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IMPACT OF HIGHWAY TRAFFIC ON VERTEBRATE FAUNA OF MUDUMALAI TIGER RESERVE, SOUTHERN INDIA

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Abstract: We have assessed the direct (road kill) and indirect (disturbance) impact of vehicular traffic on vertebrate fauna at Mudumalai Tiger Reserve, southern India. In total, we have recorded 180 road kills belonging to 40 species of amphibians, reptiles, birds and mammals. Amphibians accounting for 53% of total road kills constitute the most affected species followed by reptiles (22%) and mammals (18%), the last including an endangered leopard (*Panthera pardus)*. Amphibians and reptiles are slow to react to vehicles and drivers' ignorance probably leads to higher mortality among these species. Road kills are considerably higher on highway stretches along perennial rivers than those without perennial water bodies nearby. Rate of road kills increases significantly with increasing traffic level (linear regression $R^2 = 0.869$). Indirect impact of vehicular disturbance was assessed through direct sightings and fecal counts of common langur, chital, sambar, gaur and elephant. We infer from direct counts that elephant and gaur avoided using areas up to 1000 m from highway, while fecal counts show that areas close to the highway were also used. Vehicle-based road surveys at night proved that these species use areas along the road at night. We suggest the construction of flyovers, speed breakers and signposts along the highways to reduce vehicle-caused wildlife mortalities.

Key words: Highway impact, road-kill, vertebrate, southern India

INTRODUCTION

Highways passing through natural reserves impact wild animals considerably. Several studies show that roads can adversely affect mammals (Oxley *et al*., 1974; Rost & Baliley, 1979; Mader, 1984; Mclellan & Shackleton, 1988; Newmark, 1992; Drews, 1995; Newmark *et al*., 1996; Richardson *et al*., 1997), birds (Reijnen *et al*., 1995; Drews, 1995), reptiles (Campbell, 1953; 1956; Rosen & Lowe, 1994; Drews, 1995; Gokula, 1997; Das *et al*. 2007) and amphibians (van Gelder, 1973; Reh & Seitz, 1990; Fahrig *et al*., 1995). The most commonly reported impact includes avoidance, loss of habitat, edge effects, isolation of populations, and mortality (Andrews, 1990). Several territorial species show lower breeding density in areas adjacent to roads (Clark & Karr, 1979; Adams & Geis, 1981; Reijnen *et al*., 1995). More attention has been paid in North America, Australia, Europe and Africa to assess such impacts but Asia has not bestowed the required attention to this aspect.

In India, highways bisect many protected areas. It has been realized in recent years that highways cause severe impact to wildlife and their habitats. Such a situation leads to the shifting of some of the highways from the protected areas with a very high cost. Mudumalai Tiger Reserve with adjoining Reserved Forests (Nilgiri North and Sathiyamangalam Forest Divisions) forms a very important part of the Nilgiri Biosphere Reserve. Mudumalai Tiger Reserve has several roads including an inter-state highway cutting through the Reserve. These roads have been identified as the source of disturbance to wildlife both directly (road kills including that of endangered species) and indirectly (noise and disturbance). Most of these observations are very subjective in nature. Though undoubtedly these roads have an adverse impact on our efforts in conservation, the actual impact has not been studied or quantified. Furthermore, there is also a proposal to develop a highway to connect Mysore (Karnataka) and Calicut (Kerala) cities to Coimbatore city (Tamil Nadu) via Masinigudy, Anaikatty, Sigur and Bhavanisagar. At present, there is a road up to Sigur, but traffic level is very less, as this road comes to an end at the villages. The impact will increase tremendously if this road is connected to Coimbatore. Therefore, a study was carried out, between December 1998 and March 1999, to evaluate the impact of roads directly in terms of animals killed by vehicles and indirectly, due to disturbance by vehicular traffic, to loss of habitat through avoidance of roads.

