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Study of Interaction and its Dynamics with Reference to Spotted Deer and Sambar Populations at Spatial Scales, under the Influence of Resource and Habitat Heterogeneity : A Case Study with Special Reference to Kanha and Bandhavgarh National Park

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Abstract The Spotted deer (*Axis axis*) and the Sambar (*Rusa unicolor*) are the 2 common sympatric species that live in Kanha National Park and Bandhavgarh N. P. Central India. They are of 2 different weight categories under family Cervidae. They live in the same habitat and enjoy resources and suffer from generalist predators asymmetrically. Here we have focused on the local populations of both the S. deer and Sambar, in different location of forests, spatially apart and categorized, grouped and ranked on the basis of resource hierarchy through NDVI values. The deme structure of these 2 species show significant variation in different forest fragments. They show different degrees correlation that varies both qualitatively and quantitatively. The regression analysis with respect to the 2 populations, give a better fit model compared to when they are mixed and are not categorically grouped and ranked accordingly. The distributions of deer and Sambar and the interaction and influence between them, show a dynamic pattern that alter with the change of forest heterogeneity and resource availability and shuffle populations and the interactions accordingly from 1 deme to the next in order to coexist. Resource partitioning, habitat niche differentiation and the predatory strategies are also additional determining factors that play parts in shaping the distribution and mutual interactions between Spotted deer and Sambar, along with habitat heterogeneity and resources.

Keywords Regression study, Resource hierarchy, NDVI values, Predatory strategy, Habitat heterogeneity.

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Introduction

Kanha N. P. (longitude 80º–26´–10´´ to 81º-4´-40´´ E and latitude 22º–1´–5´´ to 22º-27´–48´´ N) and Bandhavgarh N. P. (longitude 80º-57'-30" to 80º-06´-15´´ E and latitude 23º-36´-30´´ to 23º-42´-30´´ N) are the 2 tiger reserve of Madhya Pradesh, Central India. Both the forest has Langur, Spotted deer, Sambar and Indian Gaur as dominant herbivore species. The population dynamics and behavioral interactions have been studie for long on langdur and deer. In present study we have focused on interaction between Sambar and the Deer population. The interaction was analyzed at the level of local population (Deme). It is important to consider the importance and the impact of the resources and predator pressure on the herbivores and their mutual interactions at a regional scale. The species distribution models (SDMs) and SAD emerged from this study would determine relationships between species and their environments (Loke 2015 Guisan 2005). The study of biodiversity in terms of species richness and species evenness (Hurlbert 2007) even at regional scale (Roy Debashis 2018) appears to have great impact and importance in determining relationship between species and environment (Stein 2014).

It could be used to predict climate change impacts, study biogeography, assist in reserve selection, improve species management and to develop conservation biology needs and biodiversity management (Farshid S Ahrestani 2012). In addition ideas on resource partitioning, habitat niche overlapping, and niche breadth fluctuations of different sympatric primary consumer and of their predators would be beneficial for the future study on animal interactions (Farshid S Ahrestani 2012, Bagchi 2003, Joseph 2007). The impact of habitat heterogeneity on large mammalian sympatric herbivores populations at regional scale gives us extensive ideas on conservation of large carnivores in the 2 most important tiger reserve of Central India. In Southeast Asia very few have addressed the species habitat relationships of sympatric ungulates (Bishnu Prasad Bhattarai 2012 Bagchi 2003). Majority of the emphasis was given on predators (*Panthera tigris*) and their prays (Sunquist 1995). The large dominant mammalian (Kerr 1997) herbivores like Spotted deer, Sambar, Gaur and also langur are therefore of great importance not only how they are influenced by habitat and resources but also how they interact with and influence each other (Lindenmayer 2014, Tews 2004). However with the gradual increasing human exploitation of land, habitats of the wildlife have been degraded, fragmented and lost (Haddad 2015). Therefore, it becomes important to understand the distribution (Araujo et al .2011) of sympatric species over large spatial scale with heterogeneous resources and the interactions or influences among themselves in order to develop productive and sustainable conservation management.

Materials and Methods

Surveys were conducted in both the National Parks during the month of February–March of 2014 to 2018 from 6 am to 12 noon in the morning and 3 : 30 pm to 5 pm in the afternoon. Four /five vehicle based transect routes ranging from 25 to 40 km were monitored within different zones and subzones of Kanha N. P. (Kanha Zone, Kisli Zone, Sarhi Zone and Mukki Zone) and Bandhavgarh National Park (Tala Zone and Khitouli Zone) to record Spotted deer and Sambar sighting along with other dominant herbivores (Ramesha 2012) . Data from different forest sections with respect to vegetations and habitat heterogeneity were also collected. During our survey a total distance of more than 5000 km was covered in both the National Parks. Sites, ranges between 500 m and 620 m, were selected for the purpose of data processing to minimize the effect and influence of elevational variations on the distribution dynamics of Spotted deer and Sambar.

The numbers of the different animal especially large mammalian species were taken into accounts during data collections by vote counting method (Gates 2002) with respect to their location. The different diversity indices (Strong 2016), correlation and regression statistics were carried out with respect to the different zones and subzones, categorized and ranked on the basis of habitat heterogeneity and resource availability. The assistance of binoculars (Pentax 10 × 50 ; XCF) and GPS enabled cameras were taken during the survey work. Over 1400 GPS location based photographs, of animal and plants, of different merits were taken into account while comparing and confirming the habitats and the animals within for ground level verification.

The satellite images are also taken into account for topology and vegetational study while comparing and confirming heterogeneity. The TNT MIPS Version 2016 and Q-GIS Version 2.14 software were used to process and to develop satellite images and geographical data and for subsequent analysis. Landsat 8 image and Sentinel-2 images from open achieve

Table 1. Different diversity indices in different zones of 2 National Parks.

