.), *p* (WH)	0.4051	517.06	14.97	0.0003	2
ψ (.), *p* (WC)	0.5000	525.52	23.43	0.000	2
ψ (.), *p* (GH)	0.5001	526.41	24.32	0.000	2

USC, Mean understorey cover; USH, Mean understorey height; WH, Mean weed height; WC, Mean weed cover; GH, Mean grass height.

Table 4. Summary statistics of candidate model performed and contribution of covariates for site occupancy (and SE) of sloth bear in Meghamalai hills, Western Ghats, India. Results are ranked based on AIC values of models with ΔAIC (AIC – min AIC), AIC model weight (w_i) and number of parameters (*k*)

Model	ψ	SE	AIC	ΔAIC	w_i	*k*
ψ (GC + TH + DIS), *p* (USC)	0.5478	0.0943	485.19	0.00	0.425	5
ψ (GC + GH + TH + DIS + WC + ALT + SLO), *p* (USC)	0.5464	0.1306	485.59	0.40	0.348	10
ψ (GH + GC + TH + DIS), *p* (USC)	0.5487	0.1036	487.12	1.94	0.161	6
ψ (GC + ALT + DIS), *p* (USC)	0.5536	0.0966	491.00	5.81	0.023	5
ψ (GH + TH + DIS), *p* (USC)	0.5435	0.0952	491.09	5.90	0.022	5
ψ (GC + CVN + DIS), *p* (USC)	0.5440	0.0967	492.63	7.44	0.010	5
ψ (WC + GC + DIS), *p* (USC)	0.5455	0.0970	493.18	7.99	0.008	5
ψ (GC + DIS), *p* (USC)	0.5492	0.0870	494.95	9.76	0.002	4
ψ (.), *p* (USC)	0.5370	0.0573	502.09	16.9	0.001	2
ψ (.), *p* (.)	0.5487	0.0612	503.05	17.8	0.001	2

GC, Mean grass cover; GH, Grass height; TH, Mean tree height; DIS, Cumulative anthropogenic disturbance in the grid; CVN, Coefficient of variance in NDVI; WC, Mean weed cover; ALT, Mean altitude; SLO, Mean slope and USC, Mean understorey cover.

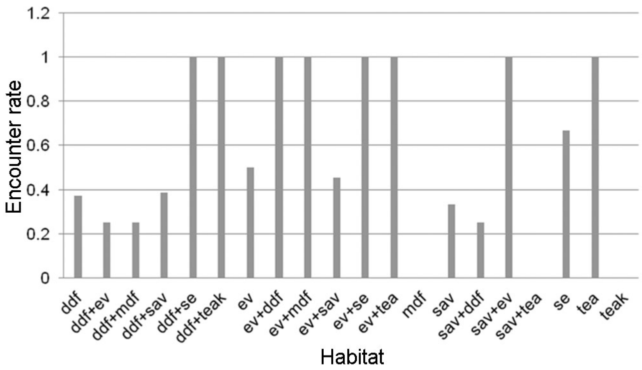

Figure 3. Naïve occupancy estimates and study efforts in different vegetation types in Meghamalai. ddf, Dry deciduous forest; mdf, Moist deciduous forest; sav, Savanna forest; se, Semi evergreen forests; ev, Evergreen forests; teak, Teak plantation; tea, Tea plantation.

summed over all models containing the particular covariate. The correlations of predicted proportion of sites occupied by species for each grid with certain tree and disturbance variables were tested using Pearson correlation. The naïve occupancy estimate was projected according to vegetation types (dry deciduous, moist deciduous, savanna, semi evergreen and evergreen forests, teak and tea plantations) and elevation.

Sloth bear was sighted during two occasions in the 586 km walk in 133 grids. The bear droppings were recorded in 58 grids (Figure 2) that provided the naïve occupancy estimate of 0.43, which varied across the grids with different vegetation types from 0.39 in open scrub forests to 0.80 in evergreen forests (Figure 3). Grids at high elevation had higher naïve occupancy estimate than those at lower elevation (high elevation – 0.8 droppings/grid; mid elevation – 0.44 droppings/grid; low elevation – 0.38 droppings/grid).

Among the six sampling covariates, detection probability (*p*) of bear droppings was influenced by understorey cover ($w_i = 0.6068$) and outperformed other candidate models (Table 3), including constant model ψ(.) *p*(.). Increase in understorey cover decreased visibility of bear droppings ($\beta = -0.2530$; SE = 0.0533). The second best model was a constant model, and all subsequent models for occupancy (ψ) were performed with detection probability as a function of understorey cover. The global model (model fitted with maximum number of parameters) perfectly fitted the data (c-hat = 0.94, chi-square probability value = 0.60).