METHODS

Study area

The Mudumalai Tiger Reserve is part of the Nilgiri Biosphere Reserve of the Western Ghats. It lies between latitudes 11°32' N and 11°42' N and longitudes 76°20' and 76° 40' E and is situated at the junction of three southern states, viz. Tamil Nadu, Kerala and Karnataka. The Reserve is surrounded by Bandipur Tiger Reserve in the north, Wayanad Wildlife Sanctuary in the west and Nilgiri North Forest Division in the east and south (Fig. 1) and covers an area of 321 km^2, with an elevation ranging between 950 and 1250 m above mean sea level. Moyar, the perennial river of the sanctuary flows eastwards. The sanctuary has three marked seasons, viz. dry season (January–April), southwest (May–August) and northeast (September–December) monsoons. The annual rainfall varies from 600 mm in the east to 2000 mm in the west. Corresponding to the rainfall gradient, the vegetation changes from thorny scrub in the east, dry deciduous in the middle to moist and semi-evergreen forests in the west. The sanctuary with diverse vegetation types supports a large faunal assemblage.

Selection of study roads

A total of three main roads traversing the Reserve was selected for quantifying the road kills and these include (1) an interstate highway of 16 km, (2) a state highway of 7 km and (3) a secondary road of 8 km (Fig. 1). The interstate highway connects the cultural capital of Karnataka, Mysore City, with the well-known hill station of south India, Ootagamund (Udhagamandalam), popularly known as Ooty. The inter-state highway cuts through the forest areas of Karnataka (Bandipur Tiger Reserve) and Tamil Nadu, where it enters the Mudumalai sanctuary in the north at the border post of Kakkanhallah and goes beyond the forest limits at Thorappalli, which is the southern limit of this study road. This stretch runs through the sanctuary for a total length of 16 km with relatively higher traffic intensity. The inter-state highway branches into a state highway at Teppakadu, leading to Udhagamandalam and beyond via Masinagudi, a small town. The stretch of 7 km between Teppakadu and Masinagudi was identified for the second sector of the study. The third sector of 8 km road connects Masinagudi and Moyar. Traffic intensity is less on this road compared to the state and inter-state highways.

Estimation of traffic intensity

In order to estimate the traffic intensity in different roads, a systematic count of vehicles was made monthly once separately for the three roads for a period of 24 hours from ideal locations. The number of vehicles plying in these roads was counted for 24 h during a two-day session (first day, between 06:00 and 18:00 h and the second day between 18:00 h and the next day 06:00 h). Traffic intensity is expressed as number vehicles plying/hour.

Quantification of road kills

To quantify the direct impact of roads on wild animals, number of road kills that occurred on different roads was counted at species level. The road-kill data collection was restricted to vertebrates, viz., amphibians, reptiles, birds and mammals. To quantify the road kills, the three roads were surveyed systematically by walk between 06:00 and 09:00 h twice a month at fortnight intervals for four months from December 1998 to March 1999. In addition, *ad hoc* data on road kills were also collected. Some of the road kill (mostly mammals) data was collected after examining the road kills reported by other researchers, forest department staff and local people. At every sighting of a road kill, information such as place, species name, number and status of the kill was recorded. The status of the kill was classified into two categories such as fresh (died within the last 24 h) and old (died more than 24 h). After recording the above details, the carcass was removed from the road and, if unidentified, it was preserved in formalin for later identification. Relationship between number of road kills/km and number of vehicles plying/h in three different roads was compared using linear regression.

In order to understand how detrimental it is for the wildlife, if interstate highway to run parallel to perennial water source, the number of road kills recorded in sub-sections of the interstate highway running parallel to perennial river Moyar (between Teppakadu–Kargudi 3.2 km, and Kargudi–Bidarhalla 2.9 km) was compared with sub-sections of same road running near non-perennial water bodies (between Kakkanhalla–Teppakadu 4.8 km and Bidarhalla–Thorappalli 5.1 km) (**Fig. 1**).

Evaluation of vehicular disturbance

Direct count or sighting method: To evaluate the disturbance caused by the vehicular traffic on wild animals, distribution pattern of large herbivores in relation to proximity to the road was recorded using line transect method (Burnham *et al.*, 1980). Larger herbivores such as the Asian elephant (*Elephas maximus*), Gaur (*Bos gaurus*), Sambar deer (*Cervus unicolor*), spotted deer (*Axis axis*) and common langur (*Semnopithecus entellus*) were monitored, as these are the most common species and also easily quantifiable. In total, 11 one–km transects were laid perpendicular to the inter-state and state highways on either side alternatively at every two km interval. Transects were surveyed between morning 06:00 and 10:00 h and evening 16:00 and 18:00 h. At every sighting, information such as sighting time, species name, number of individuals and proximity to main the road were recorded. Data was compiled to arrive at sighting or encounter rate/100 m distance for each species at different proximities from the highways.

