Spatial distribution of Asian elephant (*Elephas maximus*) and its habitat usage pattern in Kalakad–Mundanthurai Tiger Reserve, Western Ghats, southern India

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The study demonstrates the value of short term, but rapid surveys in understanding the spatial pattern of distribution of the Asian elephant (*Elephas maximus*) and its habitat usage pattern in the Kalakad–Mundanthurai Tiger Reserve, Western Ghats, southern India. Results indicated that the elephants use the habitat uniformly throughout the reserve, since encounter rates of elephant dung piles were found to be similar for most of the routes surveyed. However, data on fresh dung piles, indicative of presence of elephants at any given point of time and space, pointed to a clumped distribution. With respect to habitat use, 60% of elephant signs were recorded in the evergreen forests, 13% in grasslands and 12% in evergreen and reed belts. However, a comparison of dung density indicates a significant difference ($P < 0.0000$) across the habitats and the elephant densities appear to be more in the grasslands. The elevation of the reserve ranged from 40 to 1867 m; however, presence of elephants was limited to altitudes ranging from 300 to 1300 m, out of which 90% was restricted to altitudes ranging between 600 and 1200 m.

Keywords. Asian elephant, habitat usage, rapid surveys, spatial and field analysis.

THE elephants in southern India are distributed in eight distinct sub-regions of the Western and Eastern Ghats[1]. The population in southern India is unique in a number of ways. It consists of the largest number of elephants and also has large stretches of contiguous habitat. Many of these habitats have a combination of both large number of elephants and large available area[1]. The contiguity of many of these habitats (sub-regions) and the population is maintained by narrow corridors, while some of the contiguity is broken by a number of hydroelectric projects, highways, agricultural lands and other anthropogenic activities[1,2]. Periyar and Agasthyamalai sub-regions, located in the southern Western Ghats, are known for their large contiguous habitat with a variety of forest types such as tropical evergreen, semi evergreen, mixed deciduous, grasslands and dry forests. These two sub-regions come under the Periyar–Kalakad Tiger Conservation unit, with an area of about 5000 sq. km of productive habitat for many species of conservation interest[3,4]. The elephant habitat in Agasthyamalai sub-region comprising Tirunelveli (southern part) and Kanyakumari Forest divisions of Tamil Nadu, part of Thiruvananthapuram Forest Division (Kulathupuzha range), Shendurani, Peppara and Neyyar Wildlife Sanctuaries of Kerala, covers an area of 2400 sq. km. More than 75% of the area in this region comes under evergreen forest[3] and an approximate number of 100 to 150 elephants are estimated for this entire region[4]. The current study is significant, as not many surveys/studies on elephants and their status have been conducted in this region. Secondly, there is no compact evergreen forest elephant habitat in southern India, other than this. The main purpose of this study was to demonstrate the value of short-term, but quick surveys in understanding the spatial pattern of distribution, and habitat usage of the Asian elephant in this compact evergreen elephant habitat and little explored Kalakad–Mundanthurai Tiger Reserve (KMTR).

KMTR is situated in the Ashambu Hills, southern Western Ghats (southern India), with an area of 895 sq. km (537 sq. km is core zone), lying between 8°25′–8°53′N lat. and 77°10′–77°35′E long. The elevation ranges from 40 to 1867 m asl. The hill slopes are steep with rugged and undulating terrain intercepted by deep gorges and ravines. The soil type in the upper reaches is clay loam to sandy loam; outer slopes have reddish-yellow or sandy loam. The climate is dry, humid and hot at the lower levels, but cooler at elevations more than 500 m asl. Temperature ranges between 24°C and 44°C. KMTR receives rainfall from both southwest (May–August) and northeast monsoons (October–December), but more from the northeast, and rainfall varies[5,6] from 750 to 3000 mm. Three distinct seasons can be identified for the reserve, the northeast monsoon extend from September to December, followed by the dry season during January to May and the southwest monsoon period from June to August[7]. The reserve is called a River Sanctuary because of the presence of many streams and rivers[8]. The major river, Tamiraparani and its tributaries flow eastward through the reserve and the 12 other rivers flowing within the reserve are also a perennial water source for irrigation, hydroelectric projects in the four taluks of Tirunelveli District, southern India.