Constant model for occupancy, ψ(.) *p*(.), performed poorly as evidenced by low AIC value in the summary statistics of the model (Table 4). Among other occupancy models, the most parsimonious model (ΔAIC = 0.00) included grass cover, tree height and disturbance. Grass cover ($\beta = 0.673$, SE = 0.281) and tree height ($\beta = 0.9484$, SE = 0.375) positively influenced occupancy

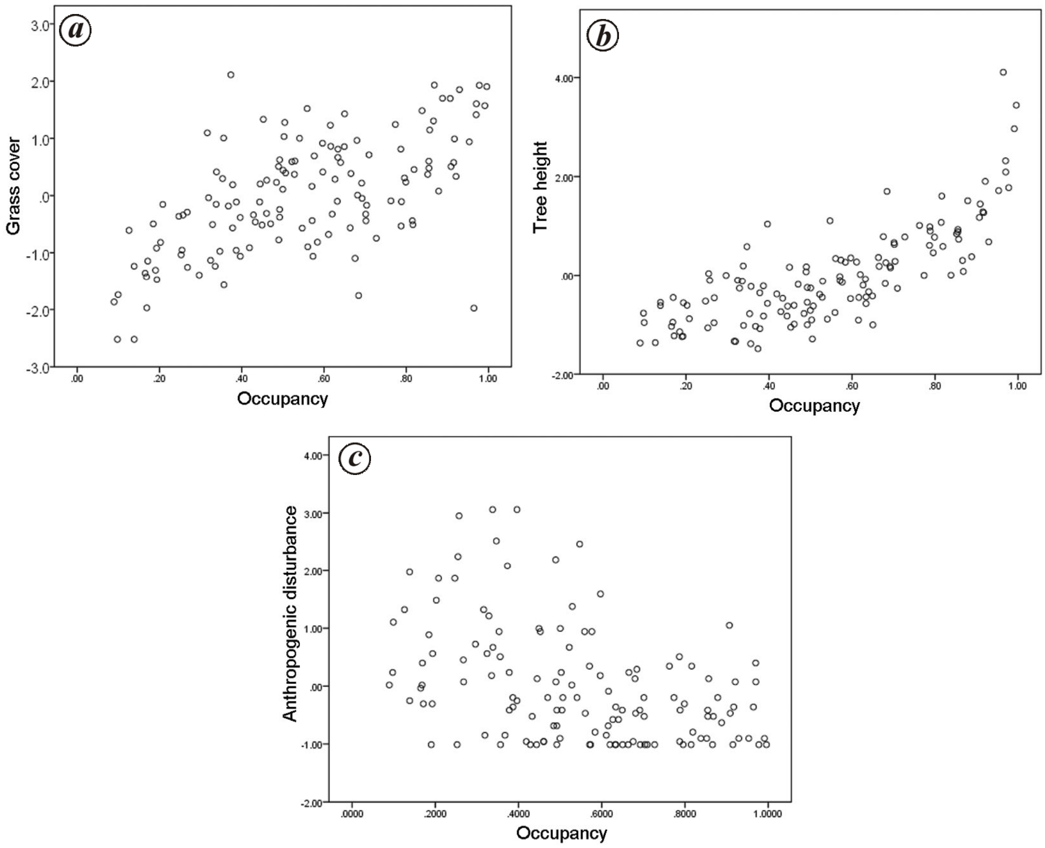

Figure 4. Relationship between estimated occupancy and site covariates: ***a***, Grass cover; ***b***, Tree height; ***c***, Anthropogenic disturbance.

Table 5. Covariates affecting the distribution and habitat use of sloth bear in Meghamalai hills, ranked based on AIC weights (of all models) and with average β coefficient and standard errors (SE) (of top three models)

Covariate	Summed AIC weights	β coefficient	SE
Disturbance	0.998	–0.3588	0.2335
Grass cover	0.978	0.6730	0.2807
Tree height	0.956	0.9484	0.3751
Grass height	0.531	–0.0075	0.2520
CV_NDVI	0.358	–0.3834	0.2688
Altitude	0.371	0.7143	0.3458
Weed cover	0.356	0.4361	0.2592
Slope	0.348	–0.2337	0.3502

of the bears, while disturbance had a negative influence (β = –0.358, SE = 0.233; Table 5). Predicted proportion of sites occupied by the species in each grid was positively correlated with tree height ($r = 0.768$; $p = 0.000$) and grass cover ($r = 0.610$, $p = 0.000$), and negatively correlated with disturbance ($r = -0.422$, $P = 0.000$; Figure 4 *a*–*c*). Among the covariates, bear occupancy was strongly influenced by disturbance factors, which is evident from higher summed AIC model weights ($w_i = 0.998$) followed by grass cover and habitat related covariates (Table 5).

The second parsimonious model ($\Delta AIC = 0.40$) is a global model which contains all covariates considered for it. Grass height influenced the proportion of sites occupied by the bears along with other variables, but ranked third in position. None of the high-ranked models ($\Delta AIC \geq 2$) showed high AIC model weight; thus model averaging of occupancy and standard error was calculated[16]. The average occupancy estimate (0.5478, SE = 0.094) corresponds to a difference of 25% from the naïve estimate of occupancy (0.4361). Higher proportion of occupancy of sloth bear was estimated over critical link and the Meghamalai hills (Figure 5).