Fecal count: Fecal samples such as scats of langur, pellets of spotted deer and sambar, and dung piles of gaur and elephant were enumerated in 20 x 1 m plots. At every 500 m intervals of highways, one–km transect was laid on either side alternatively. In this transect, a plot of 20 m length (10 m on either side of the transect line) and 1 m width was marked at every 100 m interval up to 500 m and at 250 m intervals up to 1000 m. Within these plots, the number of dung piles, pellet groups and scats were counted for target species separately. The number or encounter rate of fecal samples/20 m^2 was estimated and plotted against proximity to the road for each species.

Night transect: In order to find out whether herbivores use areas close to roads at night, vehicle-based road transect was carried out along the highway during nighttime. Transects were surveyed using a four-wheeler driven at a speed of 20 km/h between 20:00 and 22:00 h on the inter-state and state highways once during the study period. During the survey, whenever the large herbivores were sighted, sighting time, species name, group size and perpendicular distance were recorded. As visibility was limited to the vehicle's headlights, most of the animals were sighted up to15 m from the highways.

RESULTS AND DISCUSSIONS

Quantification of road kills

In total, 180 road kills belonging to 40 species were recorded both during periodic transect survey and incidental visit (**Table 1**). In total, 99 road kills were recorded through fortnight survey of three transects (248 km) over four-months workout to 0.40 road kill/km. The remaining 81 road kills were recorded during incidental visits. Among the 180 road kills, amphibians were the most affected accounting for 53%, followed by reptiles (22%) and mammals (18%). Birds were least affected by vehicular traffic and comprised 7% of the total kills. In terms of number of species, reptiles (16 species) stood topmost followed by mammals (13 species). These figures are probably an underestimate given that an unknown proportion of animals hit by vehicles are either eaten by carrion feeders or died in the nearby vegetation without being recorded. The higher road mortality of amphibians and reptiles observed in the present study could be attributed to their slow mobility, not reacting quickly to vehicles, the drivers are less likely to notice these animals because of ignorance. Vehicles killed snakes (13 out of 16 species) among reptiles the most and accounted for 67% reptilian road kills. A similar finding has been reported elsewhere in India (Das *et al.*, 2007) and United States (Rosen & Lowe, 1994) who attributed the slow movement and use of roads as substrate for thermo-regulation by snakes for higher mortality. Lower susceptibility of birds to vehicular hit could be due to their ability to fly fast.

The present study recorded 13 species of (27 individual) snakes with common wolf snake as the most affected species (7 road kills) and rate of snake road kill was estimated at 0.25 snake/4 km/day based on four very fresh snakes (4 snakes/96 h/16 km) recorded during eight survey days. However, an earlier study (Gokula, 1997) on road mortalities of snakes in the same Reserve shows that out of seven species of snakes, common wine snake was the most affected (12 out of 23 road kills) and estimated at one snake/4 km in 24 h. The difference between the two studies could be attributed to the variation in sampling period, effort and the survey area. Among the road kills recorded, Bufo (*Bufo melanostictus*) was the most susceptible species for the vehicular traffic (Appendix 1), which accounted over 50% of the total road kills. The nocturnal nature coupled with the habit of foraging in areas with artificial light due to higher availability of insects, which are attracted by vehicle headlights and streetlights, could be the possible reason for the higher susceptibility of bufo species. Higher vulnerability of bufo to road traffic has been reported elsewhere in Australia (Ehmann & Cogger, 1985).

