Cibtech Journal of Zoology ISSN: 2319–3883 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/cjz.htm
2017 Vol. 6 (1) January-April, pp.20-27/Nandhini et al.
Research Article

SPATIAL DISTRIBUTION AND RESOURCE PARTITIONING OF SYMPATRIC CARNIVORES IN THE MUDUMALAI TIGER RESERVE, NILGIRIS, INDIA

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ABSTRACT
Mudumalai tiger reserve is the most crucial tiger conservation unit in Southern India with connectivity to bordering tiger reserves. One year field study was carried out in the tiger reserve to understand the predation dynamics, prey relations, niche volume and resource partitioning between tiger and co-predators like Leopard and Indian dhole. Scat samples were collected from all the trek paths, river banks, watershed areas and vehicle tracks of the sanctuary during the winter and pre-monsoon period. Prey species were identified using forensic trichological techniques and various parameters like prey diversity, ecological niche and niche overlap were estimated. The spatial distribution was mapped using the QGIS and the data was interpolated to draw conclusions. The data shows that there is an effective resource partitioning between the sympatric carnivores in the reserve and thereby reducing the completion. The tiger adapts by accepting both strong and weak ungulate prey, increasing the niche breadth and distributed more towards undisturbed area. Co-predators adjust the competition by distributing spatially apart, increasing prey diversity, depending on arboreal and small mammal, livestock and sharing the abundant prey. The study suggests that the reserve is healthier and sustaining one in terms of prey abundance and resource partitioning.

Keywords: *Spatial Distribution, Prey Selection, Sympatric Carnivores, Resource Partition, Mudumalai Tiger Reserve*

INTRODUCTION
The prey interactions of the hefty sympatric carnivores not only convey the feeding interactions of carnivores but give information about ecosystem where the animals interrelate (Andheria *et al.*, 2007). As the apex species manage the ecosystem and shape the prey communities and other forms of biodiversity present (Wikramanayake *et al.*, 1998). By equally distributing the habitat and prey species, they also avoid the elimination of co-predators from the ecosystem. The decrease of the species saddens the ecological stability (Karanth *et al.*, 2004) likewise the diminution of prey species can purge the acme carnivores (Chapron *et al.*, 2008; Ramakrishnan *et al.*, 1999). The entire organisms influence the populace of apex species, so apex animals like tiger and leopard are indicators of forest ecosystem (Abrams, 2001; Abrams and Ginzburg, 2000; Werner and Anholt, 1996; Ramakrishnan *et al.*, 1999; Karanth, 1988).
Three major carnivores in southern tropical forests of India, which share the common ecological niche, are Tiger (*Panthera tigris)*, Leopard *(Panthera pardus)* and the Wild dog (*Cuon alpines*). Tiger is the largest felid and socially dominant over other sympatric carnivores (Schaller, 1967; Sunquist, 1981; Karanth and Sunquist, 1995, 2000; Karanth *et al.*, 2004). Leopards are more flexible and widely distributed (Gavashelishvili and Lukarevskiy, 2008; Shah *et al.*, 2009), while the wild dogs are social animal living in packs (Iyengar *et al.*, 2005). These felids are territorial and wide ranging, but the effective size of the territory is the function of density and biomass of larger prey species in its habitat (Sunquist, 1981; Kalle *et al.*, 2011). Mudumalai tiger population is a part of the single largest tiger population in India. It acts as a source for populating the northern and eastern parts of the Western Ghats landscape. This landscape has connectivity with Eastern

Ghats landscape also, thereby a possibility for genetic exchange between populations and ensures the survival of the species in the long run. These three predators are dedicated slayers of large ungulates like Wild Indian Gaurs, Sambar deer and Wild boar (Rabinowitz, 1989; Johnsingh, 1983; Karanth and Sunquist, 1995). A very little is known about the feeding ecology, competition and resource partitioning of these co-predators in such an important landscape with an array of vegetative types (Ramakrishnan *et al.*, 1999). Therefore, scientific data on their food habits and resource partitioning are imperative for scientific understanding as well as for setting conservation goals. The current study was undertaken to understand the prey predator relationship, especially the Prey diversity, Niche breadth, Niche overlap, resource partitioning and spatial distribution of the syntopic carnivores in the Mudumalai Tiger Reserve.