West coast tropical evergreen forest, sub-tropical montane forests, Tirunelveli semi evergreen forest, southern moist–mixed deciduous forest, dry teak and deciduous forests, and scrub forest are the major vegetation types in the reserve. Tropical riparian fringe forest, Ochlandra reed brakes, and grassland at low and high altitudes are the other habitats found here[6,9,10]. The KMTR is biologically rich and known for its unique endemism[3,4,8–10]. The endangered and Western Ghats endemic mountain goat, the Nilgiri tahr (*Hemitragus hylocrius*) is found here. The

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lion-tailed macaque (*Macaca silenus*), Nilgiri langur (*Trachypethicus johni*), bonnet macaque (*Macaca radiata*), common langur (*Semnopithecus entelus*) and slender loris (*Loris tardigradus*) are the five different primate species found here[3,8,11]. Kani tribes are the major inhabitants of the region, with about 120 families living here in five settlements. There are about 150 villages (with 30,000 households and a population of 0.1 million) belonging to different human communities, located in a belt within 5 km of the edge of the reserve, stretching for about 200 km distance. Out of these, 22–30% is located close to the forest[4,5].

A review of earlier studies/surveys on elephants and their habitats was done through literature searches and by interviewing researchers. Forest Department records provided useful information regarding many aspects of elephant management. Based on the literature review, past elephant sightings and habitat usage patterns, a number of survey routes (trails) were identified (Figure 1). One observer and field tracker(s) walked in these routes and a total of 24 routes were surveyed on foot during the beginning of the northeast monsoon season (mid-September–mid-October). Whenever elephant signs (track, dung, feeding, etc.) were located, time of sighting, location, altitude, forest type, number and the status of the sign (fresh or old) were recorded. While walking, uniform pace was maintained to calculate the sighting intervals (in min) of each sign. Observations of elephant signs were restricted to a width of 1 m on either side of the survey route to calculate the area scanned for each route. At regular time intervals (30 min), tree species were identified to associate with the forest types surveyed.

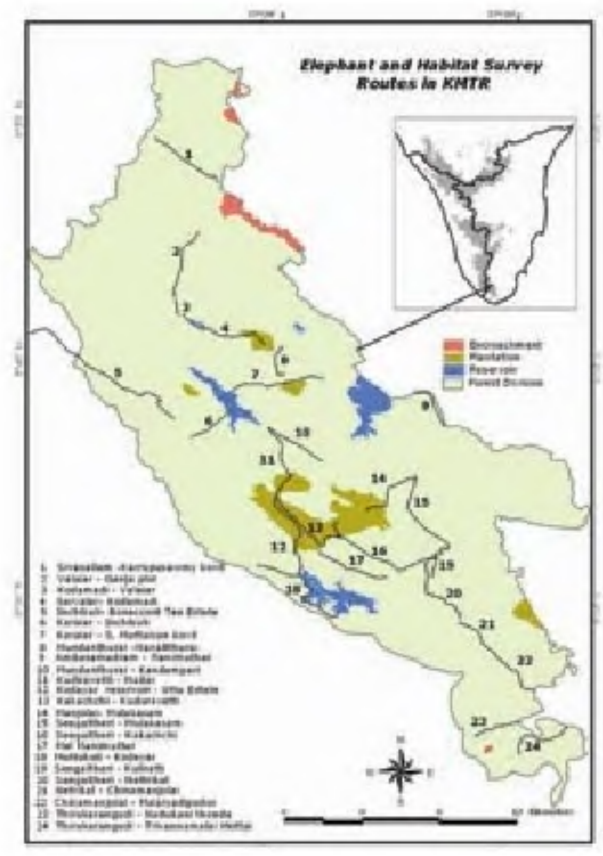

Figure 1. Elephant habitat survey routes in the KMTR.

Only elephant dung piles were considered for data processing, as dung piles were prominent and easy to locate in the field. It is known that elephants defecate 16.33 times/day[12] and the chances of missing them in the field are less compared to missing the other signs. It is important to note that the effort needed to locate other signs was more, and this was also related to the dryness, wetness or other factors associated with the terrain of the route surveyed.

Encounter rate of dung piles was calculated by dividing the total distance covered by the number of dung piles encountered for each route. The frequency of occurrence of elephant signs was calculated through sighting interval. Based on the administrative divisions (range), different sub-regions were identified and encounter rate and sighting intervals were calculated for each sub-region. Except for the Papanasam range, the survey was carried out in all the ranges.