Among the mammalian fauna, the bonnet macaque and langur come close to road to beg from tourists leading to higher incidents of mortality due to highway traffic. In Mikumi National park, Tanzania, a large number of yellow baboons, a diurnal species, was attributed partially to similar begging habit (Drews, 1995). Most of the mammalian road kills recorded in the present study are nocturnal (field mouse, bandicoot, black napped hare, sambar, leopard, palm civet and bat) species that could have been killed, as they got blinded by the vehicle's headlights, while crossing the roads. Within four months, an endangered species of leopard was killed by a vehicle. Besides this, a leopard cub at Mudumalai Tiger Reserve in February 1998 and an adult tiger at Bandipur, a neighbouring Tiger Reserve, in 2006, were killed by speeding vehicles (N. Baskaran personal observations). Though these figures seem to be very small compared to other species, such loss is unacceptable considering their low population density. There are several places where large cats have been killed by highway traffic in India (Gruisen, 1998a; 1998b), Florida (Maehr *et al.*, 1991), and in Africa (Drews, 1995). These reports indicate that such problems are increasing in recent years.

Vehicular traffic and rate of road kills in different road

The results on traffic level estimated in different roads showed that inter-state highway had the highest traffic (37 vehicles/h) followed by state highway (22 vehicles/h) and secondary road (15 vehicles/h). This inter-state highway is wider and also climbs on to Nilgiris Ghats on a gentle slope. Therefore, all the heavy vehicles from Mysore to Udhagamandalam and *vice versa* were plying through this road. Additionally, the connection of this highway with Calicut City of Kerala increases the traffic level considerably. A total of 128, 56 and 64 km distance were walked respectively in inter-state highway, state highway and secondary road during the study period. The rate of road kill observed among the three roads varied considerably with inter-state highway experiencing the highest road kill (0.52/km) followed by the state highway (0.39/km) and least in the secondary road (0.17/km). Further, a comparison of traffic level with the rate of road kills show a positive correlation (R^2 = 0.8693) indicating that the impact of road on wild animals increases positively with increasing vehicular traffic.

Highest number of road kill/km was recorded along the sub-sections of interstate highway running parallel to perennial river between Teppakadu–Kargudi (7.1 kills/km), a highly accessible river stretch, followed by Kargudi–Bidarhalla (4.0 kills/km), semi-accessible stretch, while the sub-sections of same interstate highway running near non-perennial water areas such Kakkanhalla–Teppakadu (0.9 kills/km) and Bidarhalla–Thorappalli (1.8 kills/km) experienced a relatively lower number of road kills, indicating highways located parallel to perennial water sources are more detrimental to wild animals.

Evaluation of indirect disturbance level

Direct and fecal counts: Both direct sighting (Fig. 2a) and fecal samples (Fig. 2b) of common langur and chital were recorded at all proximity from the road indicating that there was not much impact of traffic on the distribution of these two species. While in the case of sambar, gaur and elephant there was no direct sighting up to 300, 750 and 1000 m respectively (Fig. 3a). But fecal samples (pellet/dung piles) (Fig. 3b) were recorded close to highways suggesting that these species avoid using areas close to highways during daytime and may attempt during nighttime. To confirm this, data on direct sighting was collected along the highway during nighttime using vehicle.

Night transect: Since visibility is restricted to the vehicle headlight during nighttime, the maximum perpendicular distance at which animals were sighted was 15 m. The encounter rates of target species recorded on different roads are given in Table 2. The chital, sambar gaur and elephant were sighted on the state highway, but on the inter-state highway, except the gaur the remaining three species were sighted. Such difference could be due to low sampling effort. However, the data confirm that sambar, gaur and elephant also use the areas close to the highway during nighttime. These observations reveal that except langur and chital, other herbivores (sambar, gaur and elephant) were disturbed by vehicular traffic during daytime and thus they use the areas along the road side during nighttime, as evidenced by the results of vehicular survey during nighttime. This indicates that the entire area from the highways to several hundred meters (up to 1 km) was not available to these animals nearly 50% of the time due to vehicular traffic disturbance. This would result in a significant loss of habitat and such impact would likely to be even higher on sensitive species like tiger, leopard, sloth bear, etc. Similar impacts of traffic disturbances have also been documented elsewhere on the distribution of larger mammals (Newmark *et al*., 1996; McLellan & Shackleton, 1998) and birds (Clark & Karr, 1979; Adams & Geis, 1981; Reijnen *et al*., 1995).