MATERIALS AND METHODS

Mudumalai Tiger Reserve (MTR) (11.32′ & 11.43′N and 076.22′& 076.45′E) is a part of the Nilgiri Biosphere Reserve situated at the junction of three South Indian states viz., Tamil Nadu, Karnataka and Kerala. MTR is exceptional for its habitat diversity, with juxtaposition and interspersion of various habitat factors ranging from semi-evergreen, moist deciduous, dry-deciduous to thorny open scrub jungles.

Other than the major sympatric carnivores, lesser cats, hyena, mongoose and Sloth bear are also found in this area. The potential ungulate prey species are Chital, Sambar deer, Barking deer, Wild boar, Indian Chevrotain, Gaur, Black napped hare, Bonnet macaque, Langur, Indian porcupine, Malabar giant squirrel and peafowl are the prey species found.

The study was conducted during the winter and the pre-monsoon months in the reserve. Intense sampling survey was conducted through the 321Km^2, deciduous, semi evergreen and thorny forests. Since the carnivores prefer moving through clear trek paths, the focus was more on major search was conducted through the vehicle tracks, trek paths and other open areas in study area. On transects, the scats of sympatric carnivores were collected along with GPS co-ordinates and other essential details (Vegetation, Terrain and description of scats). After the scat identification with gloved hands, the scats were collected in a labeled ziplock bags.

The scat of tiger will be blackish or brownish colored massive solid or semi-colloidal and may contain small bone pieces. Leopard scats are comparatively smaller, mostly pale yellowish and brownish, less coiled, having larger distance between two successive constrictions, do not contain bone pieces.

Wild dog defecate in a common area as a pack, so we can find many scats in a single locale. Color of its scat varies from thick brown to pale yellowish, screwed up with another scat just like a chain. The doubtful scats and those which cannot be differentiated in the field were ignored to reduce plausible error.

Forensic Trichology is a non-invasive method that provides easy methods to analyze large samples of scats (Karanth and Sunquist, 1995; Garla, 2001; Mukerjee and Mishra, 2001). The dried scats were washed in hot water for ten minutes. The randomly collected hairs from the scat were taken out from the hot water and slide-mounted with glycerol. To make permanent records the hairs were mounted in DPX (*Dextrin Plasticiser Xylene*) after treated it with alcohol and xylene. Hair is often relatively undamaged in the feces of carnivores; the structure of medulla and the cortex of the hair help identify the prey species. Based on the observations, prey species were classified as weak ungulate prey includes chital, barking deer, mouse deer etc.; strong ungulate prey that includes Gaur, Wild boar Sambar deer etc.; arboreal prey includes Primates, Squirrels etc.; small mammal prey includes small mammals like black napped hare and the livestock includes the cattle, sheep and goats. Identification was done as per the descriptions given by Koppikar and Sabnis, (1976, 1981) and was confirmed by comparing with the hair specimens of common prey species kept in our museum. Prey diversity (Shannon and Weiner, 1949), Niche breadth (Levin, 1968) and Niche overlap (Pianka, 1973) were estimated as follows.

Prey diversity (H)

$$H = -\sum_{i=1}^{S} p_i \ln(p_i)$$

Niche breadth (B)

$$B = \frac{1}{\sum p_i^2}$$

Niche Overlap (O_{jk})

$$O_{jk} = \frac{\sum p_{ij} p_{ik}}{\sqrt{\sum p_{ij}^2 p_{ik}^2}}$$

Where P_i is the prey species, P_{ij} is the prey species of a predator and P_{ik} is the prey species of comparing co-predator. The GPS co-ordinates were mapped using the Q GIS software to understand the spatial distribution of the sympatric carnivores.