Forest	Zones	Shannon index	Species richness	Species evenness
Kanha N. P.	Kisli	1.604	1.945	0.824
	Sarhi	1.571	1.945	0.807
	Mukki	1.381	2.079	0.664
	Kanha	1.491	2.398	0.622
Bandhavgarh N. P.	Tala	1.23	2.3	0.534
	Khitauli	1.73	2.39	0.722

USGS Earth Explorer were taken into account for vegetational and NDVI images. While the contour and stream/drainage maps were extracted through STRM DEM from USGS Earth Explorer.

The characterization of different forest sections on the basis of NDVI values and corresponding forest types were carried out to understand the similarities and differences in diversities among the spatially apart forest sections even with in the same forest zone.

The hybrid image of NDVI and contour fitted with location of Spotted deer and Sambar were executed to get direct evidence on the animal distribution and aggregation and the forest types or habitat on which they depend. GPS based locations were used to verify the ground truth of vegetation and elevation.

The entire Kanha forest NDVI image is classified in to 1 km × 1 km grids on which the species occurrences and aggregation were mapped for evaluating the contribution of resources and the influence and interaction between Spotted deer and Sambar sympatric populations.

Results

Data collected from all 6 different zones namely Sarhi, Kisli, Mukki, Kanha (of Kanha N. P.), Tala and Khiitauli (of Bandhavgarh N. P.) were analyzed to get the values of $H'_{MAX,}$ (Shannon Index), H' Species richness (S) and Species evenness (J') (Table 1). It was found that the indices show differences and similarities when compared with each other. The species richness is found to be maximum in Kanha zone (2.398) and minimum in Kisli (1.945) and Sarhi zone (1.945). The species evenness on the other hand is maximum in Kisli zone (0.824) and minimum in Kanha zone (0.534). The Shannon index shows maximum in value in Kisli (1.604) among the different zones of Kanha N. P. But in the present discussion it is the Khitauli (1.73) zone of Bandhavgarh N. P. shows the maximum value of Shannon index.

Results of ANOVA test reveal that in different forest zones/ subzones, species composition varies significantly, ($F = 20.85$, $df = 26$, $p<0.01$), even with respect to the Sambar and deer populations. Thus, the 2 populations vary from one zone to the other; one deme to the next, significantly.

The chi square test also confirm that the forest zones and species composition are significantly depend on each other (×2 = 61.29; Df = 10; $p<0.01$). Thus, the distribution of the Deer and Sambar population appears asymmetric in nature and shows dependence towards the forest zones and subzones which are large and heterogeneous.

The correlation and regression analysis do not show any significant result when all the demes were taken in to account without any discrimination and were not ranked on the basis of resource, to evaluate the possible interaction between Sambar and Deer (Fig. 1). The same analysis on the demes, ranked on the basis of resource hierarchy, give a different and much significant result (Figs. 2—4).

ANOVA analysis on spatially separated local populations/Deme of both the Sambar and Spotted deer revealed that all the local populations (Demes) of Sambar and Deer varies significantly from one zone to other zone. The highest resource zone (HRZ) ($F=115.93$; $df=6$; $p<0.05$), moderate resource zone (MRZ) ($F=32.74$; $df=8$; $p<0.05$) and the lowest resource zone (LRZ) ($F=8.93$; $df=6$; $p<0.05$) represent significant results.

The chi square analysis of 3 different zones indicates interesting and significant results. In the high resource zones ($X^2=18.9088$; Df =3 $p<0.05$) and moderate resource zones ($X^2=37.26$; df =4; $p<0.05$) the results appear statistically significant. But in the low resource zones the results appear statistically in

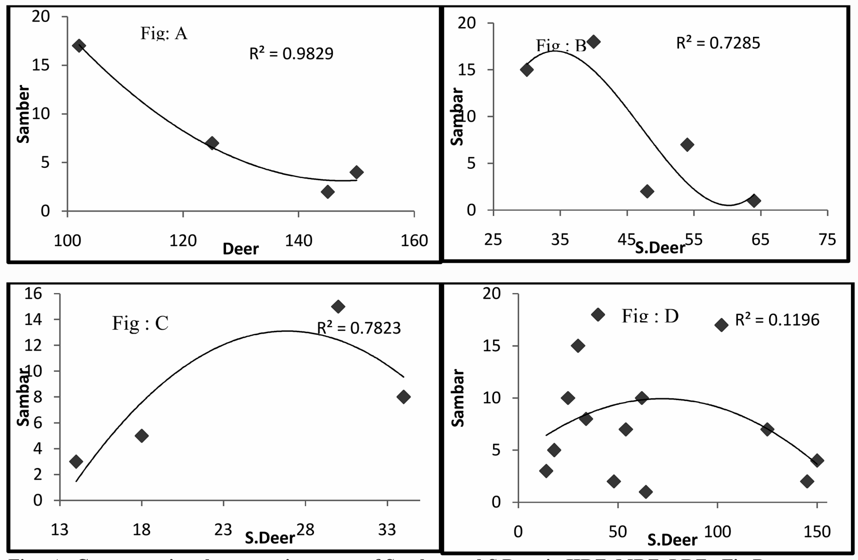

Fig.1. A–C-representing the regression curve of Sambar and S. deer in HRZ, MRZ, LRZ, D-represent the mixed and undifferentiated data.

significant (X =3.106; df = 3; p>0.05). That indicates that the HRZ and MRZ (and factors like predation) play significant role with respect to Spotted deer and Sambar population. But the LRZ has no significant role on the 2 populations. Although other factors like predators and their behavior/hunting strategies could also be the reason for the same statistical outcome.