The present study clearly shows that roads, especially those with high level of traffic, have higher impacts on wildlife and thus any changes in the existing highway that would increase the traffic load or speed limit will increase road kill rate further. Additionally, establishing new highways across wildlife refuges needs to be avoided, as it would deteriorate further the small populations of many endangered species. We have come across large number of road kills and wild animals including elephants have to wait for hours together due to vehicular traffic to access the water source especially between Teppakadu–Kargudi, where the highway runs parallel to Moyar river, we suggest the construction of flyovers for vehicular trafiic across traditional footpaths of wild animals (Kalhalla, Nadu–camp and Kargudi watch tower) leading to Moyar River. Additionally, speed breakers and adequate signposts should also be provided both at the entrance and all along the roadsides of the Reserve to reduce the direct impact of the highway on wildlife.

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Table 1. Estimate of road kills of vertebrate fauna recorded between December 1998 and March 1999 (a total 248 km covered in transect survey at the rate of 62 km/month) at Mudumalai Tiger Reserve, southern India

Species name	Number of road kills recorded		
	During fortnight transect survey	During incidental visit	Total (%)
Amphibians (3 species)	59	37	96 (53)
Reptiles (16 species)	26	14	40 (22)
Birds (8 species)	05	07	12 (07)
Mammals (13 species)	09	23	32 (18)
Total (40 species)	**99**	**81**	**180**

Table 2. Details of larger mammals sighted during the night transect in different roads (maximum perpendicular distance recorded was 15 m) at Mudumalai Tiger Reserve, southern India

Type of road	Encounter rate/km			
	Chital	Sambar	Gaur	Elephant
Inter-state highway	1.8	0.4	0.0	1.8
State highway	3.6	0.1	0.1	0.1
Secondary road	0.8	0.0	0.0	0.0