RESULTS AND DISCUSSION

The particulars of scat collection and its distribution are given in table1 and are mapped in figure 1. The scat availability varied according to different habitats. The maximum numbers of tiger scats were obtained from the southern tropical moist deciduous forest followed by dry deciduous forest. Ironically most number of leopard scats was obtained from dry deciduous forest followed by moist deciduous forest. This seems to be correctly in vice versa to the tiger scat presence in these habitats. In unison, maximum numbers of wild dog scats are obtained from thorny forests. It is also observed that, the leopard scat is uniformly distributed in all the study areas. But it is not alike incase of Tiger and Wild Dog. The former is more concerted towards deciduous forest and the latter towards thorny forest.

Prey proportion of sympatric carnivores is shown in Table 2. Albeit spotted deer is the foremost prey for all carnivores, it forms more than the half share of the total prey intake incase of wild dog. Large herbivores like Sambar deer and Gaur falls main prey for Tiger. Common langur is largely consumed by leopard rather than the tiger and is not found to be a prey for wild dog. In case of mouse deer, hare, goat etc., Wild dog takes the major share than the co-predators. So, it can be assumed that tiger is not completely depending on single prey species, instead it eats what all come in its way.

The prey diversity, prey evenness, Niche breadth and prey preference of the sympatric carnivores are given in the Table 3. It shows the proportion of various types of prey species that forms, the prey for these carnivores. The Niche breadth is more for tiger than the other two counter parts. When concerning the prey diversity, it is comparatively more for the Leopard and lesser for wild dog. The Prey evenness is almost the same for all the co- predators. When comparing the prey proportion, the weak ungulate prey like spotted deer forms the major prey of all the carnivores. However, it forms the 80% of prey species for wild dogs. Small mammal prey is highly preferred by the Wild Dogs and arboreal prey by Leopard. Tiger claims the major share of the strong ungulate prey like wild Boar and Gaur. The leopard takes the second major share of strong ungulate prey.

Comparing the Niche Overlap in Table 4, it is more for leopard and wild Dog followed by tiger and Leopard. This shows the Niche of leopard is more overlapped with its co-predators. Even though, tiger scat is obtained all over the Tiger Reserve, (Table 1, Figure 1) the tiger is more concentrated towards the undisturbed core areas. Map clearly depicts that these spatial distances between these co-predators possibly to avoid competition. The wild dogs concentrated more towards Dry thorny area and leopard towards near village fringes. But, it is also observed that all the co- predators co-exist in core areas.

The scat analysis of the syntopic co-predators proves Mudumalai Tiger Reserve have a good prey base. The predators were able to prey on diverse prey species, as the varied availability of the later is ubiquitous. The prey diversity index of all the carnivores under study is high and the evenness is comparatively medium suggesting the prey diverse environment at Mudumalai. In Mudumalai, the leopard and the Tigers are found in very high density (Kalle *et al.*, 2011; Ramakrishnan *et al.*, 1999). These two sympatric carnivores co-exist when there is high prey availability (Sankar and Johnsingh, 2002). However, the ecological separation between tiger and leopard lies in leopard's ability to survive on multiple prey species as well as on small-bodied prey. The high density of tiger and leopard in Mudumalai may be due to the availability of high prey base and continued forest cover (Kalle *et al.*, 2011).

Canids are coursing predators, and thus typically exhibit prolonged pursuit of prey through relatively open terrain (Husseman *et al.*, 2003; Schaller, 1972). Because, Canids usually chase swift prey, capture success tends to be low and depredated individuals typically are disadvantaged in some way (Randa *et al.*, 2009; Husseman *et al.*, 2003; Schaller, 1972). In contrast, felids generally stalk prey and rely more upon cover to remain concealed prior to a chase; the absence of a prolonged pursuit in felids should favor random choice of individuals from a prey population (Sunquist and Sunquist, 2002; Murray *et al.*, 1995; Rosenzweig, 1966). These patterns imply that when canids and felids are sympatric, they rely upon the same food base; both predators should select their prey having different demographic or physical attributes.

