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Species Habitat relationships of spotted deer through Geo-Spatial analysis at Kanha National park: A cluster oriented study

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ABSTRACT

The SAD (Species Abundance Distribution) and SDMs (Species Distribution Models) of species are important to understand the species habitat relationships. The major herbivores which are the primary prey of tigers and leopards in the tiger reserves are of special interest. In the present study we have focused on spotted deer (Axis *axis*) clusters of different size to understand the species habitat relationship in Kanha N.P. Distribution of Spotted deer were tracked by analyzing satellite images of forest patches and GPS enabled photographs of spotted deer clusters. The habitat heterogeneity of the forest and its roles in the distribution of the spotted deer clusters were determined. Major determining factors like elevational variations, stream drainage system, types of forests covers and land use; those contribute towards spotted deer distribution were also considered. Forest types of different NDVI values were found to have dynamic impact on the spotted deer population & distribution. It was also found that the spotted deer clusters of different sizes have reasonable impact on the habitat herbivores relationships. Therefore it is suggested that conservation of forest types with respect to the spotted deers are to be done considering different cluster sizes of spotted deer populations. Special attentions are to be given on the cluster specific analysis while framing the species habitat relationships, SDMs and SAD for a comprehensive and realistic outcome. In tiger reserves like Kanha national park, such practices are highly recommended for the conservation of habitats, spotted deers and the major generalist predators like tigers and leopards.

Key words*: Conservation, Resource, NDVI values, Foraging behavior, Habitat heterogeneity, Cluster analysis*

Introduction

Spotted deer (Axis axis) is one of the most abundant members of the family Cervidae that shows a wide distribution range from America (South and north), Europe and Asia. It is absent in Australia, Antarctica and most of the Africa(Nayak and Sukla, 2011). The spotted deer is distributed throughout India(Nayak and Sukla, 2011) and found to be the most preferred prey species for the tiger and leopards(Sunquist, 1995). It is best seen at some of the National parks in India of which the Kanha N.P is our prime target forest.

Kanha national park is located in Madhya Pradesh, central India. It extends from 80°-26‘-10′′ to 81°-4′-40′ in longitude and 22°-1′-5′′ to 22°-27′-48′′in latitude(Nayak and Sukla, 2011). It is surrounded by Maikal Hills and composed of grasslands and plenty of water bodies and dense forest vegetation. Rugged land scape, flat- top hills, and

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ridges enclose the valley that drains towards north into Narmada River (altitude 450-950m above m.s.l)(Schaller G B, 1967). It comprises of many trees of which Sal (*Shorea robusta*), Segun (*Tectona grandis)*, Arjuna (*Terminalia arjuna*,Amla (*Emblica officianalis*), Bamboos (*Dendrocalamus strictus*) *are* prevalent. Kanha N.P shows moist deciduous forest on lands below 650 meters, dominated by Sal (*Shroea robusta*). Above 650 meter it represents dry deciduous forest(Schaller G B, 1967). It shelters 10 species of ungulates and large predators like Royal Bengal tigers and leopards within 940 squares kilometers of core zones and 1134 sq. km of buffer zones (Nayak and Sukla, 2011).

We estimated biodiversity (Roy and Mistry, 2018) in terms of both species richness and species evenness (Hulbert, 2007)of the large mammalian species including the herbivores primarily spotted deer which would determine the relationships between species and environment (Guisan, 2005; Loke LHL, 2015). The distribution of the spotted deer in the different forest sections with different plant communities under variable geo spatial conditions (Elevation, river drainage system) are the primary clues of their complex habitat preference and dynamic species habitat relationships.

The habitat herbivore relationships are useful to predict climate change impact, assist in reserve selection and improve species management and to develop conservation biology needs(Guisan A., 2017). In Southeast Asia very few have addressed the species habitat relationships of sympatric ungulates (Bishnu Prasad Bhattarai, 2012; S. Bagchi, 2003). Therefore, it becomes important to understand the distribution (al, 2011) of sympatric species especially herbivores over large spatial sections of kanha N.P. The spotted deer which is the most preferred prey across the predatory pool are the most abundant species in this forest. It is our understanding that the SDM and SADs of spotted deers are to be framed with special consideration of the spotted deer clusters. By cluster we mean aggregation of 1 or more spotted deers in close proximities while foraging on similar forest vegetation/vegetations or aggregation of 1 or more spotted deers sharing same geographical coordinates. Whereas by cluster sizes we mean the number of clusters with in a grid . Largest clusters and smallest clusters are used to indicate the maximum numbers of clusters and minimum number of clusters within a specific geographical dimensions/grid .The conservation of habitats with respect to the variable clusters of spotted deers is suggested for a better outcome. It has been found in India that forest sections have specific influence on the group sizes (Ramesh, Sankata, Qureshib and Kalle, 2012)(Schaller G B, 1967) of spotted deers.

The implementation of conservation and forest management programs at regional scale are the outcome of our present research work. It is important to restore the regional heterogeneity and complex habitat structures for the conservation of spotted deer, change of which would lead to a breakdown in species diversity(Lindenmayer DB, 2014; Tews J., 2004). Demarcation of the forest in different regional sections or patches categorized and ranked on the basis of NDVI values and preferences by different spotted deer clusters, would offer important data for effective conservation. The habitat herbivores relation and the herbivore carnivore interaction would facilitate a comprehensive knowledge of habitat usage and sustainable conservation in this tiger reserve. However with the gradual increasing human exploitation of land, habitats of the wildlife have been degraded, fragmented and lost(Haddad, 2015).The anthropogenic activity, seasonal and climate changes (Wittmann, Barnes, Jerde, Jones, & Lodge, 2016) that alter the forests landscapes have reasonable impacts on spotted deer populations.