Comparison of dung-pile encounter rate and sighting interval was made across the routes and regions. The spatial data were incorporated into a GIS software (ArcView 3.2a). Maps of the study area, survey routes and other topographical features were digitized. Survey routes were considered to be independent of each other. For each route, the encounter rate data (of dung piles) were analysed and results were incorporated to develop patterns of habitat usage and distribution. A vegetation map[10] of the area was used to look for patterns in encounter rates with respect to different vegetation types. The computer program Statistica 5.5 was used to carry out statistical tests and data processing[13], Shapiro–Wilk's W test was used to test the normality and Spearman rank correlation for testing the correlation between encounter rate of dung piles and their sighting interval. χ^2 test was used to test the observed and expected values for different habitats.

The approximate number of elephants in the reserve comes from two censuses carried out in 1991 and 1997. The 1991 census estimated 107 elephants (0.11 animals/sq. km) and in 1997, 138 elephants (0.15 animals/sq. km) were counted. There were 27 sightings of elephants for various years accounting for an average group size of eight (sample size (N) = 27, standard error (SE) = 1.15, % coefficient of variation (CV) = 20) individuals. The group size of elephants sighted ranged from 1 to 23, and the most frequently seen numbers were 1, 2, 5, 7 and 8. More than 15 elephants in a group were seen only once, indicating that the group size of elephants in this reserve was relatively small. There were frequent sightings of adult males

Table 1. Route surveyed, distance covered, number of dung piles encountered for different routes and habitats in KMTR

Route	Forest type	Dist	No. dung	Number of dung piles in forest types: Eg	Eg + Rd	DEg	Dd	Gl	Dd + Gl	Dd + Sc	SC	Ot
Sengaltheri–Kakachchi	Eg	21	45	42	0	0	0	2	0	0	0	1
Mel Manimuthar	Eg & Ri	16	27	24	0	0	0	0	0	0	0	3
Kodamadi–Valaiar	Eg & SEg	14	123	123	0	0	0	0	0	0	0	0
Kudiravetti–Mailar	Eg & DEg	9	69	69	0	0	0	0	0	0	0	0
Valayar–Ganja plot	Eg & Eg + Rd	13	28	10	10	0	0	0	0	0	0	8
Kodayar reservoir–Uttu estate	Eg, Eg + Rd & Gl	20	32	17	9	0	0	2	0	0	0	4
Inchikuli–Bonaccord tea estate	Eg, Eg + Rd & Gl	24	37	30	0	0	0	7	0	0	0	0
Muthukuli–Kodayar	Eg, Eg + Rd & Gl	23.5	36	13	10	0	0	6	0	0	0	7
Tirukarangudi–Nadukani thondu	Eg, Eg + Rd, Dd & Sc	14.5	16	5	10	0	0	1	0	0	0	0
Sengaltheri–Neterikal	Eg, Eg + Rd & Dd + Gl	21.5	50	12	36	0	0	0	2	0	0	0
Karaiar–Inchikuli	Eg, SEg & Gl	12	1	0	0	0	0	1	0	0	0	0
Sengaltheri–Kuliratti	Eg, Dd & Gl	13.5	19	6	0	0	0	13	0	0	0	0
Sivasailam–Karrupusawmy temple	Eg, DEg, Tp, Dd & Sc	10	6	4	0	2	0	0	0	0	0	0
Neterikal–Chinnamanjolai	Eg, SEg, Eg + Rd & Gl	2	4	0	4	0	0	0	0	0	0	0
Sengaltheri–Mulakasam	Eg, SEg, Dd & Gl	15	33	20	0	0	11	0	2	0	0	0
Manjolai–Mulakasam	Eg, SEg, DEg, DD & Ri	15	75	0	0	20	1	50	2	2	0	0
Kakachchi–Kudiravetti	Eg, Te & Pl	3.5	4	0	0	0	0	0	0	0	0	4
Mundanthurai–Kandampari	Eg & Dd	6	6	6	0	0	0	0	0	0	0	0
Servalar–Kodamadi	Eg, Tp & Dd	9	26	0	0	9	0	0	15	0	0	2
Tirukarangudi–Tiruvannamalai Mottai	Dd & Sc	15	0	0	0	0	0	0	0	0	0	0
Mundanthurai–Manalturai	Dd & Sc	3	4	0	0	0	4	0	0	0	0	0
Karaiar–Sorimuttaiyan Kovil	Dd, Tp & Sc	13	0	0	0	0	0	0	0	0	0	0
Ambasamudram–Manimuthar	Dd, Tp & Sc	8	2	0	0	0	0	0	0	0	0	2
Chinnamanjolai–Malaiyadippudur	Md	15	0	0	0	0	0	0	0	0	0	0
Total		316.5	643	381	79	31	16	82	21	2	0	31
%				59.3	12.3	4.82	2.49	13	3.3	0.31	0	4.821

