Seasonal variation in wildlife roadkills in plantations and tropical rainforest in the Anamalai Hills, Western Ghats, India

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Wildlife–vehicle collisions on the roads lead to mortality of a range of animal taxa both within and around wildlife reserves. Quantifying and understanding impacts of roads on wildlife mortality are essential for identifying vulnerable taxa and suitable mitigation measures. We studied animal mortality on roads in relation to habitat and season in the Anamalai Tiger Reserve and adjoining Valparai plateau in the Western Ghats, India. Habitats were broadly classified as forest, monoculture plantations (tea, coffee, eucalyptus) and mixed. Eleven road transects of 3–12 km length were surveyed between 9 and 12 times each during monsoon (2011) and summer (2012). We recorded 2969 roadkills (mean = 2.01/km) during the 1473.4 km of road surveys carried out. The overall roadkill rate was 21.2 (± 3.87 SE) individual kills/10 km. Amphibians were most frequent in roadkills (overall roadkill rate of 9.3 ± 2.17 SE kills/10 km, $n = 1307$), followed by invertebrates and unidentified taxa (7.6 ± 1.81 SE kills/10 km, $n = 1066$). Roadkill rate was 2.4 times higher in monsoon than summer, with amphibians particularly averaging higher kill rate during monsoon. Frequency of roadkills of various animal groups differed between seasons in different habitats. In both the seasons, most roadkills were recorded mainly in tea, forest, and forest–tea habitats. Relative to length of roads through forest, a disproportionately large number of roadkills of herpetofauna and mammals were recorded in forest habitat. Higher vehicular movements, including tourist traffic, road widening, removal of native plants along roads and construction of sidewalls without breaks obstruct animal movements and may be responsible for roadkills. Designing roads to be more permeable for safe animal movement, particularly where roads pass through forest, and sensitizing highways authorities are essential to reduce animal mortality and make roads more wildlife-friendly in this region.

Keywords: Linear infrastructure intrusions, roadkill, road ecology, Western Ghats, wildlife-vehicle collisions.

ROAD networks are a pervasive feature of modern landscapes. In natural areas such as tropical forests or wildlife protected areas, roads act as linear infrastructure intrusions bringing various detrimental effects into the ecosystems they pass through. A wide range of studies have established that roads lead to habitat loss and fragmentation, act as barriers for movement of many animal species, resulting in injury and mortality of wildlife due to collisions with vehicles, besides causing soil erosion, landslides, hydrological alterations, spread of invasive alien plant species and pollution[1,2]. Animal mortality on roads due to collisions with vehicular traffic (wildlife roadkill) is among the most direct and visible negative impacts of roads. Studies have shown that demographic effects of roadkills on wildlife populations may be as serious and significant as those due to direct habitat loss[3]. A review of studies on the effects of roads and traffic on animal abundance and distribution found that documented negative effects of roads on animal abundance outnumbered the positive effects by a factor of five, and concluded that the serious effects of roads and traffic indicate a need for integrating prevention and mitigation options in all road construction and maintenance projects[4]. Understanding the frequency of roadkills in various animal groups and its variation across habitat and seasons helps select prevention and mitigation options appropriate for the taxa and landscape context[5].

Vehicular collisions lead to death or injury of various groups of animals from insects to large mammals such as rhinoceroses and elephants[6,7]. A number of studies have recorded such wildlife roadkills on Indian roads[6,8–13], but few have estimated roadkill of both invertebrate and vertebrate species[7]. Most of these studies focused on roads passing through wildlife protected areas and on roadkills within a single season, and did not describe variation in relation to habitat with few exceptions[9,14]. Furthermore, information on wildlife roadkills outside protected areas in India is scarce. It is increasingly recognized that conservation of wildlife species in protected areas also needs to consider the surrounding landscapes and human-modified habitats where populations of many species of conservation value are present[15]. Here, we study roadkill mortality of fauna in a road network within the plantation landscape of Valparai plateau and the adjoining Anamalai Tiger Reserve (ATR) in southern India. The study documents the frequency of occurrence of roadkills of various

