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Cover: Whale Shark *Rhincodon typus* and Reef - made with poster colours. © P. Kritika.

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COMMUNICATION

Status distribution and factors affecting the habitat selection by Sambar Deer *Rusa unicolor* in Pench Tiger Reserve, Madhya Pradesh, India

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Abstract: Sambar *Rusa unicolor* is one of the deer species distributed throughout the Indian subcontinent. The species has been listed as 'Vulnerable' on the IUCN Red List since 2008, and Schedule I Part A of the Indian Wildlife Protection Act, 1972. Populations have declined throughout its distribution range. This study aims to investigate the status, distribution, and habitat selection of Sambar in Pench Tiger Reserve, Madhya Pradesh, India. Fifteen line transects of 2-km length were laid in five different habitats. Data were collected during the winter and summer seasons during 2013 and 2015. Transects were traversed morning and evening and eight replicates were made on each transect, for a total of 1,232 km survey effort. The overall density of Sambar was 3.7 individuals per km^2, and the group density 1.4 groups per km^2. During the summer 113 individual Sambar were observed, and in winter only 80 individuals were observed. Male:female sex ratio was calculated as 100:59 in winter, and 100:56 in summer. Indirect evidence was also collected to supplement the direct sightings for analysis of habitat use. Ten-meter circular plots were laid on all 15 transects at an interval of 200 m between two plots. Principal component analysis and logistic regression were performed to understand the habitat use of this species during summer, post-monsoon, and winter seasons using pellet groups. The logistic regression model showed an efficiency of 97% correct classification during post-monsoon, 67% in winter, and 66% in summer.

Keywords: Habitat utilisation, population density, principal component analysis, logistic regression.

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Author contributions: The project was funded to OI as she was the principal investigator of the project and AH worked as researcher under the project.

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INTRODUCTION

Sambar *Rusa unicolor* is native to India, Pakistan, Sri Lanka, Philippines, southern China, Taiwan, Malaysia, Borneo, Sumatra, and Java (Wilson & Mittermeier 2011). In India the distribution range extends east along the southern Himalaya and south throughout the Deccan peninsula. Sambar are abundant in the southern states of Karnataka, Tamil Nadu, and Kerala (Sridhar et al. 2008; Timmins 2015). In other central and east Indian states, Sambar is considered very rare, and the distribution is patchy and declining due to severe hunting pressure, insurgency, and habitat destruction (Timmins 2015). Sambar have disappeared from Sikkim and Tripura (Khan & Johnsingh 2015).

Ungulates play an important role in maintaining the ecosystem by influencing vegetation structure (Augustine & McNaughton 1998; Bagchi & Ritchie 2010). They also play a major role in maintaining prey-predator relations. Sambar is known to be a preferred prey of tiger, throughout its range (Karanth & Sunquist 1992; Karanth & Nichols 2000; Ramesh et al. 2009). Tiger Estimation Report (2019) reported 2,967 tigers in India among which a maximum of 526 tigers are present in Madhya Pradesh (Jhala et al. 2018). Such population of tigers needs a good prey base and population estimation is key for managing the population of prey species. The Sambar and Chital *Axis axis* together form the bulk of the prey base for all large carnivores of the Indian subcontinent such as the Tiger, the Asiatic Lion, the Leopard, and the Dhole (Devidar 1974; Johnsingh 1983; Bhatnagar 1991; Venkataraman 1995). Sambar contributes the most to the prey biomass and is considered a keystone species in Pench Tiger Reserve (Venkataraman 1995).

Information on specific habitat requirements is important for conservation, and governing species habitat use including aspect, slope, food availability, vegetation cover, food availability, vegetation cover, terrain, and cover against extremes of weather and other biotic pressures. Conservation of species requires a good understanding of the habitat requirements and careful monitoring of populations (Yocozetal 2001; Acharya 2007). Understanding population trends and habitat use is crucial for implementation of conservation actions.

The study aims to evaluate the density and population structure of Sambar and the factors affecting its distribution in different seasons within Pench Tiger Reserve (PTR), Madhya Pradesh, India. This study will update knowledge on the abundance and habitat use of Sambar in PTR. The present study will be useful for the managers and policymakers for conservation of the species and its habiatat throughout its distribution range.

MATERIAL AND METHODS

Study Area

The Pench Tiger Reserve, Madhya Pradesh, India is one of the important protected areas of the Satpura-Maikal ranges of the central Indian Landscape. The area was declared as the 19th tiger reserve of India in 1992. PTR comprises a sanctuary and national park, covering an area of 757.85 km^2 (21.6200^0 latitude and 79.2125^0 longitude) at an altitude of 425–600 m (Figure 1). The terrain is gently undulating comprising seasonally flowing streams and nullahs. The Pench River, from which this tiger reserve is named, runs through the reserve over a length of 24 km bisecting it into two halves.