Dist, Distance covered; No. dung, Number of dung piles.

Forest types: Eg, Evergreen; Ri, Riparian; SEg, Semi evergreen; DEg, Dry evergreen; Eg + Rd, Evergreen + reeds; Dd, Dry deciduous; Gl, Grassland; Dd + Gl, Dry deciduous + grassland; Tp, Teak plantation; Te, Tea estate; Pl, Plantation; Md, Mixed deciduous; Sc, Scrub; Dd + Sc, Dry deciduous + scrub; Ot, Includes mixed deciduous, teak plantation, tea estate and plantation.

and calves, indicating scope for a growing population. According to reports of direct sightings, except in January, August and September, elephants were sighted during all the other months in this reserve. Combining the information of both direct sightings and indirect evidence, it is possible to assume that elephants use the reserve through the year.

During the elephant habitat survey, 24 different routes with an average of 13 km (N = 24, SE = 1.25, % CV = 9.7) per route were sampled. The survey covered a total distance of 316 km and a total of 643 dung piles (Table 1), with average of 26.7 (N = 24, SE = 6.09, % CV = 23) dung piles per route and 2.01 (N = 24, SE = 0.4, % CV = 19.9) piles/km. Studies showed that dung pile encounter rates for prime elephant habitat of mixed deciduous scrub forest combination[1] was 15.5 dung piles/km and elephant density[12] was 1.74 animals/sq. km; for evergreen habitat[14], there were 8.7 dung piles/km and 0.35 animals/sq. km. Comparison of these results with those of the reserve indicates that encounter rate of the dung piles for the reserve was low. High dung decay rate or low elephant density could lead to low encounter rate of dung piles in a given habitat. In the KMTR, it could be assumed that the low encounter rate may be primarily due to the low elephant density, which could be 7.6–4.28 times lower than that of the prime elephant and evergreen habitats respectively. Based on this assumption, the reserve could support a relatively low density of 0.1–0.2 elephant/sq. km.

The survey routes covered most regions (northern, southern, eastern and western extremes of the reserve) and the result of encounter rate of dung piles/km showed that the habitat usage pattern of elephants was uniform throughout the reserve. Among all the routes surveyed, 88% routes encountered dung piles and 71% of these routes encountered 1–2-dung piles/km and there was not much of a variation around the mean for these routes (mean 1.57, N = 15, SE = 0.13, % CV = 9). It should be noted that mean encounter rate for all the routes was 2.0 and there was a relatively high variation around the mean (N = 24, SE = 0.5, % CV = 19.9). These results suggest that the elephants use the habitat uniformly and as the

survey covered most parts of the reserve, the result of equal habitat usage pattern could be extrapolated to the entire reserve.

The sighting interval of encountering dung piles varied across routes on average and of every 14.5 min (N = 24, SE = 4.6, % CV = 32) of walking, a dung pile was encountered. In some routes the sighting interval of dung piles was wide (95 min). The result was comparable with the intensity of usage pattern of elephants in a given route. However, as the Shapiro–Wilk's W test for normality suggests that the distribution of encounter rate and sighting interval is not normal ($P < 0.001$), a nonparametric correlation was carried out and it was found that there was no significant correlation between the encounter rate and sighting interval ($r = 0.0193$, $P = 0.927$; Figure 2). With reference to habitat usage pattern for individual routes, the Kodamadi–Valaiar route encountered more dung piles/km (8.8/km) followed by Kudirravetti–Malilar (7.7/km), Manjolai–Mulakasam (5/km) and Servalar–Kodamadi (3/km). In the Chinnamanjolai–Malaiyadipudur, Karaiar–Sorimuttaiyan Kovil and Tirukarangudi–Tiruvannamalai Mottai routes, no dung piles were encountered.