Methodology

Surveys were conducted in Kanha N.P during the month of March of 2016 & 2018 from 6 am to 12 noon in the morning and 3:30 pm to 5p.m in the afternoon. Four /five vehicle based transect routes each ranging from 25 to 40km were monitored within different zones and subzones of Kanha N.P(Kanha zone, Kisli Zone , Sarhi Zone and Mukki Zone) to record spotted deer clusters(T Ramesha, 2012). Data from different forest sections with respect to vegetations and heterogeneous habitat were also collected during our survey.Approximately 2000 km was covered during our survey in the National Parks within 480 m to 920 m range while collecting data.

The numbers of the different animal especially large mammalian herbivores were taken into accounts during data collections by vote counting method (Gates, 2002). The different diversity indices (Strong, 2016) , were carried out. Characterization and categorization of the forest vegetations with respect to the NDVI values and respective forest types were carried out with respect to the different zones and subzones. Binoculars (Pentax 10x50; XCF), GPS enabled cameras and mobile devices (Red me note 4) were used during the survey work. For ground level verification Over 600 GPS Location based photographs of spotted deers, plants and forest sections of different merits were taken into account while comparing and confirming the habitats and different spotted deer clusters within.

The satellite images are also taken into account for study of topology, vegetations, river-drainage systems and other water sources while determining the heterogeneity of habitats. 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 USGS EarthExplorer were taken into account for vegetational and NDVI images. While the contour and stream/drainage maps were extracted through SRTM DEM from USGS Earth Explorer (Roy and Mistry, 2019).

The hybrid image (Fig. 8) of NDVI (Fig.7) , contour and river drainage system (Fig.6) fitted with GPS location of spotted deer clusters were executed to get direct evidences of the animal distribution, aggregation (clusters). It also reveal dynamic preferences of spotted deers towards forest habitat (forest sections/patches). The different satellite images of Kanha National Park including the hybrid images are divided in to 1 km x 1 km grids and 250 m radius buffer grids on which the spotted deer occurrences and aggregations were mapped (Roy and Mistry, 2019). These eventually generate important data which are used to evaluate the contribution of habitats form far and near proximities, on spotted deer clusters.

The spotted deer clusters of variable sizes were then placed on hybrid images (NDVI image and topography map). The purpose was to get visual and realistic ideas about the interactions between environmental factors and spotted deer clusters. During our study we have restricted our observation on habitats which are located between 520m to 620m elevation. We have also considered a specific season (February – March) for data collection. It is true that the elevation (Schaller, 1967) and temporal variations are important for establishing cluster specific species habitat relationships. But simultaneous consideration of so many variables will not help us to come to a conclusion. The Kanha N.P shows moist deciduous forest on lands below 650 meters, dominated by Sal (*Shroea robusta*)(Schaller G B, 1967). Above 650 meter it represents dry deciduous forest (Schaller G B, 1967) for which consideration of forest sections below 650m elevation was justified.

Results and Discussion

The different section of the national park and subsequent subzones are found to be significantly hetero-

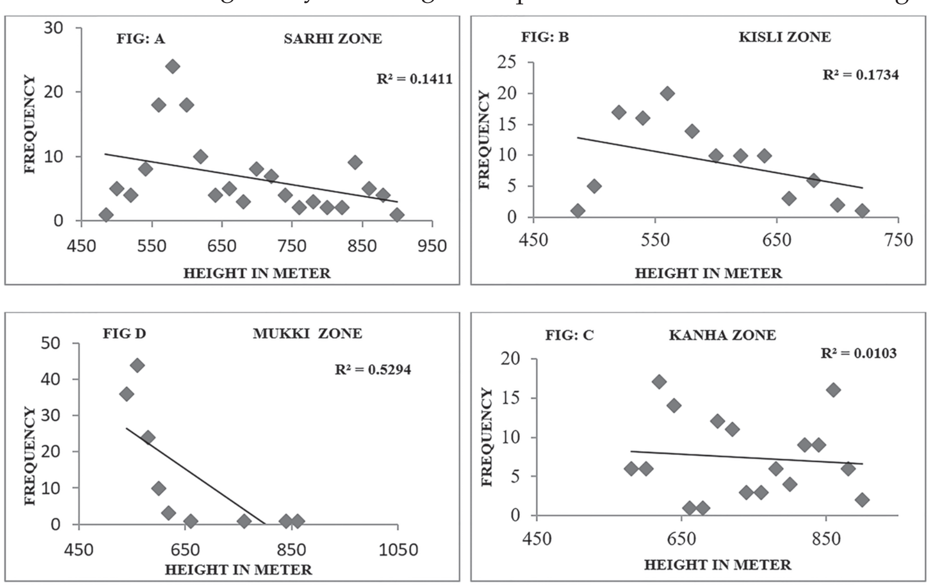

Fig. 1. Elevational heterogeneity in different zones of Kanha National Park. A: Sarhi Zone; Figure B: Kisli Zone; Figure C: Kanha Zone; Figure D: Mukki Zone

geneous (Roy and Mistry, 2018). The elevational variations, stream- drainage system and vegetations are the principle factors which were considered during our study. The kanha zone is found to be the most heterogeneous with respect to the elevational variations followed by Sarhi zone, Mukki zone and kisli zone (Fig. 1A- D.)(Roy and Mistry, 2019). The value of R^2 with respect to the elevational heterogeneity is lowest in Kanha zone and highest in Mukki zone when regression curve were plotted.