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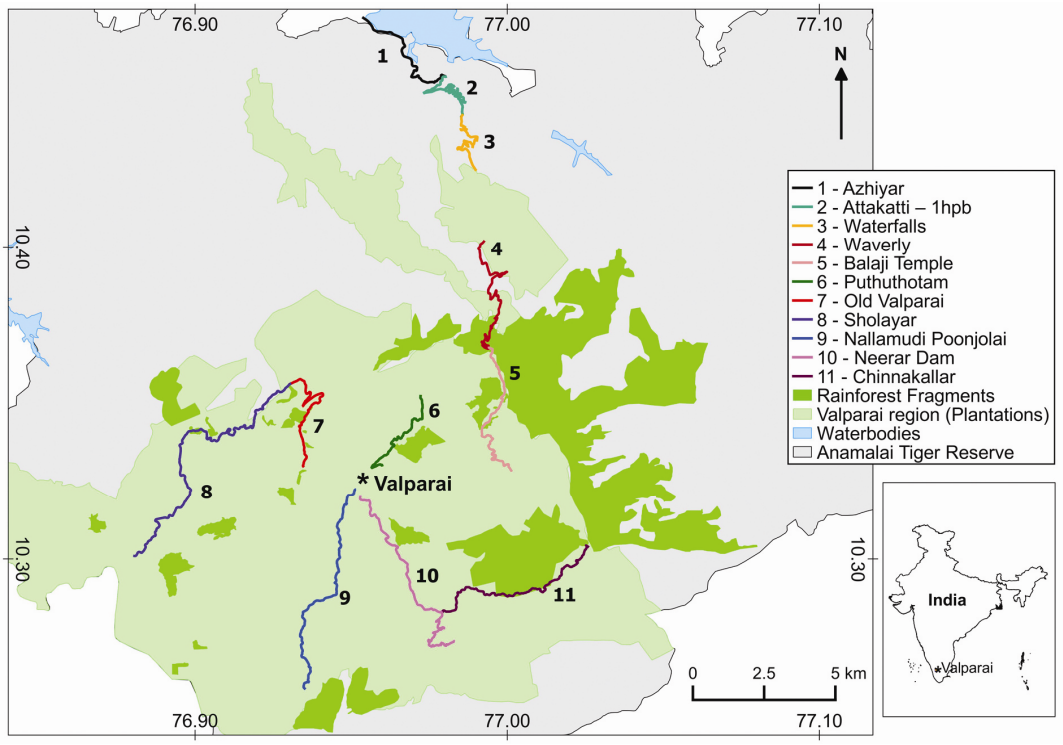

Figure 1. Map of Anamalai Tiger Reserve and Valparai plateau showing roads surveyed for the study.

animal taxa in relation to habitat and season through surveys of replicate roads across the landscape. The results are used to identify potential management measures that can help prevent or reduce the incidence of roadkill of vulnerable wildlife species in similar landscapes.

Materials and methods

Study area

The study was carried out in the Anamalai Hills, a critical conservation area within the Western Ghats biodiversity hotspot[16,17]. It was conducted in ATR (958 sq. km, 10°12′N–10°35′N, 76°49′E–77°24′E) and the adjoining Valparai plateau (Figure 1). The Valparai plateau is a 220 sq. km enclave surrounded by protected areas on all sides including ATR, Eravikulam National Park, Chinnar Wildlife Sanctuary, Vazhachal Reserve Forest and Parambikulam Tiger Reserve. Land use on the Valparai plateau (falling mostly within 800 to 1400 m in altitude) is mainly tea plantations, along with eucalyptus and coffee plantations, and small areas under cardamom. The natural vegetation of the Valparai plateau and adjoining parts of ATR is mid-elevation tropical wet evergreen forest[18], although lower elevations in ATR, surveyed in this study also have tropical moist and mixed deciduous forests. There are at least 40 rainforest remnants within the Valparai plateau, many of which are regularly used by endangered and endemic species such as Asian elephant *Elephas maximus*, lion-tailed macaques *Macaca silenus* and Great Hornbills *Buceros bicornis*[19]. The forest fragments, important as biodiversity refuges and animal corridors, have been affected by habitat degradation and fragmentation, while other threats such as roads, monoculture plantations, invasive alien species and unsustainable tourism impact fragments as well as continuous forest tracts in ATR[15,19,20]. The mean annual rainfall (2014–17) at Iyerpadi, Valparai was 2170 mm, mostly received during the southwest monsoon (June–September) with a moderate amount of rain also received during the northeast monsoon (October–December). Dry weather prevails during January to May and early June.

This study was carried out along the Pollachi–Valparai highway (Tamil Nadu State Highway 78), and on roads in other areas of Valparai plateau, some of which were improved in recent times (since 2008). These roads pass through monoculture plantations and rainforest fragments in the plateau and through moist and deciduous forests of ATR. As these include an arterial highway and roads connecting certain tourist spots, they are the most intensively used and hence were chosen for this study.