The barking deer is a shy animal and occurs in low densities across its present distributional ranges (Schaller, 1967; Kalle *et al.*, 2011). Spotted deer is known to prefer eco-tone or forest edges (Schaller, 1967; Johnsingh, 2001).

Studies on the Niche volume clearly depicts that all the three sympatric carnivores have a good Niche breadth. It is also observed that the niche of the tiger and wild dog overlap more than that of the tiger and leopard. Other studies about the sympatric carnivores in southern India shows that there is a large overlap in leopard, wild dog, and tiger diet preference (Johnsingh, 1983; Karanth and Sunquist, 1995).

Evidence suggests that among large sympatric carnivores, the larger carnivores can prey on broader size ranges of prey classes due to their prey handling capabilities (Ramakrsihnan, 1999). In Chitawan National Park where tigers and leopards coexist, tigers were recorded taking a much wider range of prey sizes than leopards (Seidensticker, 1976). In regions of high tiger density, for example, tigers are known to out-compete leopards (McDougal, 1988; Schaller, 1967, 1972), the capacity of which includes opportunistic stealing of leopard prey as well as killing leopards (Seidensticker, 1976).

Radio-tracking studies on tiger and leopard movements indicate that leopards avoid areas frequented by tigers (Seidensticker, 1976), preferring the periphery of parks near human settlements. However, in regions of low tiger density, such inter-specific social dominance is not common (Robinowitz, 1989); leopards are known to have more diverse prey base than tigers in the lower weight classes of prey. Results from the current study and that of other studies in the region appear to support these findings (Johnsingh, 1983; Karanth and Sunquist, 1995; Ramakrishnan *et al.*, 1999). Thus, a low density of prey in the higher weight classes can restrict the distribution of tigers, but may not the leopard distribution. The rapid decline in tiger population worldwide has been attributed to habitat loss and poaching (Chapron *et al.*, 2008; Wikramanayake *et al.*, 1998). The distribution maps of the carnivore suggest that Leopard is distributed in an approximate uniform fashion throughout the Reserve. The tiger prefers the deciduous forest and wild dog prefers scrub jungles.

The current study shows that the tiger have maximum niche breadth and the leopard have more prey diversity. This may be an adaptation to avoid the competition from the tiger. The tiger is more dependent on ungulate prey when compared to other two carnivores. Results clearly prove that the leopard prefer arboreal prey more than the other two carnivores. This is an excellent example of resource sharing and utilizing of the available niche in a wise way to reduce competition between the two carnivores.

Previous studies have looked at the prey preference of large carnivores as a function of prey size (Karanth and Sunquist, 1995; Ramakrishnan, 1999). These studies compared their observations in the light of foraging theory, where the most preferable prey is measured by the ratio of energy gain to prey-handling time.

Leopard prey typically range in weight from a few 100 g (e.g. rodents) to over 100 kg, with the preferred weight being between 20 and 50 kg. Similar observations have been made in Africa (Schaller, 1972) where leopards preferentially kill prey in the 20±70 kg weight class.

Thus, spotted deer would appear to be the most preferable prey as observed in the current study. Although, wild boar fall under the same weight-class category as chital deer, they are very aggressive and can retaliate viciously, which can cause serious injury to an attacking leopard. Similarly, this make the weak ungulate prey makes its diet than the strong ungulate prey. Sambar deer are larger and more aggressive than chital deer, and this could be a reason for their lower occurrence in our scat samples. Complementary findings of tiger diet support this argument (Karanth and Sunquist, 1995; McDougal, 1977; Schaller, 1967).