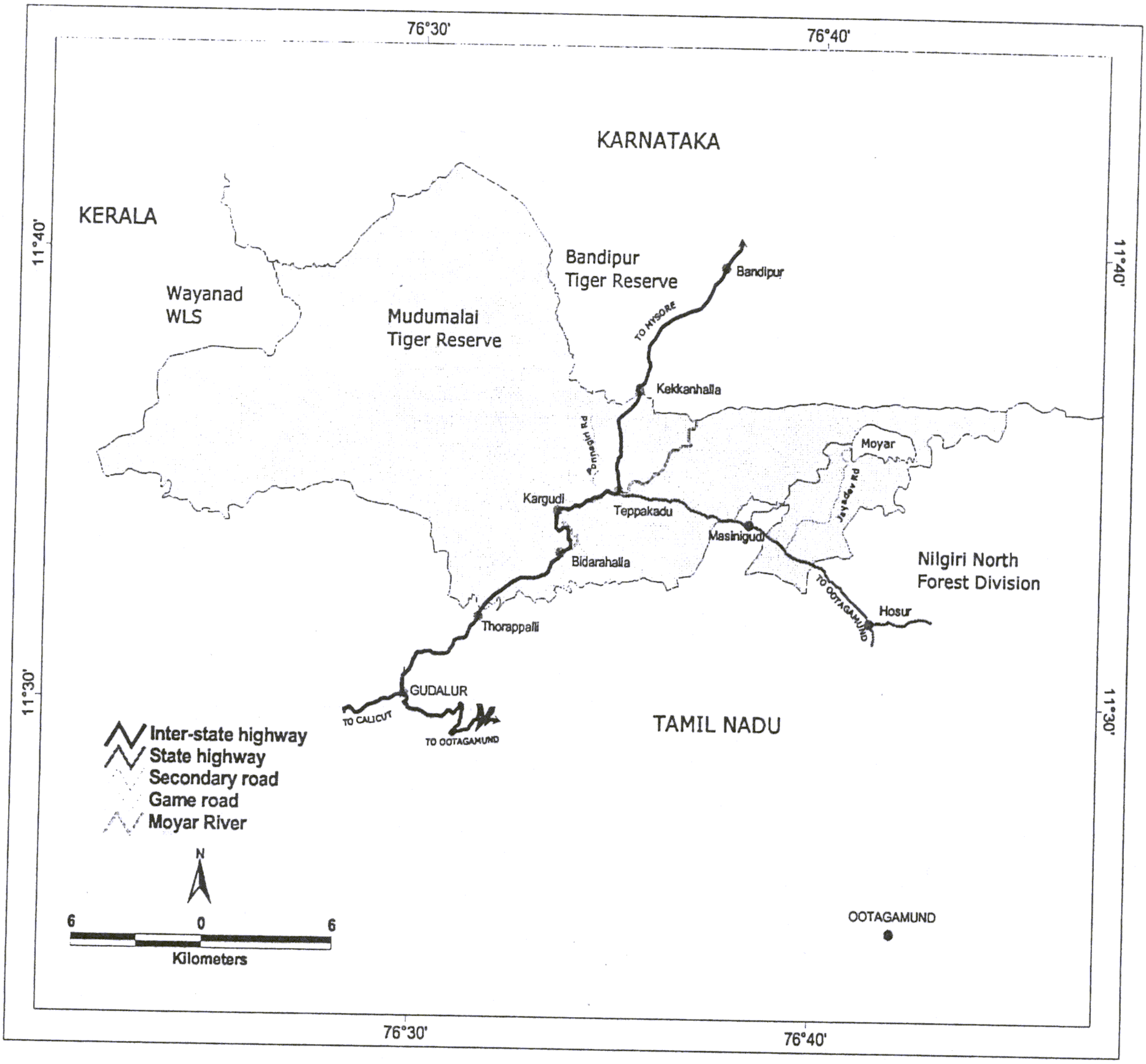


Figure 1. Map of Mudumalai Tiger Reserve showing the adjoining forest divisions and various roads selected for the study.