The river drainage system and the subsequent water availability for both the plant and animal species vary significantly among different zones and subzones (Table 1). The distributions of spotted deer and other herbivores depend on the plant communities directly for various purposes. The vegetations are the main resources towards the growth of species population and herbivore communities as a whole. Therefore it is important to track the forest plant communities and its heterogeneity spatially and temporally. In the present context the entire Kanha N.P vegetations are divided spatially in to multiple fragments on the basis of the NDVI values. The range of NDVI values (Table 2) of different zones indicate variation with respect to the tree phenology and heterogeneity. GPS enabled photographs of plant communities were taken in consideration for ground level verification and confirmation of forest patches and their respective types (Roy and Mistry, 2019). The NDVI values and its variations/range represent forest vegetations and its diversities accordingly. It also serves as the important links between species and habitat and could be explored in the future studies on species habitat relationships. ANOVA study reveals that average usages of different forest sections by the different clusters of spotted deers varies significantly ($F=2.62$, $P <0.05$; $df =5$).

Table 2. NDVI values of different zones of Kanha National Park.

Zones	Minimum value	Maximum Value	Total range
Sarhi	-0.08185	0.2745	0.356
Kisli	-0.05116	0.25252	0.303
Mukki	-0.11972	0.2604	0.38
Kanha	-0.10884	0.27659	0.3854

Total range is the difference between maximum and minimum value.

The grid scaling of 1km x1km help us to specify the comparative contribution of the different forest types to the spotted deer clusters from distance as well as from close proximities . Kanha National Park is dominated by the Sal (*Shroea robusta*), bamboo grass and plenty of grasslands. These along with the other moist and dry deciduous plant species (Table 3) satisfy the need of spotted deer population. When the cluster specific spotted deer distribution was analyzed (Table 4) significant deviations were observed. The distribution of the spotted deer varies with respect to the different grids of 1x1 sq. km (Maps). The regression study of different clusters at the spatial scale, considering latitude and longitude as the two axes, gives distribution pattern which vary in different degrees as the R^2 value suggests (Fig. 2a-2f.). The value of R^2 is lowest when the number of the cluster is minimum (Fig. 2a). The value of R^2 is highest in cluster size 3 (Fig. 2c.). Therefore the spotted deer with least clusters are less predictable and unevenly distributed. The larger clusters, with greater R^2 values, are distributed more evenly and are more predictable (Fig. 2b -2e). When the largest clusters were considered it show a R^2 value 0.6849 compared to R^2 value 0.3691 of smallest clusters which is solitary by number.

Table 1. Statistical data of river drainage system of different zones of Kanha National Park as in Map 2.

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	S.D (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

SD = Standard Deviation; SQ KM = Square Kilometer

Table 3. Major plant species in Kanha N.P during March – April (Spring Season). (Roy & Mistry, 2019).

Sl. No.	Name (Common)	Scientific Name	Family	Month of New Flower/Fruit /leaf/(All)/Other value
1	Sal	*Shorea robusta*	Dipterocarpaceae	Feb – April (All)
2	Bamboo	*Dendrocalamus strictus*	Poaceae	-
3	Mahua	*Madhuca indica*	Sapotaceae	March – April (Flower & leaf)
4	Banyan	*Ficus indica*	Cactaceae	Feb – April (Leaf & Fruit)
5	Peepal	*Ficus religiosa*	Moraceae	Feb – April (Leaf & Fruit)
6.	Goolar (Fig tree)	*Fecus racemosa*	Moraceae	March- April (Fruit & leaf)
7.	Golden Apple (Bel)	*Aegle marmeolos*	Rutaceae	Feb- March (Fruit & leaf)
8.	Haldu	*Adenia cardifolia*	Passifloraceae	-
9.	Kaim (Kadamb)	*Mitragyna parviflora*	Rubiaceae	Medicinal Plant
10.	Indian Laburnum (Amaltas)	*Cassia fistula*	Fabaceae	April – May (Flower)
11.	Jhinjheri	*Bauhinia racemosa*	Fabaceae	Feb- May (Flower)
12.	Mehroin	*Bauhinia vahlii*	Caesalpiniaceae	April – June (Flower)
13.	Kosum(Kusum)	*Schleichera oleosa*	Sapindaceae	March (Leaf)
14.	Palash	*Butea monosperma*	Fabaceae	Jan – March (flower)
15.	Indian coral tree	*Erythrina variegate*	Fabaceae	Medicial plant (Feb-March) Flower
16.	Bija	*Pterocarpus marsupiam*	Fabaceae	Medicial plant
17.	Dhobena	*Dalbargia paniculata*	Fabaceae	-
18.	Bahera	*Terminalia bellirica*	Combretaceae	Medicial plant
19.	Saja	*Terminalia tomentosa*	Combretaceae	Medicial plant
20.	Arjun	*Terminalia arjuna*	Combretaceae	Medicial plant
21.	Indian Jujube(Ber)	*Ziziphus mauritiana*	Rhamnaceae	Medicial plant
22.	Dhawa	*Anogeissus latifolia*	Combretaceae	Medicial plant
23.	Harra	*Terminalia chebula.*	Combretaceae	Medicial plant
24.	Neem	*Azadirachta indica*	Meliaceae	Feb- March (Flower)
25.	Mahaneem	*Alianthus excela*	Simaroubaceae	Feb- March (Flower)
26.	Semul	*Bombax ceibaB. malabaricum*	Malvaceae	Feb - April
27.	Achar	*Buchanania lanzan*	Anacardiaceae	Medicinal Plant
28.	Aam (manga)	*Mangifera indica*	Anacardiaceae	Feb - March
29.	Shisham (Sissoo)	*Dalbergia sissoo*	Fabaceae/ Leguminosae	-
30.	Tendu	*Diospyros melanoxylon*	Ebenaceae,	Apr- June(Flower)
31.	Kusum	*Schleichera oleosa*	Spinadaceae	March-April (New leaf)
32.	Sirish	*Albizia lebbeck*	Fabaceae	Feb-April (Flower)
33.	Crocodile Bark tree	*Terminalia elliptica*	Combretaceae	Stores water
34.	Sejhi	*Laegostroemia parbiflora*	Lythraceae	April – June (Flower)
35.	Kakai	*Flacourtia indica*	Salicaceae	Dec – April (Flower & + Leaf) March (fruit)
36.	Khair	*Acacia catechu*	Leguminosae	April -May
37.	Amla	*Emblica officianalis*	Phyllanthaceae	March-May(All);Medicinal Plant
38.	Bhirra	*Chloroxylon swietania*	Rutaceae	Medicinal plant
39.	Kari	*Murraya koenigii*	Rutaceae	Medicinal plant
40.	Katnar	*Acacia torta*	Fabaceae/ Mimosaceae/ leguminoceae (touch me not)	Medicinal plant
41.	Grass	*Themeda triandra*	Poaceae	——
42	Bamboo species	*Dendrocalamus strictus*	Poaceae	——
43	Climber	*Bridelia squamosal*	Euforbiaceae	—-
44	Casearia graveolens	*Casearia graveolens*	*Salicaceae*	—-
45	Combretum flagrocarpum	*Combretum flagrocarpum*	Combretaceae	—-