The survey estimated an average encounter rate of 0.09 (N = 24, SE = 0.05, % CV = 48) fresh dung piles/km and 0.07 (N = 24, SE = 0.037, % CV = 38) two-week-old dung piles/km. Encounter rate of one-month-old dung piles was 0.29 (N = 24, SE = 0.07, CV = 26) and 0.27 (N = 24, SE = 0.07, % CV = 27) for old dung piles/km. Fresh dung piles were encountered only in eight routes (Figure 3), while two-week-old dung piles were noticed only on six routes. This may indicate that though elephants use most of the reserve throughout the year, at any given point of time they restrict themselves to a small proportion (30%) of the area. A pattern of clumped distribution of elephants was noticed from the survey, as most of the fresh dung piles encountered were from one region of Kodayar.

The survey also provided data on dung pile encounter rate for each habitat type (Figure 4). Among all the dung piles encountered, 60% was from the evergreen habitat, while grasslands encountered 13% and evergreen and reed belts 12%. Mean encounter rate of dung piles also was significantly more in evergreen forest (N = 24, mean = 1.1, SE = 0.5, % CV = 41). More dung piles appearing in evergreen forest could be due to the habitat of the KMTR being predominantly evergreen, and out of 24 survey routes, 18 (75%) had evergreen forest. This pattern could also be due to the decay rate of dung piles; i.e. in some habitats the decay rate could be slow and dung piles remain for longer periods due to the habitat having more closed canopy forests. Wherever the combination of evergreen and reed belts along with *Caryota urens* (common name Koondapani) and *Arenga wightii* (common name: Alapanai) were found, the dung encounter rate and density were high, suggesting a preference of elephants for the microhabitats. However, as the data were processed in proportion to the habitat size (for major habitat types), the grasslands were used more than their availability (Figure 5). There was significant difference ($P < 0.0000$) in habitat usage pattern, and the calculated elephant density for grassland was 0.32 elephant/sq. km, for evergreen it was only 0.04 elephant/sq. km and for dry deciduous forest as low as 0.0019 elephant/sq. km.

The elevation of the reserve ranges from 40–1867 m, but dung piles were sighted only in the altitude range 300–1300 m, a large percentage of which was seen in the 600–900 m range (64%). Ninety per cent of dung sightings was in the range 600–1200 m. The evergreen and

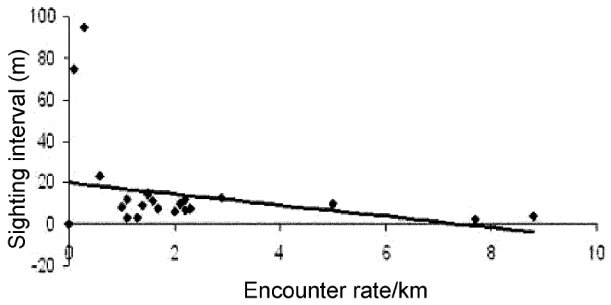

Figure 2. Encounter rate vs sighting interval.

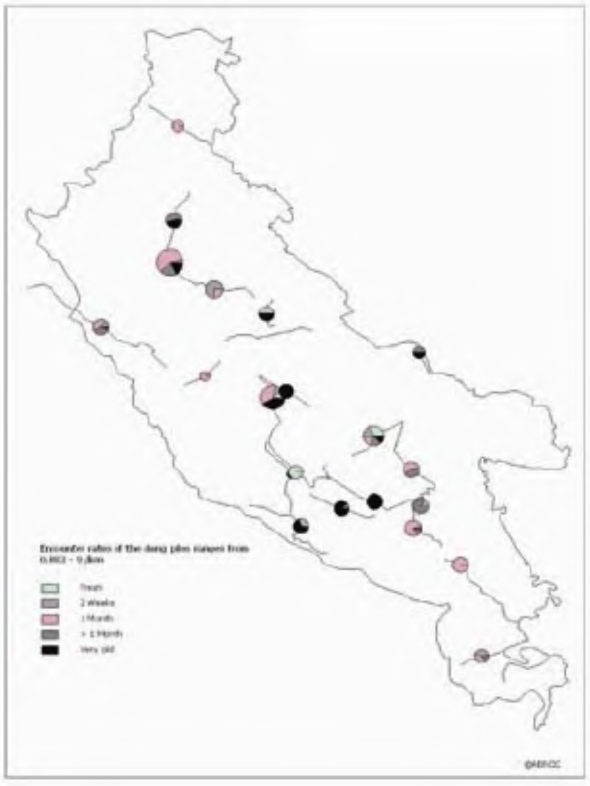

Figure 3. Status of dung piles encountered in the KMTR.