The value of Pearson's correlation coefficient (r=0.0165) found to be in significant when data of Spotted deer and Sambar were considered without any discrimination. But when different zones and respective local populations were categorized, grouped and ranked on the basis of resource hierarchy considering NDVI images and NDVI values and the data were grouped under 3 different categories namely HRZ

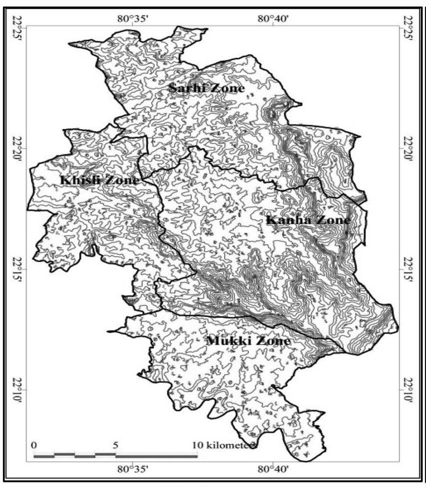

Fig2

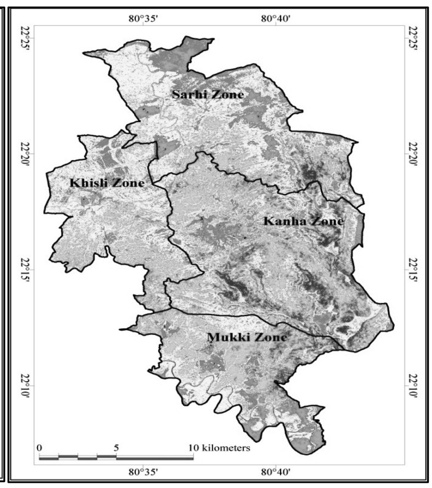

Fig3

Fig. 2. Contour map showing elevational heterogeneity in different zones of Kanha National Park. **Fig. 3.** NDVI image showing vegetational heterogeneity in different zones of Kanha National Park.

(Highest resource zone), MRZ (Moderate resource zone) and LRZ (Lowest resource zone) the values of r appear significant (Fig.4) The HRZ and MRZ shows strong negative correlation. (r = -0.9528 and r = -0.809) and LRZ shows positive correlation (r=0.733).

The regression statistics gives us significant result ($p<0.05$) at HRZ; at 5% level of significance. But the level of significance decreases in the MRZ ($0.1>p>0.05$) and become insignificant in LRZ ($p>0.1$).

While the regression curves (Figs. 1-4) and the respective values of R^2 give better fitment under the condition where the data points were categorized and ranked as described earlier. The HRZ shows the highest value of R^2 ($R^2 = 0.9829$), whereas the MRZ and LRZ indicates value $R^2 = 0.728$ and $R^2 = 0.782$, respectively. The value of R for the 2 populations appear to be lowest ($R^2 = 0.1192$) and do not fit well when the data are mixed and are not categorized, grouped and ranked on the basis of resource hierarchy.

The NDVI image of Kanha N. P. (Fig.3) indicates different forest types and their respective range of NDVI values. The contour map (Fig. 2) on the other hand represent the elevational variations along the spatial scale. Thus the NDVI—Contour hybrid image represent the variation of forest habitat along the spatial scale under a definite time of year (March—April). The different forest types in the horizontal and vertical axis as represented by the satellite imagery are clarified after ground level verification by means of GPS enabled photographs.

The sympatric herbivores and their mutual aggregations are tracked. Their respective locations with variable cluster size are incorporated in the NDVI-Contour hybrid image (Fig. 4). This has been done to get direct visual evidences in support to the spatial distribution of two sympatric species. The same was done to substantiate the statistical outcomes on the influences and impact of resources on Sambar and Spotted deer sympatric population and possible mutual influences or interaction in between.

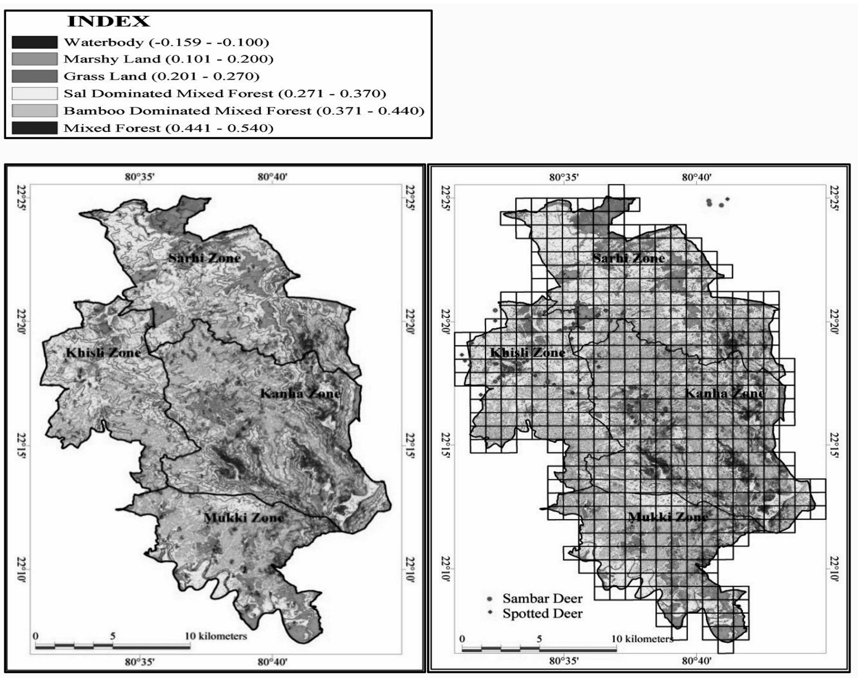

Fig. 4. NDVI contour hybrid image of Kanha N. P. distribution. NDVI contour hybrid image with species.