Table 3. *Continued ...*

Sl. No.	Name (Common)	Scientific Name	Family	Month of New Flower/Fruit /leaf/(All)/Other value
46	Assyrian plum	*Cordia myxa*	Boraginaceae	March – April (Flower)
47	Sadora	*Terminalia alata*	Combretaceae	Medicinal plant
48	Papra/indian Boxwood	*Gardenia latifolia*	Rubiaceae	Flower April - July
49	Gamhar	*Gmelina arborea*	Lamiaceae	-
50	Rose apple	*Eugenia vulgaris* *Syzygium jambos*	Myrtaceae	Feb – April (Flower)
51	Hoom	*Milusa tomentosa*	Annonaceae	March- May (Flower)
52	Fragrant padre tree	*Stereospermum chelonoides*	Bignoniaceae	Medicinal plant

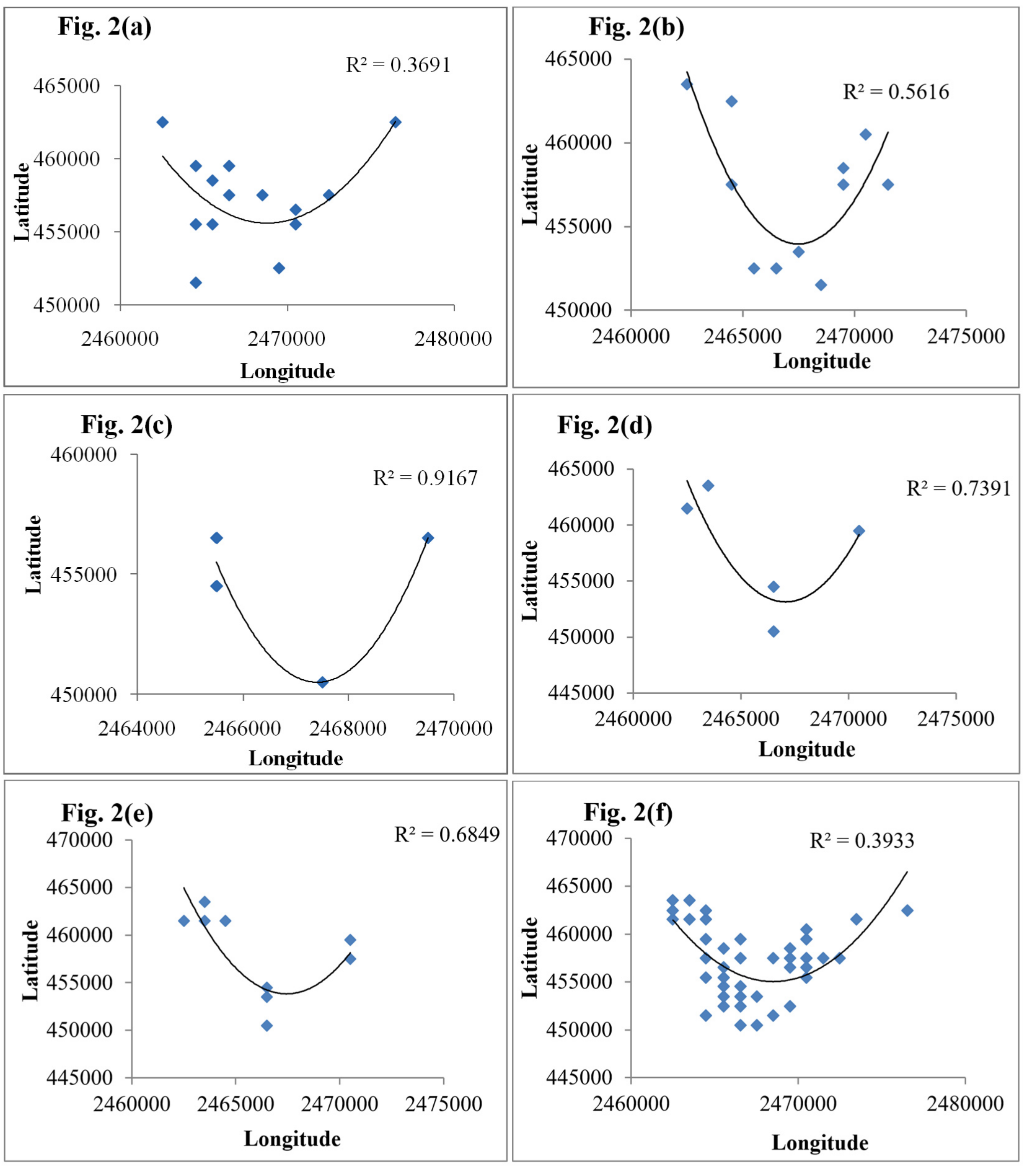

Fig. 2. Representing the regression curves of distribution of different spotted deer clusters. 2(a). Cluster size 1; 2(b). Cluster siz 2; 2(c). Cluster size 3; 2(d). Cluster size 4; 2(e). Cluster size 5-10; 2(f) Cluster of all sizes.