The tiger reserve has four seasons: Summer (March–June), Monsoon (July–August), Post-monsoon (September–November), and Winter (December–February). The temperature ranges from 4^0 C in peak winter to 45^0 C in the peak summer. The PTR receives an average annual rainfall of 1,300 mm. The PTR is a dry deciduous forest dominated by *Tectona grandis*, *Boswellia serrata*, *Anogeissus latifolia*, *Sterculia urens*, and *Gardenia latifolia*. Tiger *Panthera tigris*, Leopard *Panthera pardus*, Dhole *Cuon alpinus*, Jungle Cat *Felis chaus*, Small Indian Civet *Viverricula indica*, Striped Hyena *Hyaena hyaena*, Sloth Bear *Melursus ursinus*, Golden Jackal *Canis aureus*, and Common Palm Civet *Paradoxurus hermaphroditus* are the carnivore species of the reserve. Herbivores, apart from Sambar, include Chital, Gaur *Bos gaurus*, Nilgai *Boselaphus tragocamelus*, Barking Deer *Muntiacus muntjac*, and Chowsingha *Tetraceros quadricornis*.

Methods

Distance sampling was used to study the population density of Sambar in PTR. A total of 15 line transects of 2-km length were traversed morning and evening. The study area was divided into five different habitats on the basis of vegetation composition, and the transects were set to cover all the five habitats and three transects were laid in each one, i.e., Bamboo forest, Grassland, Mixed forest, Teak forest, and Teak mixed forest.

Two seasons were selected to reduce the bias in data collection: Summer and Winter. Eight monitorings were made on each transect in summer and winter, 0600–0900 h and 1600–1800 h. The direct sightings of

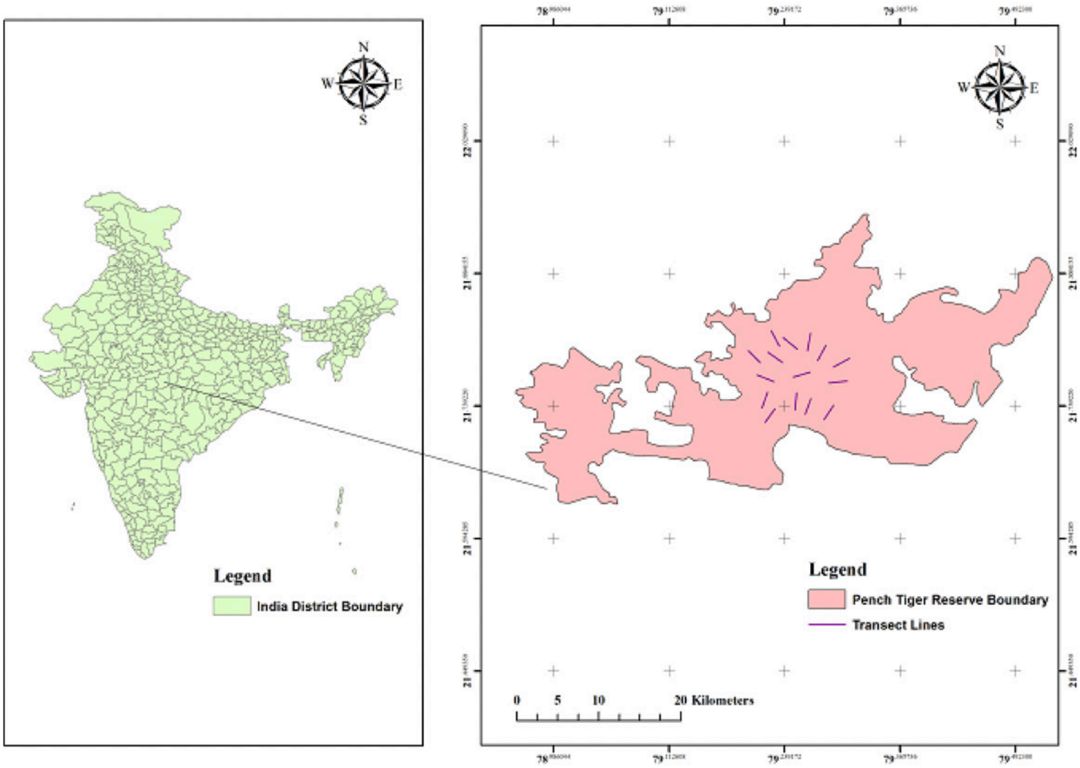

Figure 1. Map of the study area with location of transects.