The Sal and Bamboo dominated mixed forest has a lesser degree of variations with lower NDVI values (0.271–0.370 and 0.371–0.440 respectively) when compared with that of pure mixed forest (0.441–0.540) but represent higher NDVI values when compared with that of grasslands (0.201–0.27) (Fig.3). All the 4 maps that are represented here are of Kanha National Park. But similar maps of Bandhavgarh N. P. are not given to prevent further elaboration.

Discussion

Both Spotted deer and Sambar live in same habitat in Kanha and Bandhavgarh National Park which are the 2 most important tiger reserves of Madhya Pradesh, India, Southeast Asia. They share ecological resources in the same habitat and suffer threats from the generalist predators for survival (Loke 2015). Both of them belong to different body weight categories (Schaller 1967, Sunquist 1995). Therefore, they interact with the ecosystem with respect to resources and predators asymmetrically, as found in between Spotted deer and langur (Newton 1989).

In the present work the spatially fragmented forest sections, in a specific season (month) are ranked and classified on the basis of resource hierarchy, represents both the extremes of resource availability. It looks further towards subsequent conflict and co-existence of 2 interacting dominant herbivorus species (Spotted deer and Sambar). The mutual co-existence and conflicts between these 2 species (Krishna Prasad Pokharel 2016), (Bagchi 2003) are to play significant role in conservation (Stein 2014) under different circumstances related to habitat heterogeneity and resources primarily (Joseph 2007, Tews 2004). Here the availability of resources are considered, at spatial scale instead of seasonal/temporal in order to get specific information for SDM and SADs (Guisan 2005, Stein 2014, Arellano 2017) of the concerned species populations under a definite point of time (Onset of summer, February – March). Moreover it appears justified to track any mutual interaction or influence symmetric or asymmetric between these 2 species when the seasonal variations are eliminated. The variation in heterogeneity and resources/ vegetations along the spatial scale during a specific time would help to focus on the prediction of mutual interaction in much specific manner.

Table 2. Result of ANOVA in different section of forest segments categorized on the basis of resource hierarchy.

Resource	F	Df	p value
Lowest	8.93	6	P<0.01
Moderate	32.74	8	P<0.01
Higher	115.93	6	P<0.01

Both Deer (*Axis axis*) and Sambar (*Rusa unicolor*) live in same habitat (Loke 2015, Pokharel 2015, Purves 2011, Ramesha 2012) in different Indian forests including Kanha N. P. and Bandhavgarh N. P. They share both the ecological resources (Schaller 1967, Bagchi 2003, Dhar 2012, Krishna Prasad Pokharel 2016) and threats from the generalist predators (seidensticker 1976) for their survival. Both of them belong to different body weight categories (Schaller 1967) under family Cervidae.

Study on spatially separated local populations of both the Sambar and Spotted deer revealed that All the local populations of Sambar and Deer vary significantly from 1 forest zone to other zone (Tables 2 and 3). The different zones and subzones of the forest show variations, both horizontally and vertically (Tables 4A-B and 5). The topology and the river/drainage system show a significant variation (Table 6).

The vegetation of the forest which is one of the primary contributors to habitat heterogeneity varies significantly from zone to zone or from one forest section to the other (Fig.3). The major large mammalian species under such condition show variable bio-diversity index values (Table 1) with respect to the different zones, both in Kanha and Bandhavgarh National Parks. The herbivores populations show variations in distribution which are significant across the different forest zones and subzones spatially

Table 3. Chi square values in different section of forest segments categorized on the basis of resource hierarchy.

Resource	Chi square value	Df	p value
Lowest	3.106	3	P>0.05
Moderate	37.26	4	P<0.05
Highest	18.9088	3	P<0.05

Table 4 A. Pearson correlation coefficient (r) in different section of forest segments categorized on the basis of resource hierarchy.

Zones	Subzones	Value of r
Mixed and undifferentiated data		0.0165
	HRZ	-0.9528
Categorized and ranked on the	MRZ	-0.809
basis of resource hierarchy	LRZ	0.733

apart. The habitat heterogeneity has significant role on the Sambar and Deer distribution and population configuration (Table 3) as our finding suggests. Correlation (Table 2) and regression analysis (Table 4 B) suggest that availability of resource does play an important role on Sambar and Deer distribution, mutual influence and their distribution. Forest zones with highest resources show a negative correlation values between these 2 species. But with gradual decrease of availability of resources the correlation values decreases gradually and becomes positive in the demes where the resources are found to be least. The regression statistics (Table 4 B) indicates that the interaction between Deer and Sambar is significant statistically in HRZ. The significance drops gradually in the MRZ and become in significant in the LRZ.

The 2 sympatric species, spotted deer and Sambar are belongs to family Cervids and use similar habitat features in each season (Bagchi 2003). In general, there was some similarity between the 2 deer were found in terms of topography and vegetation (Bagchi 2003). It was also reported that the Spotted deer shifted its feeding behavior under different conditions (Farshid S Ahrestani 2012). The grazing and browsing habits are interlinked with the habitat that undergoes temporal and spatial variations. The Spotted deer was reported to be involved in browsing more than grazing in dry conditions. (Ramesha 2012, Farshid S Ahrestani 2012).