Table 4. Statistical data of spotted deer distribution with reference to cluster size in different grids (1x1 sq.km).

Grid No.	Species_ Name	Centre_ Latitude	Centre_ Longitude	Water Body Area in SqM	Marshy Land Area in SqM	Grass Land Area in SqM	Sal Dominated Mixed Forest Area in SqM	Bamboo Dominated Mixed Forest Area in SqM	Mixed Forest Area in SqM	Cluster	No of Species (Minimum)	No of Species (Maximum)	No of Species (Mean)	No of Species (Variance)	No of Species (StdDev)
2.	Spotted Deer	450500	2466500	0	0	2300	16200	300	0	4	1	12	6	22	4.64
3	Spotted Deer	450500	2467500	0	1300	27700	44900	2300	0	3	4	17	11	29	5.35
9	Spotted Deer	451500	2464500	0	100	4800	30100	20600	0	1	3	3	3	0	0
13	Spotted Deer	451500	2468500	0	15900	52200	530700	52200	100	2	3	6	4.5	2	1.5
19	Spotted Deer	452500	2465500	0	2700	92400	816100	88500	300	2	1	2	1.5	0	0.5
20	Spotted Deer	452500	2466500	0	1300	243700	597700	155100	2000	2	2	7	4.5	6	2.5
23	Spotted Deer	452500	2469500	0	0	7100	143300	21200	600	1	1	1	1	0	0
29	Spotted Deer	453500	2465500	2300	52400	331400	586500	26500	200	1	7	7	7	0	0
30	Spotted Deer	453500	2466500	10800	160300	357300	412800	55500	2200	10	1	10	5.6	10	3.14
31	Spotted Deer	453500	2467500	0	5600	113200	718100	158500	4400	2	2	7	4.5	6	2.5
41	Spotted Deer	454500	2465500	900	5300	99100	686300	203100	5200	3	1	2	1.33	0	0.47
42	Spotted Deer	454500	2466500	1300	32300	342400	539600	78600	5600	4	2	9	5	8	2.74
54	Spotted Deer	455500	2464500	0	0	700	459300	522900	17100	1	7	7	7	0	0
55	Spotted Deer	455500	2465500	0	2500	49700	392100	515400	40100	1	5	5	5	0	0
60	Spotted Deer	455500	2470500	0	0	322000	586900	89700	1100	1	1	1	1	0	0
78	Spotted Deer	456500	2465500	0	200	19500	533400	428400	18400	3	1	9	5.67	12	3.4
82	Spotted Deer	456500	2469500	3200	3500	23300	790300	176600	3100	3	7	10	8.67	2	1.25
83	Spotted Deer	456500	2470500	0	0	15900	606200	373400	4300	1	4	4	4	0	0
102	Spotted Deer	457500	2464500	0	0	7000	396900	514900	81100	2	1	2	1.5	0	0.5
104	Spotted Deer	457500	2466500	0	200	123800	735300	135600	5000	1	2	2	2	0	0
106	Spotted Deer	457500	2468500	0	5400	118000	742200	129800	4500	1	8	8	8	0	0
107	Spotted Deer	457500	2469500	13600	61000	172500	606100	144600	1700	2	2	9	5.5	12	3.5
108	Spotted Deer	457500	2470500	0	63600	170100	594900	169200	1100	5	5	19	9.8	25	4.96
109	Spotted Deer	457500	2471500	0	12000	82400	758700	146300	400	2	2	9	5.5	12	3.5
110	Spotted Deer	457500	2472500	0	126200	129200	656500	87400	100	1	1	1	1	0	0
131	Spotted Deer	458500	2465500	0	0	108600	597900	290600	2600	1	1	1	1	0	0
135	Spotted Deer	458500	2469500	1100	209600	159700	485800	142300	700	2	2	11	6.5	20	4.5
160	Spotted Deer	459500	2464500	0	100	32600	403500	544600	19100	1	3	3	3	0	0
162	Spotted Deer	459500	2466500	0	0	6300	246200	675400	72100	1	1	1	1	0	0
166	Spotted Deer	459500	2470500	400	135000	218100	434000	205400	6100	4	2	10	6	13	3.54
196	Spotted Deer	460500	2470500	100	40700	149900	406300	391000	11100	2	3	4	3.5	0	0.5
219	Spotted Deer	461500	2462500	0	52000	384600	338000	201600	23700	4	2	30	15.5	170	13.05
220	Spotted Deer	461500	2463500	2600	147700	650700	131300	56200	10300	6	1	30	7.83	105	10.27
221	Spotted Deer	461500	2464500	800	120300	363500	342800	162700	8600	5	1	15	5	27	5.22
230	Spotted Deer	461500	2473500	0	7300	180000	764600	47100	700	1	1	1	1	0	0
248	Spotted Deer	462500	2462500	0	14300	432800	376700	153900	21800	1	8	8	8	0	0
250	Spotted Deer	462500	2464500	2300	8800	283400	344900	294200	66000	2	4	11	7.5	12	3.5
262	Spotted Deer	462500	2476500	0	47700	221600	111500	2700	200	1	2	2	2	0	0
278	Spotted Deer	463500	2462500	0	2700	144700	325500	387000	140100	2	3	4	3.5	0	0.5
279	Spotted Deer	463500	2463500	23200	53000	356700	217600	298400	50300	4	3	11	7	13	3.54

The difference in R^2 values indicates that the largest cluster is more uniformly distributed along the geographical coordinates compared to the smallest one. The smallest cluster on the other hand indicates that they are least predictable when the entire forest sections, below 650m are considered.