Methods

Roadkill surveys were carried out within an elevation range of 328–1462 m above mean sea level (msl) in the study area. Eleven road transects of 3.7–12.9 km length (total length = 80.2 km, average = 7.2 km) were

Table 1. Details of sampling sites and efforts of roadkill survey conducted in and around Anamalai Tiger Reserve in 2011 and 2012

		Monsoon (2011)				Summer (2012)			
Transect	Length (km)	Start (dd-mm)	End (dd-mm)	N walks	Total (km)	Start (dd-mm)	End (dd-mm)	N walks	Total (km)
Azhiyar	5.1	04–11	15–12	10	51	23–05	20–06	8	40.8
Attakatti – 1 hpb	6.7	03–11	17–12	11	73.7	22–05	13–06	8	53.6
Waterfalls	5.2	02–11	16–12	11	57.2	21–05	18–06	8	41.6
Waverly	8.5	16–08	31–10	10	85	19–05	30–06	8	68
Balaji Temple	6.7	15–06	22–10	12	80.4	20–03	10–05	7	46.9
Puthuthotam	3.7	13–06	12–10	13	48.1	06–03	20–05	8	29.6
Old Valparai	6.1	12–08	30–10	10	61	10–03	14–05	8	48.8
Sholayar	12.9	19–08	29–10	10	129	09–03	23–05	8	103.2
Nallamudi	9.3	16–06	23–10	11	102.3	18–03	22–05	8	74.4
Neerar Dam	9.2	17–08	25–09	9	82.8	17–03	24–05	8	73.6
Chinnakallar	6.8	15–08	01–11	10	68	16–03	24–05	8	54.4
Total	80.2			117	838.5			87	634.9

systematically surveyed during monsoon and summer (Table 1). Overall, these transects were walked 117 times (9–13 repeats each) from June to December 2011 (monsoon) and 87 times (7–8 repeats each) from March to June 2012 (summer). Transects walked in June 2012 prior to the onset of monsoon were pooled with summer for analysis. The total length surveyed during the study period was 1473.4 km (monsoon = 838.5 km, summer = 634.9 km). Surveys were conducted on foot between 0600 h and 0800 h. Of the eleven transects surveyed, seven road transects passed through ATR and the remaining four passed through rainforest fragments, tea, coffee and eucalyptus plantations on the Valparai plateau.

For roadkills found, the species, the number of individuals and the roadside habitat were noted, and their locations were recorded using a hand-held Garmin GPSMAP 60CSx device. To avoid duplicate counts on subsequent visits, roadkills were removed from the road (and placed outside the road verge) after noting the details. Supplementary observations and roadkill incidents in the study area were also recorded opportunistically. However, roadkill specimens were not collected and only photographs were taken to aid in identification. Roadkills were identified to species level in case of mammals and birds. Amphibian and reptile roadkills were often in a badly damaged state, especially during monsoon, making it difficult to identify them even up to genus level. Such records were categorized up to the group level or left unidentified. Invertebrates were recorded up to phylum level or sub-phylum level.

At the location of each roadkill, the adjoining habitat on either side of the road was noted. Habitats were broadly classified as forest and monoculture plantations (tea, coffee, eucalyptus). As two different habitats sometimes occurred on either side of the road at habitat edges, the following combinations of mixed habitats were also categorized: forest-tea, forest-coffee and eucalyptus-tea.

Analysis

Roadkills were categorized in 11 taxonomic groups: annelids (earthworms), arachnids (spiders and scorpions), centipedes, crabs, millipedes (millipedes and pill millipedes), insects, molluscs (snails and slugs), amphibians (frogs, toads and caecilians), reptiles (snakes, lizards and geckos), birds and mammals besides an 'unidentified' category. Invertebrates and vertebrates were kept as two broad groups for some analyses. To estimate roadkill rate (number of roadkills/10 km), the total frequencies of roadkills were summed across replicate surveys, averages calculated per km and then multiplied by 10. An average roadkill rate was first estimated for each transect using the data from repeat surveys, and the overall roadkill rate was represented as an average of these averages and its SE was estimated to represent variation across the 11 transects. Roadkill frequency data were analysed using chi-square (χ^2) tests to assess whether relative frequencies of different taxa varied by season or habitat. Statistical significance of overall roadkill rate was assessed using paired *t*-tests (paired by transect). Opportunistic data were treated separately and not included in the above analysis. We used *R* (ver. 3.2.0; *R* Development Core Team 2015) for performing statistical analysis.