Sambar were recorded. During the field survey a total of 1,232km efforts were given while traversing the transects.

To assess the habitat utilization pattern, indirect data were also collected. Ten-meter radius circular plots were laid on all of the 15 transects at an interval of 200 m from one another. The tree species present were counted within each plot. Five-meter circultar plots were laid to assess shrub cover and 1-m quadrats for grasses and herbs. Pellet groups are another indicator of the presence of a species in a given habitat. For assessing the habitat utilization pattern of Sambar, along with the vegetation data, data on Sambar pellet groups were also collected.

On each sampling plot, canopy cover was measured at four different points, using a mirror of 25 x 25 cm divided into 100 equal grid squares. The mirror was held horizontally at 1.25 m above ground level, and grid squares covered by more than 50% tree foliage were counted. Percentage canopy cover for each sampling plot was calculated from these counts. Shrub cover, grass cover and herb cover was also measured for each plot in different seasons through ocular estimation.

Data analysis

Line transect data collected were analyzed using DISTANCE 7.0. The distribution of the data was firstly examined by assigning very small cut-off points to the distance intervals during the curve fitting. After choosing convenient cut-off points for the distance intervals, the best key function (with the appropriate adjustment term, where necessary) was selected using the criterion of lowest AIC (Akaike information criteria).

Age classification of Sambar followed Schaller (1967), Sankar (1994), and Sankar et al. (2001). Data on group size and composition were analyzed following Schaller (1967) and Johnsingh (1983). Mean group size was estimated by taking the average of different group sightings, and group size was classified into different class intervals for better explanation between different seasons.

Analysis of indirect evidence such as pellet groups was organized in a simple habitat matrix in order to investigate the habitat selection at macro level. The pallet group density was calculated using following formula:

Density / ha = (Number of pallet groups / Area) × 10000.

Species diversity and richness were calculated by using modified version of "SPECDIVER BAS" (Ludwing & Reynolds 1988), a module of software STASTICAL

ECOLOGY written in BASIC.

One-way ANOVA was used to test significant differences in mean pellet group density in different habitats in different seasons using the computer program SPSS 6.1 (Norusis 1994).

To understand the habitat selection at micro level, principal component analysis (PCA) was performed to avoid confounding highly correlated variables. All the quantitative data in the matrix were transformed using log and arcsine transformation and transformed data were standardized by calculating the mean and standard deviation of each column of data matrix.

Factor analysis was used to reduce the dimensionality of different habitat variables. The first two factors were used for interpretation as these explained maximum variations in the data set. Before using PCA most of the auto-correlated variables were dropped. As habitat selection analysis concentrated on 30 variables around different sampling plots in different season, were recorded out of which different variables in different seasons were used for PCA, and factor scores were saved. Utilized and available plots were plotted in two dimension space defined by PCI, and PCII. All the extracted factors with eigen values of more than one were saved and used for logistic regression analysis. In logistic regression, the principal component was then used as candidate variables in logistic regression model with forward step-wise entry.

RESULTS

Population density and abundance of Sambar

During the winter season, a total of 80 sightings were observed, while in summer 113 sightings were observed (sightings for both years were pooled). The long distance sightings were trancuated to reduce the bias. A total number of detection of Sambar was 80 in winter, and 113 in summer were used to estimate density. Half-normal cosine model was selected for both winter and summer season as best fit estimator. The effective strip width for winter season was (23.7 ± 3.45) m whereas for summer season it was (18.7 ± 2.34) m. The estimated density of Sambar was 6.93 (± 1.69) km^{-2} in winter 2014, 4.27 (± 1.05) km^{-2} in winter 2015 and 3.36 (± 0.71) km^{-2} for overall winter season. Summer density was 10.2 (± 2.58) km^{-2} in 2013, 15.7 (± 4.88) km^{-2} in 2014, 8.53 (± 2.48) km^{-2} in 2015 and 4.06 (± 0.74) km^{-2} for summer overall (Table 1). Group density of Sambar in different seasons are also shown in Table 1.

Mean pellet group density of Sambar during post monsoon, summer and winter season were maximum (100.8±101, 89.8±88, 98.2±94), respectively, in Teak forest, teak mixed forest, & bamboo forest and minimum (30.78±37.85, 50.24±62.78, 53.07±65.20) in teak mixed, grassland, & teak mixed forest, respectively. Analysis of two way ANOVA shows significance differences in mean pellet group density in different habitat in different seasons [F8 1043 = 3.706, η2 (166748.3), P <0.05]. Post hoc test shows that mean pellet group density of Sambar in grassland and teak forest were found significantly different with each other. It also shows that mean pellet group density of Sambar shows significant differences between post monsoon season and winter season. The group density ± SE was highest in Teak forest (1.22 ± 0.24) followed by Mixed forest, (0.54 ± 0.14), Grassland (0.50 ± 0.12), Teak mixed (0.33 ± 0.07), and Bamboo forest (0.27 ± 0.06) (Table 5).