Sloth bear occupies a broad range of ecosystems, from dry plains to montane grasslands, decisively varying with temporal and spatial scales[17–19]. Principally being a lowland animal, it occurs at 2000 m altitude in the Western Ghats[1]. Though the rate of occupancy varies across altitudinal gradients, the bear was recorded from low-altitude scrub forests to high-altitude evergreen forests of the Meghamalai hills. Estimated occupancy for sloth bear in Meghamalai hills was 0.54 with $p = 0.33$, which is comparatively lesser than Mudumalai ($p = 0.23$; $\psi = 0.83$)[20] and Daroji ($p = 0.46$; $\psi = 0.78$)[21]. Low occupancy in Meghamalai hills may be due to the inherent low density of bears.

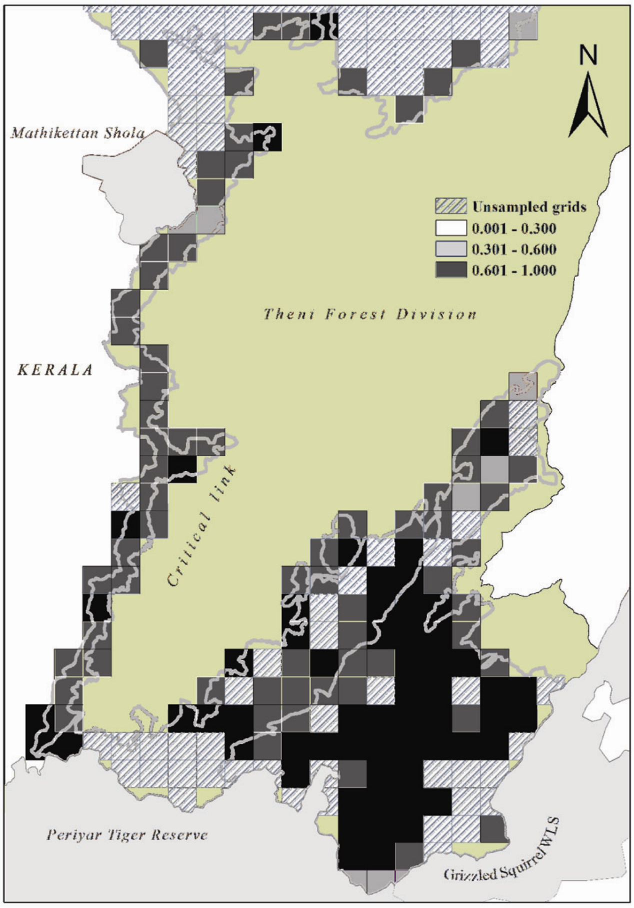

Figure 5. Predicted estimates of occupancy of sloth bear within the sampling framework of Meghamalai hills.

Among the six sampling covariates, understorey cover negatively influenced the detection of droppings. Similarly, a study in Bandipur Tiger Reserve[22] reported the negative influence of understorey in detecting the pellets of four-horned antelope, *Tetracerus quadricornis*. The habitat covariates broadly corroborate with two life-history characteristics of bears, i.e. habitat devoid of human disturbance for roosting (evergreen with less disturbance) and an imperative need for foraging ground (grass land). Grasslands being a major source of ants and termites, reported as important foraging ground for bears across India[23,24] and Chitwan NP in Nepal[25], thus positively influence the proportion of sites occupied by bears in Meghamalai hills.

The evergreen forest is one of the major determinants (higher tree height) of occupancy of bears in Meghamalai hills, which is contrary to the findings from Mudumalai[20–23] and Parambikulam[26], where bear occurrence was higher in deciduous forests with tall grasses. The sampling period of the present study coincides with other studies; thus the influence of study time can be ignored here. Higher estimates of occupancy in evergreen forests can be attributed to: (1) the availability of fruits throughout the year in evergreen forests than in dry forests; (2) dry forests in Varusanad and Meghamalai experience tremendous anthropogenic pressure that might have pushed the bears towards higher elevation; (3) *Zizyphus* spp. is reported[19] as the major food plant of bears in deciduous forests, which may have been suppressed due to heavy *Lantana camara* infestation in the deciduous forests[27].

Occupancy of sloth bear was higher in the reserve forests of Meghamalai hills, which is highly vulnerable to anthropogenic pressure. Natural forests encircled with plantations in the Ammagajam – Upper Mannalar not only show high occupancy of sloth bears, but also hold large populations of endangered lion-tailed macaque[28] and Nilgiri tahr[13], and facilitate movement of mammals between Grizzled Squirrel Wildlife Sanctuary, Periyar Tiger Reserve and Meghamalai Wildlife Sanctuary. Thus, these forest patches need to be brought under the PA network to enhance the protection of these animals.

In addition to high occupancy of sloth bears in the critical link, it also supports the occurrence and movement of many large mammals between Periyar–Agastiyamalai and Anamalai corridors. In spite of its high biodiversity value, the link also endures severe anthropogenic pressures and developmental activities such as new roads, hydro-electric projects, and existing inter-state highways. Considering the crucial biodiversity value and surging anthropogenic pressure of the link, the area requires immediate conservation attention. We suggest that further development projects should be avoided and the critical link should be included with the Meghamalai Wildlife Sanctuary.

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