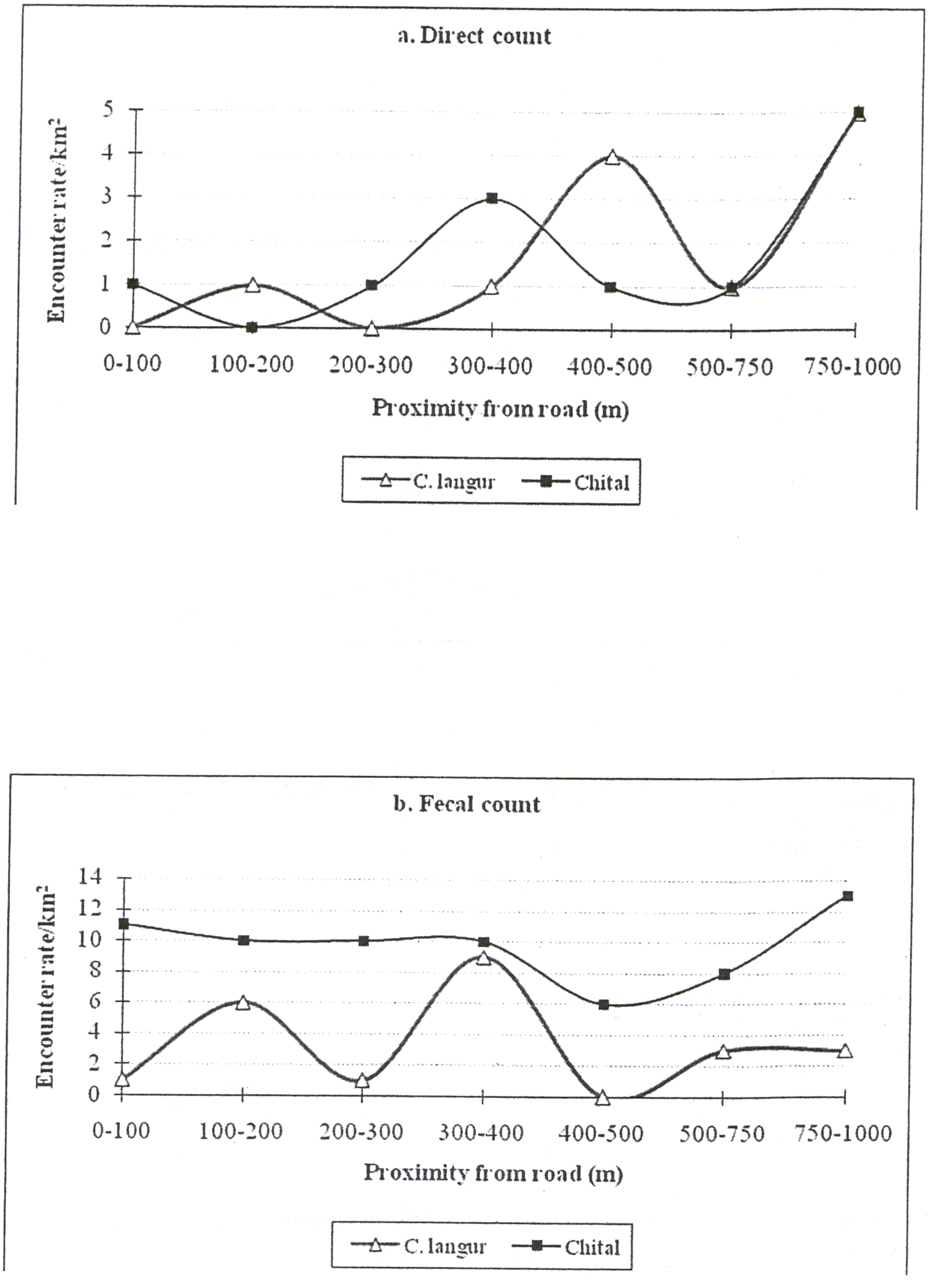
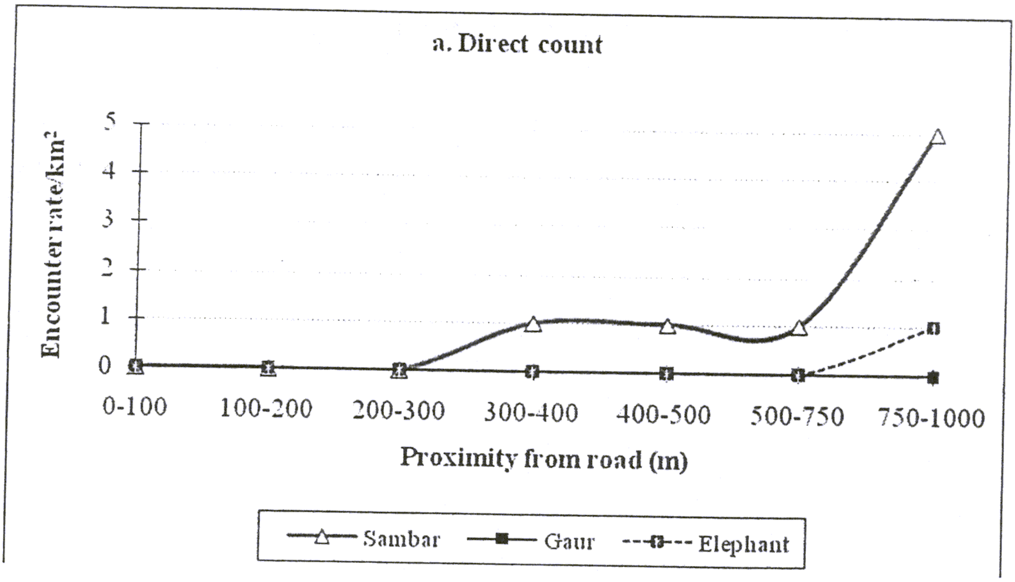


Fig. 2. Encounter rate of common langur and chital direct count (a) and fecal count (b) in relation to proximity from highway recorded between December 1998 and March 1999 at Mudumalai Tiger Reserve, southern India.