Age and sex structure of Sambar

Adult males (AM) and adult females (AF) were observed more (31% and 53%, respectively) in winter than in summer (27% and 48%, respectively). Observations of yearlings (Y) were (15%) in summer and (10%) in winter. The sex ratio wasfound biased towards females. In winter, out of 165 individuals, the AF:AM sex ratio was 100:59, and AF:Y 100:18. In summer out of 341 individuals, the AF:AM ratio was 100:56 and AF:Y 100:32. The mean group size ± SE of Sambar, during winter was 2.08 (±0.11) and in summer 3.15 (±0.18).

Factors affecting the selection of habitats by Sambar in different seasons

For Sambar during post monsoon season, there were 15 variables that had correlation coefficient above 0.80 therefore, these variables were removed from the analysis for avoiding multicollinearity (Table 2). The first two principal components accounted for 26.52% of the variation on data set. The first principle component (PC 1) was highly positively correlated with herb diversity (r = 0.84), herb density (r = 0.79), and tree diversity (r = 0.70). The second PC 2 was highly positively correlated with grass diversity (r = 0.88) and grass density (r = 0.86). Figure 2 indicates a relationship between the use of PC 1 and PC 2 in the selection of habitat by Sambar during the post-monsoon. Our analyses showed a clear shift in habitat use in response to the increased use of low to medium grass diversity and grass density and medium to high herb diversity, herb density, and tree diversity. Overall, the logistic regression model had an efficiency of 97.40% correct classification of cases that identified tree density, as a key predictor of Sambar habitat use

Table 1. Sambar Densities (Individuals/km2) in Pench Tiger Reserve, Madhya Pradesh, during winter and summer seasons (2013 to 2015).

Years/Seasons	Winter				Summer			
	2013	2014	2015	Pooled	2013	2014	2015	Pooled
Total effort (km)	NA	272	240	512	240	240	240	720
TotalObservations	NA	48	32	80	27	41	45	113
Truncated at (m)	50				45			
Observation after Truncation	NA	48	32	78	27	41	40	104
Density±SE/km²	NA	6.93 ± 1.69	4.27 ± 1.05	3.36 ± 0.71	10.21 ± 2.58	15.73 ± 4.88	8.53 ± 2.48	4.06 ± 0.74
Group Density ± SE/ km²	NA	2.46 ± 0.57	2.17 ± 0.51	1.60 ± 0.32	2.17 ± 0.48	3.43 ± 0.97	2.99 ± 0.82	1.28 ± 0.22
Mean Group Size ± SE	2.08 ± 0.11				3.15 ± 0.18			
Effective Strip Width± SE (m)	23.66 ± 3.45				18.67 ± 2.34			
A value	201.68				213.34			
Model+ Adjustment term	Half-normal Cosine				Half-normal Cosine			

Table 2. Principal component analysis of Sambar pellet group during post-monsoon season.

Variables	PC I	PC II	PC III
Bear Ground	0.0331	0.107829	0.105539
Grass Density	0.027686	0.868578	-0.136
Grass Diversity	0.136071	0.883648	-0.06249
Herb Cover	-0.03474	0.262041	0.084252
Herb Density	0.799433	-0.12273	0.133806
Herb Diversity	0.840358	0.278337	0.011688
Sapling Density	0.248571	0.018811	0.109222
Sapling Diversity	0.005983	0.06579	-0.0031
Shrub Cover	-0.36659	-0.01112	0.660385
Seedling Density	0.095794	-0.0226	0.079414
Seedling Diversity	0.101087	0.134554	0.063229
Shrub Diversity	0.12455	-0.04253	0.77041
Shrub Density	0.186455	-0.15938	0.777779
Tree Density	-0.02252	0.295619	0.346735
Tree Diversity	0.701757	0.086988	-0.04878
% of Variance by each component	14.17153	12.35785	12.25404
Cumulative Variance	14.17153	26.52938	38.78343

Table 3. Principal component analysis of Sambar pellet group during the summer season.