When the 2 species (*Axis axis* and *Rusa unicolor*) under family Cervids, were compared, it was found that habitat niche differentiation is redundant between them (Farshid S Ahrestani 2012, Bagchi 2003, Dhar 2012). Our findings in the present context are strongly aggregated with it and also with some of the most recent findings (Farshid S Ahrestani 2012, Ramesha 2012, Krishna Prasad Pokharel 2016, Arellano 2017, Pokharel 2015). The interactions between these 2 sympatric species populations show strong negative correlation (Krishna Prasad Pokharel 2016) when the populations were studied under forest sections with high resource. The competition for resource between these 2 species under Cervidae family is the result of extended and overlapped niche breadth and poor habitat niche differentiation (Krishna Prasad Pokharel 2016, Arellano 2017). However we also found different opinions (Gordon 1989, Schoener 1974).

We also considered other factors like particularly predation (Odden 2010, Holt 2009), which was found to contribute to the co-existence of sympatric ungulates (Holt 2009). Thus *Axis axis* and *Rusa unicolor* compete for resources in one hand (Fig.4) and suffer asymmetric predator pressure at the same time (Schaller 1967, Holt 2009, Sunquist 1995). The Sambars are preferred over deer for its larger body weight as the predators follow an energy maximiser strategy (Griffiths 1975) while hunting in a high resource zone. The competition over resource, either as a pair of sympatric competitor or/and being a pair of prey as a choice to the generalized predators, they remain negatively related (Bishnu Prasad Bhattarai 2012, Krishna Prasad Pokharel 2016, Joseph 2007, Odden 2010). The presence of one species thus negatively affected the probability of the presence of the other (Krishna Prasad Pokharel 2016). Here survival success of one species, of a pair of interacting sympatric species, get materialized by competing (Bishnu Prasad Bhattarai 2012, Ramesha 2012, Dhar 2012, Krishna Prasad Pokharel 2016, Lovari 2015) its

Table 4 B. Regression statistics of different section of forest segments categorized on the basis of resouce hierarchy. SE =Standard error, r = Pearson's correlation value.

Zones	SE	R^2	R	F	P	Level of significance
Highest resource zone	8.11	0.908	-0.95	19.74	0.047	$p<0.05$
Moderate resource zone	5.17	0.655	-0.809	5.703	0.096	$0.1>p>0.05$
Lowest resource zone	4.37	.537	0.733	2.32	0.266	$p>0.1$

Table 5. Topological data of different zones of Kanha N. P. in Map E. SE = Standard error, SD = Standard deviation, All the values are in the meter except SE, SD, and data points.

Zones	Mean	SE	Median	Mode	SD	Range	Minimum	Maximum	Data points
Sarhi	649.54	8.98	600	580	108.07	416	484	900	145
Kisli	578.78	4.94	560	560	53.00	240	480	720	115
Mukki	570.59	4.26	560	560	46.49	320	540	860	115
Kanha	731.75	8.83	720	620	99.16	320	580	900	126

sympatric counterpart in order to win the habitat and resource in one end. On the other end these pair of interacting herbivores defend itself, over its sympatric counter parts from the generalist predators through a better survival strategies by means of alarm call and alarm behavior (Bagchi 2003, Ramesha 2012, Schaller 1967, Newton 1989, Bagchi 2003, Dhar 2012, Krishna Prasad Pokharel 2016). If the competition for resource and habitat among these 2 cervids is 1 of the causes then the energy maximizer strategy (Griffiths 1975, Sunquist 1995) opted by the generalist predators, under high resource zones, is the other 1 for which the strong negative correlation as our work suggests is well justified in the HRZ (Krishna Prasad Pokharel 2016, Lovari 2015, Gordon 1989).

While considering the NDVI image and forest vegetations it is been found that the Sal (*Shorea robusta*) dominated mixed forest is preferred site of Spotted deer and Sambar. The availability of the water was also appeared as another associating important factor for both the species. The bamboo dominated mixed forest also show animal aggregation. The pure mixed forests with the highest NDVI values were not considered as it mostly located on the higher topographic locations which are beyond the limits of selected data point. The pure grasslands do not appeared to be the suitable site for this two sympatric species (Schaller 1967).

After ground level verification it has been found that the mixed forests zones are composed of mixed plant communities that includes a wide range of different plant species (Table 7), which is the underlying cause of Sambar and Spotted deer distribution and aggregation. It was also found that 40% of large plant species consumed by the Sambar were shared with Spotted deer (Table 8) which are also a component of their mutual conflict. The data of sympatric animal distribution and diversity assessment must not appeared as a perfect match as the importance are imposed asymmetrically on the underlying factors like elevations, resources and predators. Here heterogeneous resources are the prime target while the elevational variations are kept under limited fixed range (520 m to 600 m). Considerations of numerous variables simultaneously do not help to come in a conclusion under the present circumstances.

In contrary in low resource zones the interaction between these 2 Cervids shows a positive correlation when compared. The 2 interacting species populations are to adopt specialized niche in order to avoid mutual conflicts and competition over niche overlapping. Under this condition both the Cervids reduces the niche breadth (Bagchi 2003, Krishna Prasad Pokharel

Table 6. Statistical data of stream and drainage stystem of different zones of Kanha N. P. SD = Standard deviation, SQ.KM = Square kilometer.

Zones	Total areas	Total boundary	No. of stream	Total stream length	No. of streams sq.km	Mean length of streams	Mean stream length sq.km	SD mean length
Sarhi	114.35 Sq. km	75.75 km	219	190.25 km	1.91	0.87 km	1.66	0.66
Kisli	76.75 Sq. km	60.06 km	137	115.61 km	1.78	0.84 km	1.5	0.68
Mukki	80.02 Sq. km	61.53 km	145	144.79 km	1.81	0.99 km	1.8	0.7
Kanha	143.02 Sq. km	64.56 km	255	210.54 km	1.78	0.83 km	1.47	0.57

Table 7. Major plant species in Kanha and Bandhavgarh N. P.