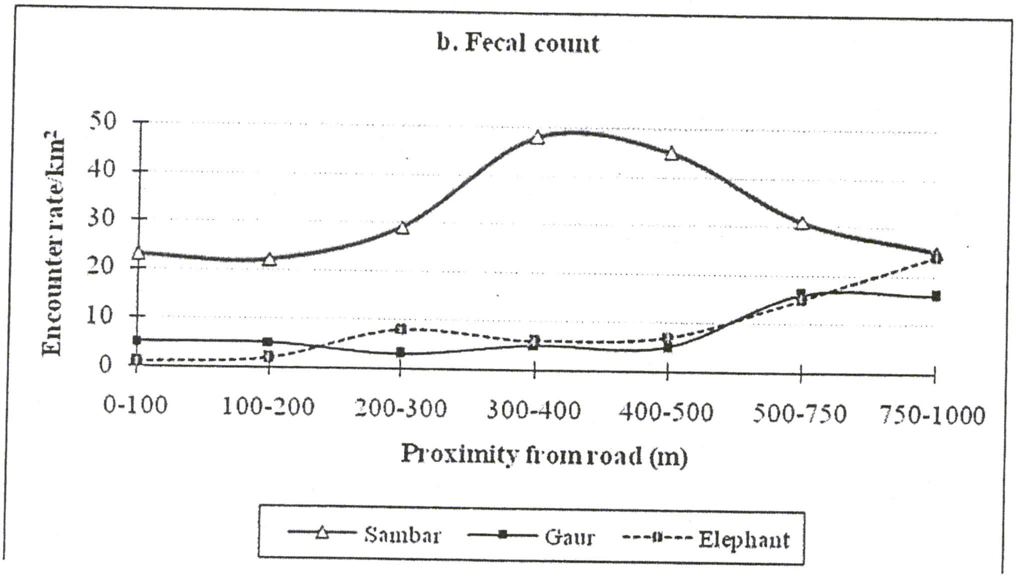


Fig. 3. Encounter rate of sambar, gaur and elephant direct count (a) and fecal count (b) in relation to proximity from highway recorded between December 1998 and March 1999 at Mudumalai Tiger Reserve, southern India.

Appendix 1. List of road kills recorded between December 1998 and March 1999 (total 248 km covered in transect survey) at Mudumalai Tiger Reserve, southern India

Species Name	Number of road kills recorded	
	During fortnight transect survey	During incidental visit
Amphibians		
Bufo (*Bufo melanostictus*)	59	35
Malabar gliding frog (*Rhacopohrus malabaricus*)	0	1
Unidentified frog	0	1
Reptiles		
Russell's viper (*Vipera russelli*)	2	1
Common wolf snake (*Lycodon aulicus*)	4	3
Bronze back snake (*Denderalaphis tristis*)	2	1
Checkerd keel back snake (*Xenochrophis piscator*)	0	1
Variegated kukri snake (*Oligodon taeniolatus*)	1	1
Green keel back snake (*Macropisthodon plumbicolor*)	1	0
Indian gamma (*Boiga trigonata*)	1	1
Common worm snake (*Typhlina bramina*)	0	1
John's earth boa (*Eryx johni*)	1	1
Diard's worm snake (*Typhlina diardi*)	1	0
Golden tree snake (*Chrysopelia ornata*)	1	1
Buff striped keel back (*Amphiesma stolata*)	1	0
Common green whip snake (*Ahaetulla nasutus*)	1	0
Lizards		
Common garden lizard (*Calotes versicolor*)	5	2
Common skink (*Mabuya carinata*)	3	1
Chameleon (*Chamaeleon zeylanicus*)	2	0
Birds		
Coucal (*Centropus sinensis*)	0	1
Common Indian Nightjar (*Caprimulgus asiaticus*)	2	0
Indian myna (*Acridotheres tristis*)	0	2
Spotted dove (*Streptopelia chinensis*)	0	2
Magpie Robin (*Capsychus saularis*)	0	1
Yellow-throated sparrow (*Petronia xanthocollis*)	1	1
Hoopoe (*Upupa epops*)	1	0
Unidentified birds	1	0

Contd...

Species Name	Number of road kills recorded	
	During fortnight transect survey	During incidental visit
Mammals		
Leopard (*Panthera pardus*)	0	1
Wild boar (*Sus scrofa*)	0	1
Sambar (*Cervus unicolor*)	0	2
Chital (*Axis axis*)	0	1
Mouse deer (*Tragulus meminna*)	0	1
Common langur (*Semnopithecus entellus*)	2	1
Bonnet macaque (*Macaca radiata*)	0	6
Black naped hare (*Lepus nigricollis*)	0	3
Palm civet (*Paradoxurus hermaphroditus*)	0	1
Palm squirrel (*Fanampulus palmarum*)	0	1
Bandicoot (*Badicota indica*)	0	1
Field Mouse (*Mus booduga*)	7	3
Unidentified Bat	0	1
Total (40 species)	**99**	**81**

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