Variables	PC I	PC II	PC III
Grass Density	0.83167	0.275057	0.010902
Herb Cover	0.207257	0.698108	0.041515
Herb %	0.317452	0.768572	0.048339
Herb Density	0.747446	0.401299	0.053116
Herb Diversity	0.25406	0.449724	0.400123
Litter	-0.82924	-0.04759	0.018185
Rock	0.25652	-0.61443	0.028021
Seedling Density	-0.00611	-0.04101	0.892497
Seedling Diversity	-0.0352	0.089607	0.872159
Tree Cover	-0.0003	-0.05004	-0.09414
Weathered Stone	0.542355	-0.35789	-0.03183
% of Variance by each component	22.79538	18.51902	15.77547
Cumulative Variance	22.79538	41.31441	57.08987

in the post-monsoon season. During summer, 11 out of 30 variables were selected from data collected from 519 sampling plots (Table 3). The first two principal components accounted for 41.31% of the variation. The first principle component (PC 1) was highly positively correlated with grass density (r = 0.83), herb density (r = 0.74), weathered stone (r = 0.54) and negatively correlated with litter (r = -0.82). The second principle component (PC 2) was highly positively correlated with herb cover (%) (r = 0.76) and and negatively correlated with rocks (r = -0.61). During summer the distribution of available and utilized plots in relation to first and second component is shown in Figure 3. The graph shows that during summer Sambar preferred the area with low to high herb cover % and and medium to high grass density, herb density and weathered stone and on the other hand avoiding rock and litter. The logistic regression model had an efficiency of 66.28% correct classification of available and used plots by Sambar during summer. According to this model, herb diversity was the most important predictor for Sambar's habitat selection.

During winter, 12 variables from 350 sampling plots of 30 variables were selected (Table 4). The first two principal components accounted for 33.32% of

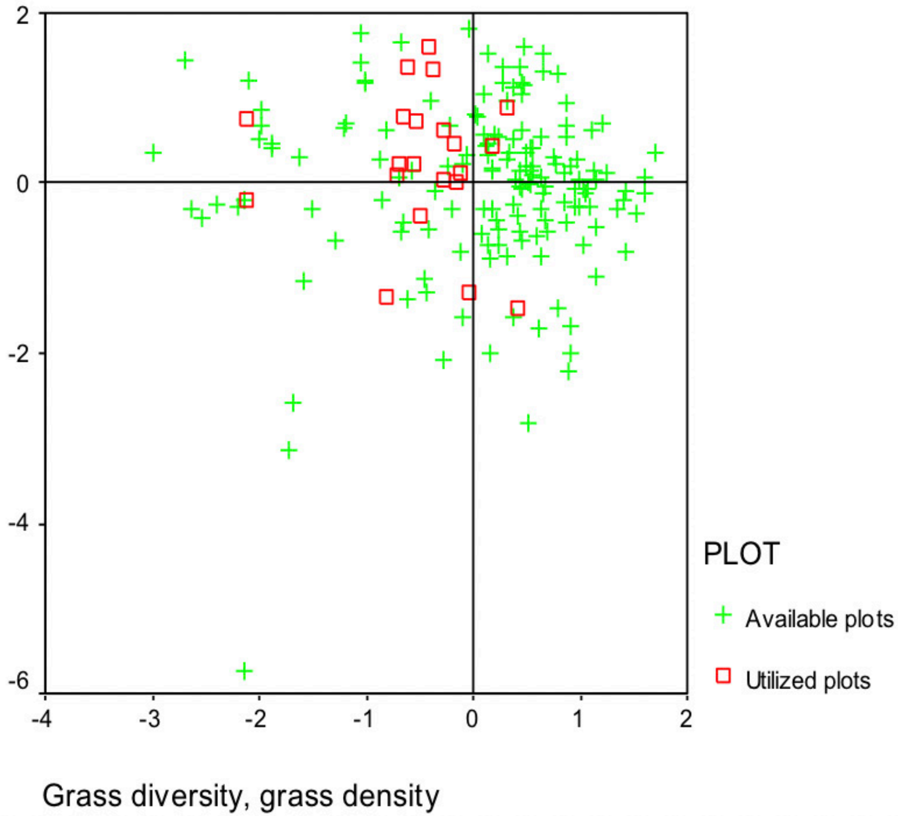

Figure 2. Ordination of available and utilized plots for Sambar during post-monsoon season in Pench Tiger Reserve.