Sl. No.	Name (Common)	Scientific name	Family	Month of new Flower/ Fruit/Leaf Other value
1.	Sal	*Shorea robusta*	Dipterocarpaceae	Feb—Apr (Leaf and Fruit)
2.	Bamboo	*Dendrocalamus strictus*	Poaceae	–
3.	Mahua	*Madhuca indica*	Sapotaceae	Mar—Apr
4.	Banyan	*Ficusindica*	Cactaceae	Feb—Apr (Leaf and Fruit)
5.	Peepal	*Ficusreligiosa*	Moraceae	Feb—Apr (Leaf and Fruit)
6.	Goolar (Fig tree)	*Fecus racemosa*	Moraceae	Mar—Apr (Fruit)
7.	Golden apple (Bel)	*Aegle marmeolos*	Rutaceae	Feb—Mar (Fruit)
8.	Haldu	*Adenia cardifolia*	Passifloraceae	–
9.	Kaim (Kadamb)	*Mitragyna parviflora*	Rubiaceae	Medicinal plant
10.	Indian laburnum (Amaltas)	*Cassia fistula*	Fabaceae	Apr—May (Flower)
11.	Jhinjheri	*Bauhinia racemosa*	Fabaceae	Feb—May (Flower)
12.	Mehroin	*Bauhinia vahlii*		
13.	Kosum (Kusum)	*Schleicheraoleosa*	Sapindaceae	Mar (Leaf)
14.	Palash	*Buteamonosperma*	Fabaceae	Jan—Mar (Flower)
15.	Indian coral tree	*Erythrina variegate*	Fabaceae	Medicial plant (Feb—Mar) Flower
16.	Bija	*Pterocarpusmarsupiam*	Fabaceae	Medicial plant
17.	Dhobena	*Dalbargia paniculata*	Fabaceae	–
18.	Bahera	*Terminaliabellirica*	Combretaceae	Medicial plant
19.	Saja	*Terminaliatomentosa*	Combretaceae	Medicial plant
20.	Arjun	*Terminaliaarjuna*	Combretaceae	Medicial plant
21.	indian jujube (Ber)	*Ziziphusmauritiana*	Rhamnaceae	Medicial plant
22.	Dhawa	*Anogeissuslatifolia*	Combretaceae	Medicial plant
23.	Harra	*Terminaliachebula*	Combretaceae	Medicial plant
24.	Neem	*Azadirachtaindica*	Meliaceae	Feb—Mar (Flower)
25.	Mahancem	*Alianthusexcela*	Simaroubaceae	Feb—Mar (Flower)
26.	Semul	*Bombaxceiba* *B. malabaricum*	Malvaceae	Feb—Apr
27.	Achar	*Buchaanialanzan*	Anacardiaceae	Medicinal plant
28.	Aam (manga)	*Mangiferaindica*	Anacardiaceae	Feb—Mar
29.	Shisham (Sissoo)	*Dalbergiasissoo*		–
30.	Tendu	*Diospyrosmelanoxylon*	Ebenaceae	Apr—Jun (Flower)
31.	Kusum	*Schleicheraoleosa*	Spindaceae	Mar—Apr (New leaf)
32.	Sirish	*Albizialebbeck*	Fabaceae	Feb—Apr (Flower)
33.	Crocodile bark tree	*Terminaliaelliptica*	Combretaceae	Stores water
34.	Sejhi	*Laegostroemiaparbiflora*	Lythraceae	Apr—Jun (Flower)
35.	Kakai	*Flacourtiaindica*	Salicaceae	Dec—Apr (Fl + L) Mar (Fruit)
36.	Khair	*Acacia catechu*	Leguminosae	Apr—May
37.	Amla	*Emblicaofficianalis*	Phyllanthaceae	Mar—May
38.	Bhirra	*Chloroxylonswietania*	Rutaceae	Medicinal plant
39.	Kari	*Murrayakoenigii*	Rutaceae	Medicinal plant
40.	Katnar	*Acacia torta*	Fabaceae /Mimosaceae/legumi-noceae (touch me not)	Medicinal plant
41.	Grass	*Themedatriandra*	Poaceae	_
42.	Bamboo species	*Dendrocalamus strictus*	Poaceae	_
43.	Climber	*Brideliasquamosa*	Euforbiaceae	_
44.	Casearia graveolens			_
45.	Combretum flagrocarpum		Combretaceae	–
46.	Assyrian plum	*Cordiamyxa*	Boraginaceae	Mar—Apr (Flower)
47.	Sadora	*Terminaliaalata*	Combretaceae	Medicinal plant
48.	Papra / Indian boxwood	*Gardenia latifolia*	Rubiaceae	Flower Apr—Jul

Table 7. Continued.

Sl. No.	Name (Common)	Scientific name	Family	Month of new Flower/ Fruit/Leaf/Other value
49.	Gamhar	*Gmelina arborea*	Lamiaceae	–
50.	Rose apple	*Eugenia vulgaris* *Syzygium jambos*	Myrtaceae	Feb—Apr (Flower)
51.	Hoom	*Milusato mentosa*	Annoonaceae	Mar—May (Flower)
52.	Fragrant padre tree	*Stereospermumchelo-noides*	Bignoniaceae	Medicinal plant
53.	Jamun	*Syzygium cumini*	Myrtaceae	May—Jul (Fruit)

2016, Pokharel 2015) and opt resource partitioning to co-exists under a different predatory strategy where the predators becomes number maximiser (Sunquist 1995, Griffiths 1975, Krishna Prasad Pokharel 2016).