When the distributions of the spotted deer clusters of different sizes were considered against their habitat and vegetational priorities, we found some interesting facts. The Sal dominated mixed forest is the most preferred site of spotted deer, where the clusters sizes varies from 1 to 3 (Fig. 3 & 4). But clusters in higher numbers (4, 5-10/ 4, 5, 6-10) show a different tendency (Fig. 3 & 4). The Sal dominated mixed forest is no longer the most preferred forest section when the number of clusters is largest (Fig 3&4). The distribution of spotted deerspopulations (clusters number 4)are most uniform across different forest sections, compared to the spotted deer distribution of other clusters (Table 5 & 6). The grasslands (32.47%) with lesser NDVI values are preferred as much as the Sal dominated mixed forests (38.47%). The bamboo dominated mixed forest (19.52%) is also in list of preferences (Table 5&6) (Fig. 3&4). When the use of forest patches are compared between the highest (cluster 10) and lowest cluster (cluster 1) of spotted deer (Fig. 5.) they appear significantly different (F= 5.549093; P <.05; df= 5) different. The largest cluster (cluster 10) explore areas like water body (NDVI value : -0.159-0.10) , marshy lands (NDVI value : 0.101-0.2), grass lands (NDVI value : 0.201- 0.270) more when compared with the smallest cluster (cluster 1). In both the occasions the Sal dominated mixed forests (NDVI values 0.271 -0.370) are preferred with different proportion as the peaks of the two graphs are not overlapped. The peak of cluster 1 distribution is more or less centrally placed that corresponds to the Sal dominated mixed forest (NDVI values 0.271 - 0.370). In cluster 10 it is clear that the peak is shifted more towards left of the curve and lies in between the grassland and Sal dominated mixed forest (Fig. 5). Therefore it is our suggestion that the Sal dominated mixed forest and grassland areas jointly (NDVI values 0.201 -0.370) serves the need of spotted deer (Newton, 1989) when the clusters are most. It is important to consider the proportion of sal dominated mixed forest and grass land areas along with marshy land areas (Table 6). In contrary the spotted deer prefer the Sal dominated mixed forestmost, followed by bamboo dominated mixed forest and then grass land areas (Table 6) when remain confined in smallest number of clusters (Fig. 5.) as suggested by the grid scale data. When obser-

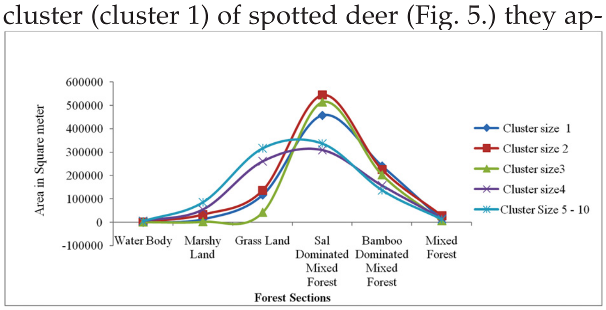

Fig. 3. Different forest sections (in square meter) as used by the different cluster sizes (1, 2, 3, 4, 5-10) of spotted deer.

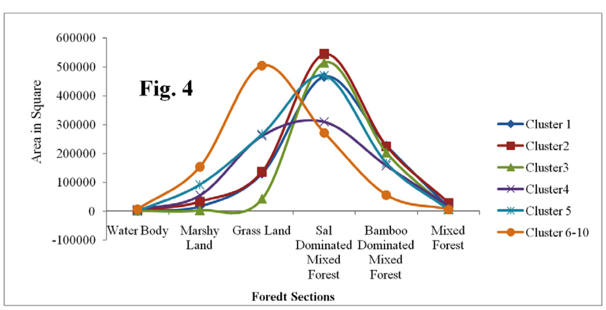

Fig. 4. Different forest sections (average usage in square meter) as used by the different cluster sizes (1, 2, 3, 4, 5, 6-10) of spotted deer.

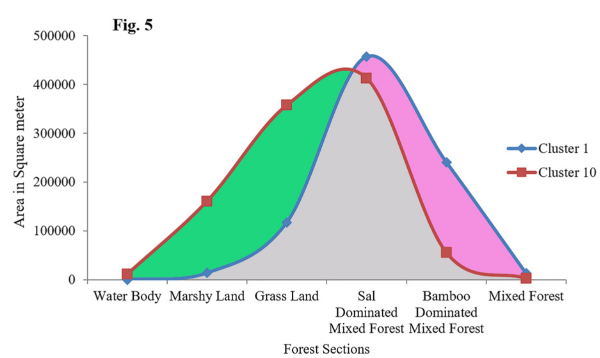

Fig. 5. Comparison between the different forest section (average use in square meter) as used by the lowest (Cluster 1) and the hig hest cluster (10) of spotted deers. Green area indicates type of forest sections and respective vegetation preferred by the spotted deers of highest clusters (cluster 10) over the lowest cluster size (cluster 1). Pink area indicates type of forest sections and respective vegetation preferred by the spotted deers of lowest cluster size (cluster 1) over the highest clusters (cluster 10). Grey area indicates a common area preferred by both the clusters while explore the rest of the forest differently.