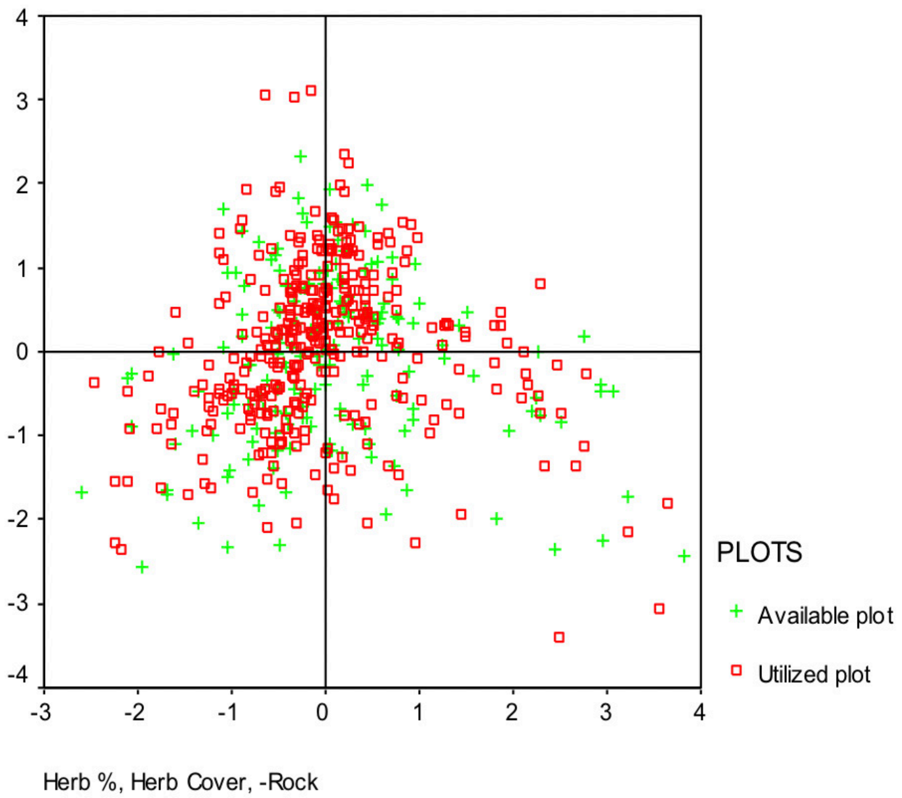

Figure 3. Ordination of available and utilized plots for Sambar during the summer season in Pench Tiger Reserve.

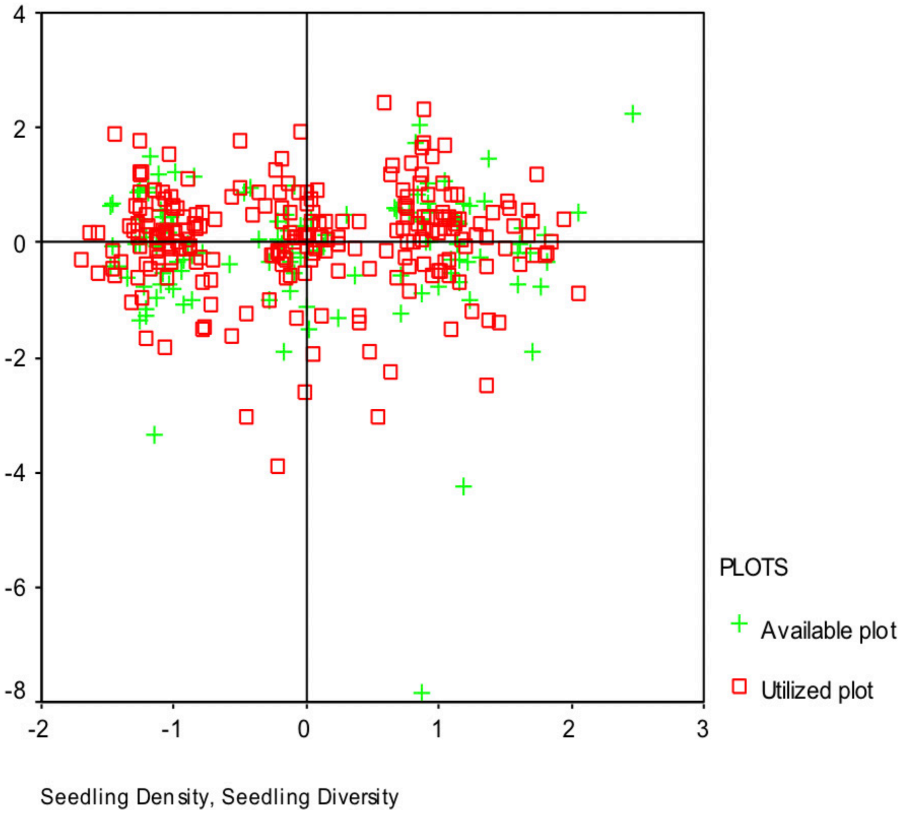

Figure 4. Ordination of available and utilized plots for Sambar during the winter season in Pench Tiger Reserve.