An effective resource partitioning between the sympatric carnivores can be seen at MTR. Leopard adjusts the competition by occupying areas where the tiger movement is comparatively less. Even though the animal is almost evenly distributed in all the habitats of the tiger reserve, the GIS map shows the presence of animal is more leaned towards the fringe or boarder area of the reserve. To cope up with the increased competition from the co-predators, the animal increases its prey diversity (H=1.90).

Leopard is solely accepting an additional share of the arboreal prey (17.65%) and comparatively good share of domestic prey (4.41%), than the tiger to reduce competition is an excellent example of resource sharing in this area.

The leopard also shares the weak ungulate prey with other co-predators, thereby reduce the competition and make it possible to co-exist by sharing resources. The tiger partitions the resource by accepting both weak and strong ungulate prey, increasing its niche breadth, sharing the abundant prey, distributing in all the habitats, & spatially distributed more in the undisturbed area. The wild dog cope the situation by spatially restricting more to thorny forest were competition is less and the environment were canids are more favored; sharing the abundant, relying on small mammal prey, exploiting the livestock prey and absent in areas of high competition.

In conclusion, in an ecosystem where the competition is medium with all the need resources available may considered as a stable one.

In Mudumalai, the ample prey base and the efficient resource partitioning by utilizing all the available ecological niche and spatial separation promise this ecosystem to be a stable and major tiger conservation unit.

Table 1: Scats collected from various types of vegetation

Vegetation Types	Tiger	Leopard	Wild Dog
Southern Tropical Dry Deciduous Forest	28	20	8
Southern Tropical Moist Deciduous Forest	39	14	5
Southern Tropical Semi Evergreen Forest	9	15	0
Southern Tropical Dry Thorny Forest	10	12	28
Moist Bamboo breaks	2	5	0
Riverside fringes	3	2	0

Table 2: Prey Preference by Sympatric Carnivores

Prey Species	Tiger (%)	Leopard (%)	Wild Dog (%)
Spotted deer	37.36	47.06	53.66
Sambar deer	14.29	2.94	0.00
Gaur	23.08	8.82	2.44
Common langur	2.20	7.35	0.00
Giant squirrel	1.10	4.41	0.00
Hare	0.00	4.41	9.76
Mouse deer	4.40	7.35	12.20
Bonnet macaque	0.00	5.88	0.00
Barking deer	5.49	2.94	2.44
Goat	1.10	4.41	7.32
Wild boar	3.30	1.47	0.00
Domestic Cow	1.10	0.00	2.44
Porcupine	0.00	0.00	2.44
Rat	3.30	0.00	0.00
Unidentified	3.30	2.94	7.32