reed belts start at an altitude of 600 m and this could explain the reason for more dung piles encountered above 600 m. The number of dung piles sighted below 600 and above 1200 m was low (Figure 6). Elephants rarely used habitats below 300 m (foothills) and above 900 m (the habitat becomes open grassland and deciduous vegetation and in some regions at this altitude, the terrain is very steep).

It was previously known that the habitat in the KMTR could support only a small population of elephants. This is due to low abundance of elephant food plants and high variance in their spatial and temporal distribution. The main food sources are reeds and grasses that occur in patches of low density and are widely separated from one another and thus do not provide enough food for the elephants. The evergreen area (700 m) has reed patches and other elephant food species such as *Calamus* sp, *Mallotus phillipinensis* and *Helictres isora*. The deciduous forest and grasslands of the slopes and the foothills have *Grewia tiliaefolia*, *Dendrocalamus strictus*, *Borassus flabellifer*, *Phoenix* and *Buchannia*. These food species are also distributed in patches. Therefore, the elephants move extensively from one patch to another. Secondly, except in Mundanthurai plateau and a few lower regions (Singampatti ex-jamin), most of the areas in the reserve are steep and precipititious with many valleys rising to the peaks. This pattern has a major impact on the movement of elephants, not allowing them to descend into the valleys. They are therefore restricted mostly to the upper reaches. Elephants do come to the foothills, but mainly to feed on the cultivated crops in villages and also for the *palmyra* palm (*B. flabellifer*) trees; (grown naturally or planted to demarcate the forest boundary along the foothills).

The survey provided basic information on elephant distribution in different administrative ranges of the reserve. It was understood that, information on range-wise usage was important, as some of the ranges are crucial for elephants, while some reported human–elephant conflict. The number of elephant sightings was higher in Kodayar and Mundanthurai. Free movement of elephants across most ranges was apparent, except in Kadayam where their movement was not direct but through the neighbouring state of Kerala due to the steep terrain. Kodayar region encountered more dung piles (2.77/km), followed by Mundanthurai (2.39/km) and Kalakad (1.77/km). The encounter rate (0.25/km) and frequency of occurrence (every 95 min) of dung piles were low for the Ambai range (Figure 7).

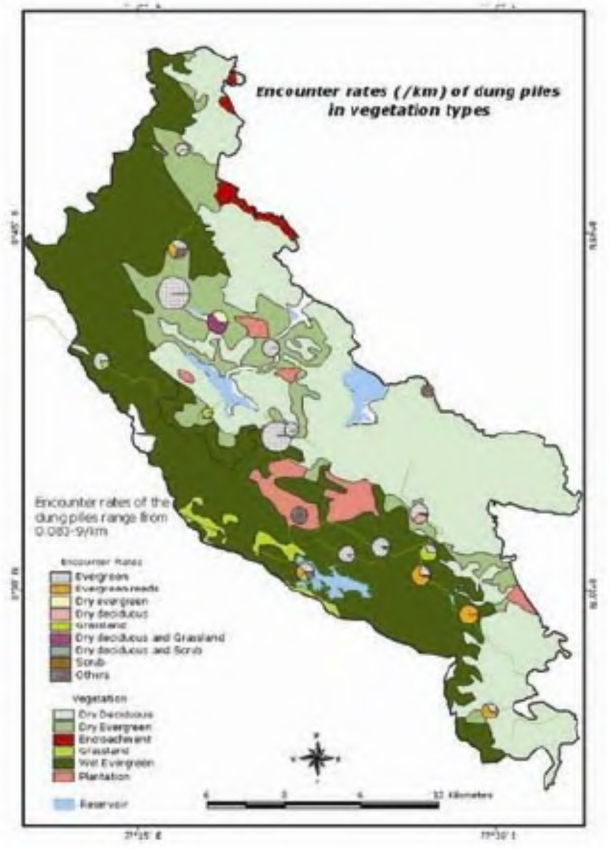

Figure 4. Encounter rate (per km) of dung piles in vegetation types in the KMTR.