Table 4. Principal component analysis of Sambar pellet group during the winter season.

Variables	PC I	PC II	PC III
Grass Density	0.617863	-0.04698	-0.27626
Grass Diversity	0.525874	0.300114	-0.19871
Herb Cover	0.651132	-0.01108	0.147166
Herb Density	0.674319	0.013231	0.116658
Herb Diversity	0.62023	0.166813	0.171585
Rock	-0.53704	0.072539	0.282335
Sapling Density	0.090378	0.061656	-0.08938
Seedling Density	-0.01843	0.890214	0.110038
Seedling Diversity	0.090306	0.878828	0.016763
Shrub Diversity	0.054001	-0.10344	0.854835
Shrub Density	0.005772	0.232585	0.779192
Tree Cover	-0.08705	-0.05413	0.171437
% of Variance by each component	18.64389	14.68341	13.73232
Cumulative Variance	18.64389	33.3273	47.05962

Table 5. Seasonal variation in density of Sambar in different habitats of Pench Tiger reserve, Madhya Pradesh (2013 to 2015).

Habitat	Sambar (Density±SD)		
	Post monsoon	Summer	Winter
Bamboo Forest (n=180)	45.64±51.34	69.70± 83.63	98.19 ±94.59
Grassland	41.40 ±45.15	50.24 ±62.78	61.04± 78.29
Mixed (n=180 in PNP & n=144 in PMS)	64.85 ±66.56	65.89 ±69.94	82.51 ±82.67
Teak Forest (n=180)	100.84± 101.77	72.54± 65.28	80.67 ±78.55
Teak-mixed (n=180)	30.78 ±37.85	89.87 ±88.36	53.07 ±65.20

PNP—Pench national Park | PMS—Pench Mowgli Sanctuary.

the variation. The first principle component (PC 1) was positively correlated with herb density (r = 0.67), herb cover (r = 0.65), herb diversity (r = 0.62), & grass density (r = 0.61) and negatively correlated with rocks (r = -0.53). The second principle component (PC 2) was highly positively correlated with seedling density (r = 0.89), seedling diversity (r = 0.87). For Sambar during winter season the distribution of available and utilized plots in relation to first and second component is shown in Figure 4. The graph shows that during winter season Sambar preferred the area with low to medium seedling density and seedling diversity and medium herb density, herb cover, herb diversity, grass density and avoiding rocks. The logistic regression model had an efficiency of 66.57% correct classification of available and used plots by Sambar during winter season. According to this model, sapling density was the most important predictor for Sambar's habitat selection.

DISCUSSION

Sambar density is showing a declining trend inthe last two decades in PTR. During 1995–2000 Sambar density was reported to be 9.6 animals/km^2 (Karanth & Nichols 2000). Sambar favours dense forest patches as well as hilly terrain (Biswas & Sankar 2002; Kushwaha et al. 2004) and a similar trend was observed in the present study. Our results show that Sambar prefers the teak dominated habitat with hilly terrain and dense forest during winter and summer, and feeding results also confirm the same as Sambar utilizes *Tectona grandis* less than the availability in both seasons (Ilyas 2015). Most of the sightings were around water holes. Studies conducted in different parts of India suggest the Sambar tend to concentrate their activity around these waterholes (Ilyas 2001; Biswas & Sankar 2002; Kushwaha et al. 2004). Being a deer that prefers relatively dense forest, distribution pattern of Sambar was found to be clumped type with highest pellet group recorded in Teak forest. Studies on a variety of other ungulates have also shown clumped type distribution patterns due to the availability of food resources (Adhikari & Khadka 2009). The Chital density in PTR was reported to be 31.48 (± 3.47) in winter and 39.99 (± 2.73 during summer), 8–9 times higher than Sambar density (Ilyas 2015). The increased population of chital may also be one of the reasons for the clumped distribution of Sambar, to avoid competition. The overabundant population of Spotted Deer in PTR is a major concern for the management point of view, and translocation of chital to unoccupied areas outside PTR could resolve the issue to some extent for Sambar (Ilyas 2015).

Schaller (1967) and Eisenberg & Lockhart (1972) reported that Sambar does not remain in permanent social groups. In PTR, the observed Sambar male:female ratio was 0.59:1 in winter and 0.56:1 in summer. The observed low male ratio might be due to selective predation by tiger on male Sambar as reported in other studies (Schaller 1967; Johnsingh 1983; Karanth & Sunquist 1992). Sambar male:female sex ratio of the present study can be compared with Gir—0.5:1 (Khan et al 1996), Wilpattu—1.2:1 (Eisenbrg & Lockhart 1972), Ranthambore—0.83:1 (Bagchi et al. 2003), and Florida—0.73:1 (Flynn et al. 1990). In Sambar, group size is generally small, numbering fewer than six individuals (Schaller 1967). The characteristic social unit in Sambar is one hind and one fawn or one hind, one yearling, and one fawn (Schaller 1967; Downes 1982). In the present study group size of 1–5 individuals was recorded throughout the year, as was also reported in Mudumalai (Ramesh 2010).