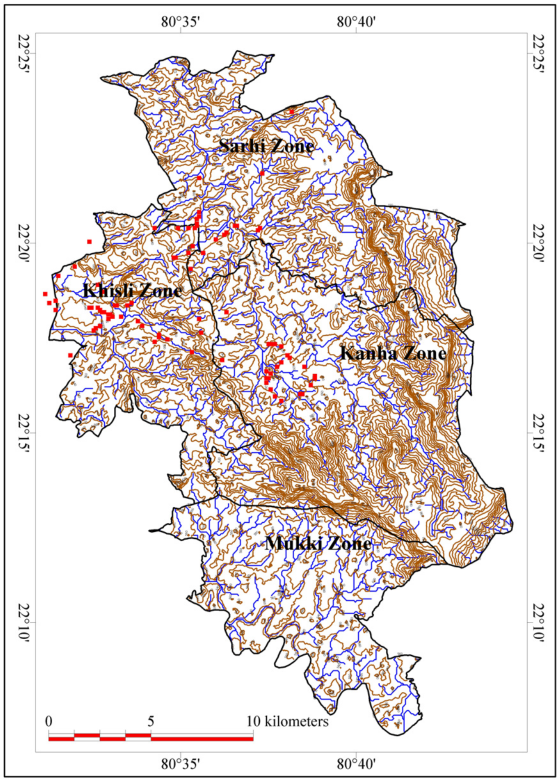

Fig. 6. Kanha Contour and Drainage_final

vation was made through the vegetational maps (Fig. 7) it appears that the different sections of the national parks compriseof forest types with different NDVI values. Ground level verification and GPS enabled photographs confirms the vegetational heterogeneity. It is important to note that the degrees of preferences of different forest of variable NDVI values (Fig. 3,4,5,) as used by different clusters must not be judged as segregated and separate manner. Rather it represents the proportion of different forests mixed in a space that extend spatially (Table 5 & 6). The heterogeneity of the forest habitat asrepresented by our grid scale data(Table 5&6) is well justified so as the heterogeneous forest used by the different clusters of spotted deers (Table 5 & 6).

It is noteworthy that the spotted deer with smaller cluster sizes (cluster 1, 2 & 3) can be grouped under a category as they show similar tendency of distribution peaks in the Sal dominated mixed forests (Fig. 3.). Cluster size 4 & 5 show their distribution peak in between Sal dominated mixed forest and grasslands. Cluster size 6-10 show distribution peak more towards grassland areas.Therefore all of these groups can be grouped

Table 5. Cluster-wise distribution of spotted deer in 1x1 km grid and corresponding proportion of forest types in percentage derived from remote sensing data.

	Water Body	Marshy Land	Grass Land	Sal Dominated Mixed Forest	Bamboo Dominated Mixed Forest	Mixed Forest
Cluster 1	0.017	1.883	15.318	54.665	26.725	1.393
Cluster2	0.161	3.384	14.098	56.226	23.240	2.892
Cluster3	0.133	0.335	5.514	66.804	26.346	0.868
Cluster4	0.620	6.779	32.467	38.474	19.526	2.134
Cluster 5	0.040	9.206	26.712	46.941	16.615	0.486
Cluster 6-10	0.671	15.418	50.458	27.236	5.591	0.626

Table 6. Cluster-wise distribution of spotted deer in 1x1 km grid and corresponding proportion of forest types in percentage derived from remote sensing data. (Rank clustering)

Cluster numbers	Area in percentage (ascending order from left to right α)					
Cluster 1	**0.017**	**1.393**	**1.883**	**15.318**	**26.725**	**54.665**
Cluster2	**0.161**	**2.892**	**3.384**	**14.098**	**23.240**	**56.226**
Cluster3	**0.133**	**0.335**	**0.868**	**5.514**	**26.346**	**66.804**
Cluster4	**0.620**	**2.134**	**6.779**	**19.526**	**32.467**	**38.474**
Cluster 5	**0.040**	**0.486**	**9.206**	**16.615**	**26.712**	**46.941**
Cluster 6-10	**0.626**	**0.671**	**5.591**	**15.418**	**27.236**	**50.458**

The value in percentages indicates the forest types of corresponding colour. **Water Body(-0.159-0.10), Marshy Land (0.101-0.20), Grass Land(0.201-0.270), Sal Dominated Mixed Forest(0.271-0.310), Bamboo Dominated Mixed Forest(0.371-0.440), Mixed Forest(0.441-0.540);** (Range of NDVI value -0.159 to + 0.540).