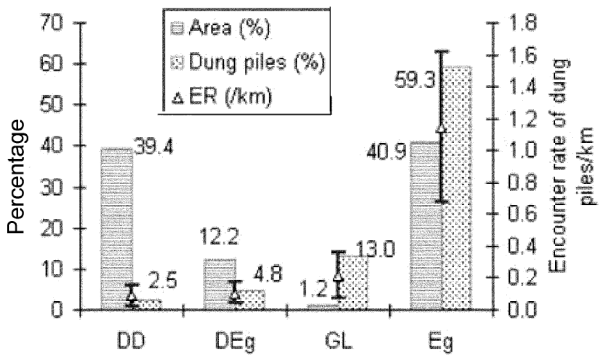

Figure 5. Encounter rate, percentage of dung piles and area for different habitats in the KMTR.

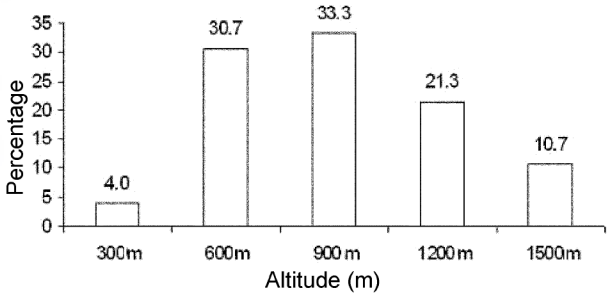

Figure 6. Dung piles sighted across the altitude range of the KMTR.

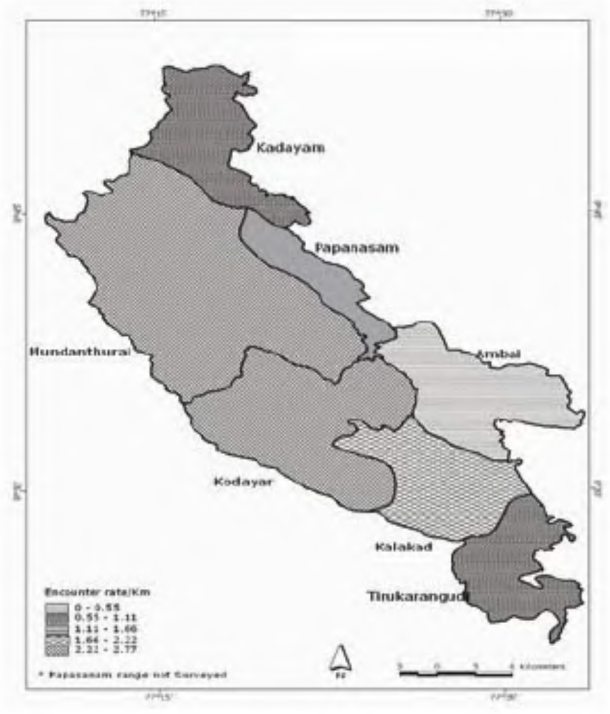

Figure 7. Encounter rates of dung piles in different administrative ranges of the KMTR.

This survey, though carried out for a short period of time (a month), has provided collective knowledge of the species, the habitat and its usage pattern. The survey results indicate that elephants use the habitat uniformly and at any given point of time they have a clumped distribution and restrict themselves to altitudes ranging from 300 to 1300 m (64% to 600–900 m). The reserve experiences moderate to marginally high biotic pressure; however, some part of the habitat (within the KMTR) is intact and has a long-term conservation value for the species.

Conservation of elephants and their habitats in the KMTR cannot be considered in isolation. The KMTR is a part of a compact unit of sanctuaries such as Neyyar, Peppara and Shendurani (Kerala) across the political border, buffered by Kanniyakumari, Tirunelveli (Tamil Nadu) and Thiruvananthapuram (Kerala) Forest divisions. Any aspect of elephant management should be based on the surroundings and the quality of the habitat available for elephants in the adjoining areas of the KMTR. A comprehensive understanding of elephants within this unit is important. Apart from this, connecting the link between this compact unit (currently Ariankavu Pass of the Shencotah Gap separates this unit) and the remainder of the north of the Western Ghats (to Periyar sub-region), would provide a much larger habitat for the elephants.

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