Habitat studies provide crucial information about the ecological requirements of a species or community. Habitats of animals have been studied for long. From the days of Aristotle (344 BCE) where man learnt about habitat use by animals due to innate curiosity to today's times when understanding ecological relationships (Morisson et al. 1992), conservation of natural resources (e.g. Soule 1986), and management of areas with specific requirements (e.g. Fox et al. 1988; Rahmani 1989) have made it mandatory to understand habitat requirements of different species. Increasing habitat loss causes a significant increase in extinction risk among many species, especially habitat specialists (Rahmani 1989; Birdlife International 2001; Mallon 2003; Norris & Harper 2003). While it is important to assess the habitat usage, it is equally important to conduct studies addressing the pattern of usage. It is assumed that high quality resources will be selected more than low quality ones and use may change with availability when the latter is not uniform (Manly et al. 1993).

Unoccupied habitat with little selection cannot be assumed to provide low fitness potential. Although effects of habitat cover, landscape structure and spatial variables on abundance of birds has been reported (Heikkinen et. al. 2004), fitness potential of habitat cannot be assumed to vary with habitat selection and a gradient in observed density does not necessarily indicate a gradient in habitat quality (Hobbs & Hanley 1990). The approaches used in the present study for collecting data on habitat use reduced chances of collecting insufficient or biased data. Ungulates defecate at a particular rate, which varies between species, but is usually constant within species (Marques et al. 2001; Laing et al. 2003). Using pellets as indirect evidence of presence have their understandable strengths, but also have some challenges. Although the issue of detectability is reduced to a great extent when areas were combed thoroughly for faecal matter, disintegration rate and site selection pose concerns (Marques et al. 2001; Laing et al. 2003).

In the present study most of the pellet groups of Sambar were recorded from hilly terrain with Teak dominated forest type. The study shows that Sambar avoid dense forest which is also supported by Imam (2014). This, however, is contrary to the studies conducted by Ramesh et al. (2012) and Khushwaha et al. (2014). Findings of factorial analysis state that density and diversity of trees and herbs were the most important factors for their habitat preference which is significantly supported by logistic regression analysis. These findings are similar to the study conducted by Khushwaha et al. (2004). Water is an important resource, particularly in hot temperatures. Sambar, being an animal of hilly terrain, reduce energy expenditure by restricting their home ranges around the water resources in summer. In certain occasions they rush into a water body to avoid predation (Yahya 2014), often unsuccessfully. Our study also shows a similar trend. It is also supported by studies conducted by Johnsingh (1983), Eisenberg & Lockhart (1972), and Imam (2014). The study area consists tropical dry and tropical moist deciduous forests, so that covering of the ground with leaf litter is common during summer. Sambar avoids habitats covered with high amount of litter as they contain very few plant materials to be utilized as food. In the present study similar results were recorded, where Sambar avoids litters in summer. The rocks do not provide any protection from predators, high temperature and forage. This has resulted in a decrease of suitable habitat for this habitat specialist species. The woodland contains climax stage species with interspersion of shrubs was the most preferred habitat type and favourable for its grazing and browsing requirement throughout the year.

Ungulates in general and Sambar in specific are a good indicator of the health of the forest. Their population structure should be assessed at temporal and spatial levels at different landscapes. The Pench Tiger Reserve is one of the best managed tiger reserve and contains a very good prey base for the thriving tiger population. For effective Sambar conservation a large undulating tract of undisturbed habitat is required. Such tracts should have protection from poaching as poachers prefer Sambar as it provides more meat. At the global level Sambar population has declined and in peninsular Malaysia Sambar has lost more than 50% of its historical range. (Kawanishi et al. 2014). In India also Sambar has disappeared from Sikkim, Tripura and many other places, which is an alarming condition for the managers (Khan & Johnsingh 2015). The government as well as NGOs involved in conservation should pay special attention to Sambar conservation. Sambar is not only ecologically important for the ecosystem but is also a main prey for tigers. We also recommend IUCN Red List authorities to review the Red List category of Sambar, presently listed as 'Vulnerable' (Timmins et al. 2015). If Sambar continue to disappear from other areas, then soon it may be included in the Endangered category.

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