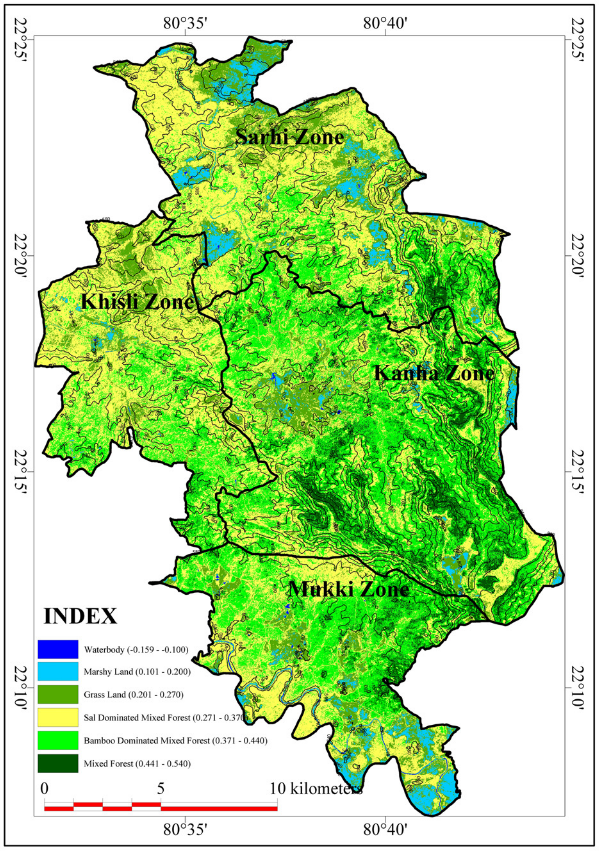

Fig. 7. Kanha NDVI- vegetation with Contours

under different category (Fig. 3 & 4). They show a direction shift of their preferred habitats / more towards hybrid patches with forest types mixed in different proportions (between 520m – 620m) as appeared form the Contour map (Fig. 6), NDVI contour hybrid maps (Fig. 7) and NDVI contour hybrid maps with 1 sq. km grid (Fig. 8) with species distribution (Fig. 8). Our observation is incremented with the previous findings of some authors (Schaller G B, 1967). The forest patches with lower NDVI values are now explored more along with the zones of higher NDVI values (Fig 7). The grassland areas which are of low NDVI values as well as are of low nutritional values are not ignored by the spotted deers. The utilization of these LRZs are considered as the secret of their survival success. It can be said that higher cluster size of spotted deers are more fit in grass land areas compared to the spotted deers of smaller clusters in Kanha N.P. The reason for this is that the largest clusters (cluster 6-10) can explore the low LRZs 65.87 % better that the HRZs 32.82% (Table 6). When smallest no of clusters (cluster 1) were considered it was found to explore 89.39% HRZs and 17.21% of LRZs (Table 6). Therefore the spatial distributions of the spotted deers are appeared as a cluster dependent phenomenon. The peak shift of the higher clusters distribution curve (Fig. 3 & 4) towards the patches of low NDVI values add a great degrees of advantages. The deciduous forest of kanha national parks changes with the change of season from winter to spring and appeared as most resource rich (Table 3) during this time of the year (Feb to April). Whereas, the grasslands turnout to be areas with least resources as it dries up with the gradual increasing heat and dryness of the coming summer (Schaller, 1967). The changing floral composition imposes a commendable impact on the spotted deer populations which becomes more browser than a grazer (Bhattarai, 2012; Pokharel and Storch, 2016). Therefore a change of preferred vegetations as a result of directional shift of spotted deer foraging behavior, appeared in our cluster oriented study is well justified. The other herbivores like sambar which forage on the grasslands would not create competition with the spotted deers as both the species have restricted/compressed niche breadth (Pokharel and Storch, 2016) and partitioned resources (Roy and Mistry, 2019)(Bagchi, 2003). Whereas in the HRZs (Sal dominated mixed forest) they competes other species for resources due to more expanded niche structure (Bishnu Prasad Bhattarai, 2012; Bagchi, 2003). Therefore the grass land areas in spite of having low resources are not bad alternative for the spotted deers due to least competition from its nearest competitors either inter species (Dar *et al.*, 2012) or intra groups (Sheppard, 2019).

Conclusion

The spotted deer is the major herbivores in the Indian forests. It serves as one of the most preferred pray to the tigers and leopards, especially in the tiger reserves. It's average body weight is 85 kg and it is placed under the family Cervidae. This species is the most abundant in Indian forests and play important part in energy flow and prey predator relationship (Sunquist, 1995). The habitat conservation and restoration of wildlife in connection to the spotted deer is therefore play important part in forest management. The gradual depletion of the forests and the change of forest covers also have grave consequences on wild life conservation (Haddad, 2015). It is the tiger reserves of India where it is important to maintain a persistent flow of major prays for sustainable population of major predators (tigers and leopards). Therefore, the spotted deer and it's relations with the habitats in diversified mosaic landscape of kanha national park are important.The species habitat relationship with respect to the spotted deer clusters appears as dynamic. The spotted deers are to depend mostly on the Sal dominated mixed forest as our finding suggest. But other forests also have their part to contribute as habitat, under spatial and temporal variation and other environmental changes. It is our suggestion to consider the clusters while studying the species habitat relationships.

The dynamic behavioral attributes (browsers and grazers) (Bhattarai, 2012; Bagchi, 2003) and forest habitat preference of spotted deer under different clusters makes the species habitat relationship a complex one, spatially. It not only varies with respect to the forest heterogeneity at the spatial scale but also with the spotted deer cluster. The spotted deer enjoys variable degrees of fitness that varies with multiple factors. Group sizes (Ramesh *et al.,* 2012), intra species interaction (Sheppard, 2019), foraging habits are the intra specific parameters whereas the heterogeneities of the habitats (Griffiths, 1975), inter specific competitions (Dar *et al.,* 2012), (Farshid and Ahrestani, 2012), seasonal and climatic changes are the external parameters for which dynamic foraging behaviors are well justified.

The cluster oriented population structure and distribution of spotted deer in one end and the temporal and spatial variations of forest floral contents at the other, play important roles on determining the species habitat relationships in a better way. Therefore our observation of species habitat relation not only centers the habitats but also consider variable vegetational preference of different spotted deer cluster under a variable heterogeneous mosaic habitats array. It is noteworthy that the above findings link the species with its habitat in a more integrated way through remote sensing data and NDVI values. Changes in habitats, as the NDVI values suggests and changes in spotted deer cluster sizes , have influence on the species habitat relationships and spotted deer foraging habits. Spotted deers having different population (group) size (Ramesh *et al.,* 2012) have explored the forest habitats differently. The forest fragments of Kanha National park, spatially apart and divided in 1x1 km grids give handful evidences towards habitat heterogeneity in regional scale. It is also appears justified that the spotted deers with different cluster numbers explore the forests on the basis of its regional merits. Habitats adjacent to each other also often differ in their levels of productivity and the types and amounts of resources that they offer (Schluter, 2017). In birds and mammals the overall level of genetic divergence between populations of individual species are greater in tropics than in temperate zones (Chek, 2003).

The uses of remote sensing appear as an important tool for monitoring a large forest like Kanha National Park. It is helpful not only to track vegetational heterogeneity either spatial or temporal but also to unfold how the spotted deer (cluster) dependson dynamic ecological conditions. The climatic and seasonal changes and their impact on the spotted deer populations are important for the conservation especially in a tiger reserve. In addition to species habitat relationship, remote sensing data on small localized sections could provide us important information towards α (within population) and β (between population) diversities (Chek, 2003). Although it isbeyond the scope of the present study.

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