The large predators like tiger and leopards do not differentiate the 2 Cervids with respect to their asymmetric body size under such condition. Here both the preys are evenly susceptible to the predators (Table 9). The number maximiser predators kill prey as they encounter (Sunquist 1995). The more the frequency of a prey the more the chance of mortality here the frequencies, which are dissimilar with respect to the 2 Cervids, appears to be the deciding factor and serve as the primary criterion of prey selection.

Thus, it is our anticipation that natural selection in the low resource zone, takes a different strategy to prevent extinction of any particular species and also maintain biodiversity that reflects through higher values of Shannon index and species evenness. The predatory pressure is distributed among the different pray species populations in accordance with their respective frequncies. Because that could be a way the natural selection could shift the predatory pressure from a least frequent species to the relatively abundant one in order to allow the former species to have a greater chance of relief and better survival success. Otherwise an energy maximiser predatory strategy, in low resource zone would have facilitated the process of elimination of prey of larger body size (in that case Sambar over Spotted deer). But we would suggest further research works on that aspect.

In low resource zones thus a greater species evenness appears to be beneficial (as appeared in certain subzones of Kisli and Kanha; Table 3) because under such condition the predatory pressure are more evenly distributed among most of the major herbivores with least discrimination (Griffiths 1975, Sunquist 1995, Karanth 2016). The highest values as represented by the species evenness in some of the subzones of Kisli, Sarhi and Khitauli are thus well justified. The NDVI value of these sites and the NDVI, contour hybrid images and respective forest types image (Figs 3 and 4) also justify our findings.

If the specialized niche and reduced niche breadth have reduced competition among sympatric Sambar and Deer populations in low resource zones (LRZ) helping in the mutual co-existence (Farshid S Ahrestani 2012, Bishnu Prasad Bhattarai 2012, Ramesha 2012, Dhar 2012, Krishna Prasad Pokharel 2016) then the alarm calls and alarm behaviors appears to be the most important mutual beneficial strategies that are the primary factor for mutual survival success under the pressure of generalist predators (Schaller 1967, Krishna Prasad Pokharel 2016) like tiger and leopard. Thus a positive correlation as well as positive influences, between the Sambar and the Deer, in low resource zone, appears to be well justified (Krishna Prasad Pokharel 2016, Lovari 2015). The insignificant regression statistic (Table 4B) with respect to the 2 sympatric Cervids, Spotted deer and Sambar at the

Table 8. Plants eaten by Spotted deer and Sambar in Kanha N. P. (Schaller 1965).

Species	Number of species	Number of species shared by both the species	Number of species not shared by them
Spotted deer	51	6	45 (88.23%)
Sambar			9 (60%)

low resource zones (LRZ) be due to specialized niche and resource partitioning (Krishna Prasad Pokharel 2016) is well justified.

In contrary a significant regression statistics in HRZ (0.05% level of significance) and MRZ (0.1% level of significance) with respect to the sympatric Sambar and Deer are logical due to expanded niche breadth, relaxed niche structure (Krishna Prasad Pokharel 2016), habitat niche overlap and energy maximiser strategy of predators (Sunquist 1995). Although we suggest further study on this area to understand it in a better way.

The results of the present work show similar results with that of Pokharel, Bagchi, Dhar et al. but with some reservations. The usages of spatial scale, data collection in a specific transitional season (February to March/ Basanto), the evaluation of forest resources and its spatial demarcation and classification on the basis of NDVI values are appeared to be the underlying causes of such deviations. The data on the predators kills and scats results were collected from the previous work (Table 9) that neither considered the spatial scale nor the NDVI values while collecting the data. Therefore more and more works which, could give better and comprehensive picture, are suggested.

In the present study we have found a positive relationship in habitat use between these 2 Deer species particularly in the LRZ areas, open habitats-grassland and dry deciduous forest. The GPS enabled photographs of the sympatric species clusters were incorporated in the NDVI image. The dry deciduous forests and grassland surely areas are of low NDVI values though not equal. But the classification of forests as LRZ, HRZ and MRZ in our study was not done on the basis of the types of forests as done by the previous workers. Rather it was done on the basis of forest cover and NDVI values first and then was related and linked with the types of vegetation (Fig.3).

Therefore these low resource zones give us substantive evidences suggesting towards a positive correlation between Deer and Sambar for better co-existence . It is also expressed by some recent scientists that the lowland forests have greater inter-

Table 9. Number of items and proportions (%) of different prey species in predator diets, as derived from the kill and scat data (Karanth 1992).

Prey	Tiger Kills (%)	Scats (%)	Leopard Kills (%)	Scats (%)
Chital	16 (10.4)	153 (31.2)	69 (83.1)	234 (43.7)
Sambar	44 (28.6)	122 (24.9)	8 (9.6)	72 (13.5)
Gaur	69 (44.8)	85 (17.4)	1 (1.2)	39 (7.3)
Langur	0	19 (3.9)	1 (1.2)	38 (7.1)

specific competition (Strong 2016, Arellano 2017). But it is not clear from their study if the species show resource partitioning or not. Here the parameters that were considered mostly are of topological and physical in nature. Thus, the species and their distributions in lowlands appear apparently justified. But the whole picture appears different when ecological and behavioral factors like complexity of habitat, resource and predatory strategies were considered. If the topography and the least physical barriers help them to relate negatively through convergent migration then the divergent migration could be an easy solution of interspecific competition and mutual conflicts. The successful co-existence of multiple species in a flat terrain thus could only be achieved and justified once they show positive correlation in LRZ (Bagchi 2003, Dhar 2012, Krishna Prasad Pokharel 016) as our finding suggest. The topology and physical barriers might be a factor for sympatric aggregation, but for co-existence and mutual survival success resource partitioning, predatory strategies and harbivorous alarm calls and alarm behavious are of great importance (Sunquist 1995, Dhar 2012, Krishna Prasad Pokharel 2016, Odden 2010, Griffiths 1975).