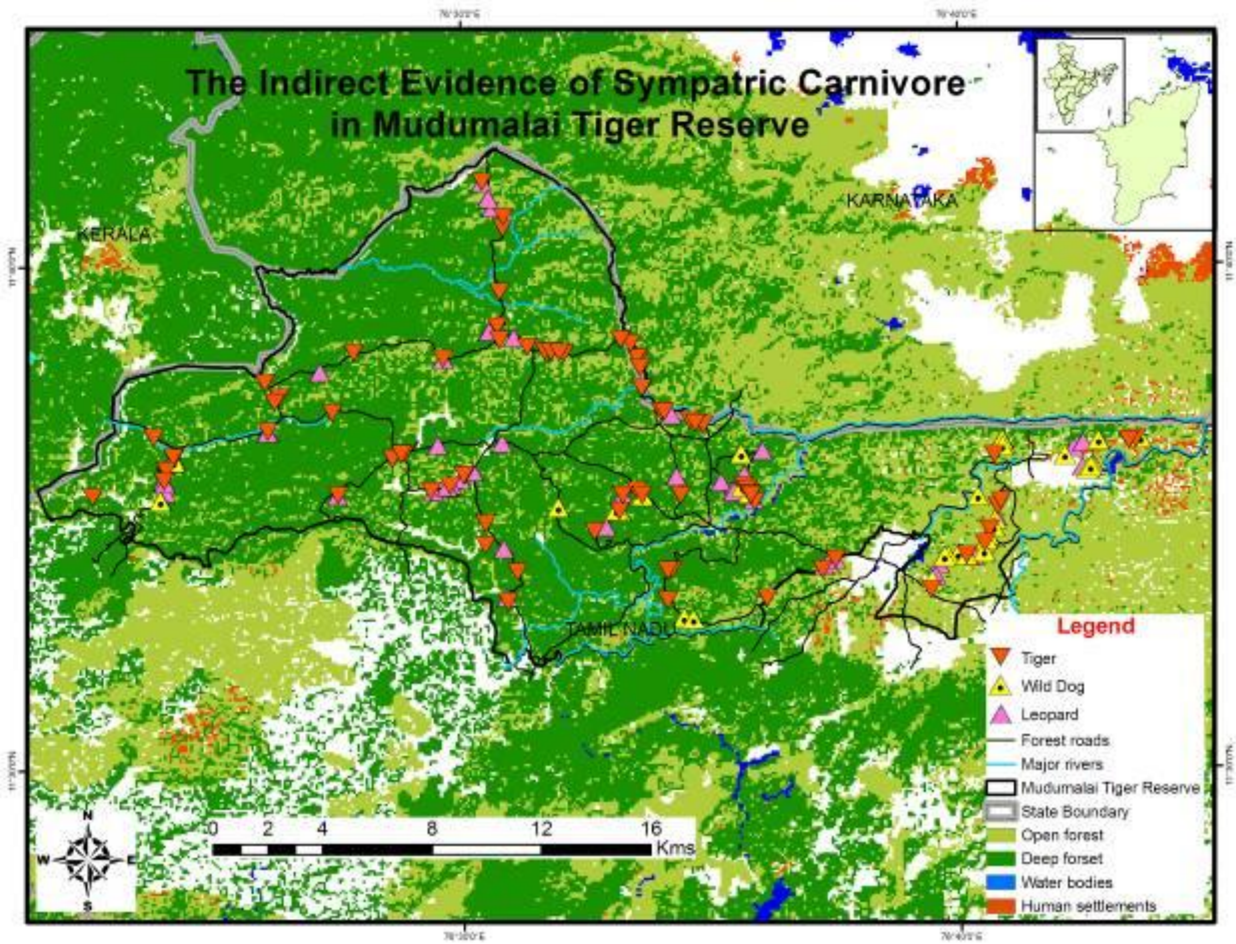

Figure 1: Spatial Distribution of Sympatric Carnivores in MTR Based on Scat Evidence

Table 3: Prey Diversity & Niche Breadth and Prey Share of Sympatric Carnivores

Predator	Prey Diversity	Prey Evenness	Niche Breadth	Arboreal Prey (%)	Weak Ungulate Prey (%)	Small Mammal Prey (%)	Strong Ungulate Prey (%)	Domestic Prey (%)
Tiger	1.85	0.53	4.50	03.30	65.93	03.3	26.37	2.20
Leopard	1.90	0.56	3.97	17.65	67.65	4.41	10.29	4.41
Wild Dog	1.56	0.53	3.07	00.00	80.49	9.76	02.44	9.76

Table 4: Niche Overlap between Sympatric Carnivores

S. No	Comparing Predators	Niche Overlap
1.	Tiger vs. Leopard	0.88
2.	Tiger vs. Wild dog	0.80
3.	Leopard vs. Wild dog	0.96

ACKNOWLEDGMENT
The first and the second authors deeply acknowledge Tamil Nadu State Council for Science and Technology, Chennai for funding the Project (TNSCST/SPS/AR/2009-10) under TNSCST- DBT Scheme. The cooperation rendered by the Tamil Nadu Forest Department by permitting us to conduct the study is also deeply acknowledged.

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