The hybrid image of NDVI contour map with the animal distribution when analyzed we get the following results (Table 10). The Spotted deer shows a significant dependence on the Sal dominated mixed forest during our study across the grids (1 km ×1 km). The Sambars on the other hand also show dependence on Sal dominated mixed forest but when were associated with the Spotted deer (Table 10). Thus both the species shows higher degrees of preferences towards the Sal dominated mixed forest. But it has been found that grasslands areas with lower NDVI values are not shared by the 2 species when distributed together. The Sambar shows preferences towards grasslands when

Table 10. Comparative study of dependence of Spotted deer and Sambar on vegetations with respect to the grid scale analysis of NDVI image of Kanha National Park.

	Water body		Marshy land		Grass land		Sal dominated mixed forest		Bamboo dominated mixed forest		Mixed forest	
Species	Cell count	Area in SqM	Cell count	Area in SqM	Cell count	Area in SqM	Cell count	Area in SqM	Cell count	Area in SqM	Cell count	Area in SqM
Sambar mean	0	0	262.5	26250	5814.5	581450	3803.5	380350	108.5	10850	7	700
Spotted deer mean	13.5625	1356.25	333.0625	333.06.25	1692.8	169278.1	4255.875	425587.5	2171.5	217150	187.8125	18781.25
Sambar and Spotted deer mean	24	2400	406.5	40650	1480	148000	6111.125	611112.5	1501.125	150112.5	38.75	3875

distributed without being associated with the Spotted deer. The separate grids for separate species, groups, in areas with low NDVI values appear to be the effect of resource partitioning.

The large predators namely the tiger and leopards show a higher value of niche overlaps (Seidensticker 1976) and poor resource partitioning (Sunquist 1995). Therefore, it appears justified that habitat heterogeneity and resource availability not only contributes towards SDM and SADs (Arellano 2017) of Sambar and Deer along the spatial scale but also shape up their niche breadth and niche specialization. Because if the secondary consumers or predators fail to execute a specialized niche and are still well fitted in the ecosystem with poor resource partitioning (Joseph 2007) then it is also justified that the primary consumers also may follow the same tendencies under similar environmental condition. Only difference is that the herbivores, Sambar and Spotted deer, co-exists and survive through resource partitioning and reciprocating alarm calls and alarm behaviors (visual, olfactory and auditory signals) that forms an interconnecting system of response to predators (Schaller 1967) whereas the large carnivores co-exists through spatial and / or temporal partitioning (Lovari 2015).

Conclusion

Habitat heterogeneity has significant influence on biodiversity (Caceres 2014). It shapes SDM and SADs of major animal species in vertical and horizontal scale (Karanth 2016). The large mammalian herbivores which are the primary consumers are not exception though they are greatly overlooked in Southeast Asia (Farshid S Ahrestani 2012). In this work the 2 primary consumers Spotted deer and Sambar which are most abundant in both Kanha N. P. and Bandhavgarh N. P. are targeted to unfold the role of habitats on them regionally and spatially apart.

Our findings do suggest that large forests have diverse heterogeneity and thus influence the herbivores in diverse ways (Farshid S Ahrestani 2012). The role of habitat in shaping the mutual influence and interaction between Sambar and Spotted deer are taken in to consideration for adaptive and behavioral importanc. The remote sensing data, satellite imagery, GPS based photographs and subsequent characterization, classification and ranking of heterogeneous forest in to different spatial fragments on the basis of resource hierarchy, are major outcomes which are beneficial to understand the habitat, habitat–herbivores relationship (Guisan 2005, Kerr 1997, Farshid S Ahrestani 2012, Krishna Prasad Pokharel 2016) predictive habitat modeling (Stein 2014 Purves 2011) and the inter specific interactions (Krihna Prasad Pokharel 2016) or mutual influences. The impacts of resources/vegetations on the primary consumers are not static (Schaller 1967) as our finding suggests. The Spotted deer and the Sambar show dynamic and asymmetric mutual interactions and mutual influences for co-existence and survival under different spatially apart forest fragments (Krishna Prasad Pokharel 2016). The present outcome would help to understand the role of habitat on the major prays of tiger in these 2 tiger reserves. It will also be beneficial for framing conservational strategies, flexible yet adaptive with respect to the heterogeneous resources along spatial scale (Roy Debashis 2018, Stein 2014, Karanth 2016).

The influence of one species on the other, gives us ideas on mutual co-existence, niche habitat overlap, niche breadth and also on resource partitioning. The importance of resource and the effect of climate changes are also important (Guisan 2017) with respect to the SADs and SDM. It will be also beneficial to understand how the evolutionary forces affect sympatric community under different habitats in heterogeneous and large forests. The present work will also beneficial for estimation of habitat loss and habitat fragmentation which are major threats to the survival of mammals worldwide (Clark 2013, Jnawali 2011).

The knowledge on habitat requirement of sympatric species are essential for the conservation of animals in the protected place (Whittakar 2005) like the Kanha N. P. and Bandhavgarh N. P. which are tiger reserves. Research reports are still rare in Southern Asia on ecology of sympatric herbivore communities (Farshid S Ahrestani 2012).

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