Results

In total, 2969 roadkills (21.2 ± 3.87 SE kills/10 km) were recorded along road transects during the study (2217 during monsoon 2011, 752 during summer 2012). Apart from these, 58 roadkills were also recorded opportunistically in different locations during other field visits until May 2013 (Appendix 1).

Out of the 2969 roadkills, amphibians constituted the most (44.0%, 9.3 ± 2.17 SE kills/10 km, $n = 1307$), followed by invertebrates and unidentified taxa (35.9%,

7.6 ± 1.81 SE kills/10 km, $n = 1066$) (Figure 2). Among the amphibian roadkills recorded, 93% ($n = 1220$) were frogs and toads and 7% ($n = 87$) comprised caecilians. Among reptile roadkills (14.8%, 3.2 ± 0.51 SE kills/10 km, $n = 438$), more than 80% were snakes ($n = 210$), with 33.6% ($n = 147$) being shieldtail snakes (family: Uropeltidae). Red-whiskered Bulbul *Pycnonotus jocosus* was most frequent ($n = 4$) in the bird roadkills recorded (0.3%, 0.07 ± 0.02 SE kills/10 km, $n = 10$). Of the mammal roadkills recorded (5.0%, 1.1 ± 0.29 SE kills/10 km, $n = 148$), rodents and shrews comprised 81.1%. Other significant mammal roadkills recorded during the transect survey were Western Ghats striped squirrel *Funambulus tristriatus* ($n = 8$), unidentified bat species ($n = 7$), Indian crested porcupine *Hystrix indica* ($n = 5$), black-naped hare *Lepus nigricollis* ($n = 2$), bonnet macaque *Macaca radiata* ($n = 2$) and brown palm civet *Paradoxurus jerdoni* ($n = 1$). Invertebrates and other unidentified organisms formed 35.9% of the total roadkills recorded, of which molluscs (snails and slugs) were most frequent (34.1%, $n = 364$), followed by diplopods (millipedes and pill millipedes) constituting 25.9% ($n = 276$) and annelids (earthworms) constituting 20.6% ($n = 220$). The remainder were insects 12.2%, centipedes 3.8%, arachnids 1.6%, crabs 1.5% and other unidentified organisms 0.2%. Other roadkills recorded during supplementary observations in the study were Indian rock python *Python molurus* ($n = 2$), barking deer *Muntiacus muntjak* ($n = 1$), Indian spotted chevrotain (mouse deer) *Moschiola indica* ($n = 1$), sambar *Rusa unicolor* ($n = 1$), Indian giant squirrel *Ratufa indica* ($n = 1$), common palm civet *Paradoxurus hermaphroditus* ($n = 2$), small Indian civet *Viverricula indica* ($n = 1$) and lion-tailed macaque *Macaca silenus* ($n = 2$).

Seasonal variation in road mortality

Among the four groups of vertebrates, amphibians were proportionately higher in roadkills both during summer and monsoon, followed by reptiles and mammals (Table 2). Although the frequency of amphibian roadkills was higher during monsoon and in terms of percentage of total roadkills, they formed a higher percentage (51.9%) in summer than in monsoon (41.4%). The seasonal difference in relative frequency of these groups of vertebrates killed was statistically significant ($\chi^2 = 18.2$, $df = 3$, $P = 0.0004$).

Among the invertebrates and other unidentified organisms, we recorded a greater percentage of molluscs (snails and slugs), millipedes (millipedes and pill millipedes) and annelids (earthworms) during monsoon. There is a significant difference in relative frequency of different groups of invertebrates killed between monsoon and summer ($\chi^2 = 80.7$, $df = 7$, $P < 0.0001$). Notably, seasonal differences for earthworms and insects contributed to 50% of the χ^2 value.

The overall roadkill rate was over 2.4 times higher in monsoon (28.2 ± 5.32 SE kills/10 km) compared to summer (11.7 ± 2.25 SE kills/10 km), a difference that was statistically significant (paired t-test, $t = 4.048$, $df = 10$, $P = 0.002$, Table 2). Amphibians suffered higher average roadkill rate during the monsoon in 10 out of 11 transects, leading to their overall roadkill rate nearly twice as high as in summer ($P = 0.059$, Table 2). These were followed by reptiles, molluscs and annelids in terms of roadkill rate, which again was significantly higher during monsoon than in summer ($P < 0.05$, Table 2). Amphibian roadkill rate was high even during summer, with around 6 animals killed/10 km.

Variation in roadkill across habitats and transects

Habitat influenced the frequency of occurrence of road mortality, with significant variation in the frequency of roadkills of various groups between seasons in different habitats ($\chi^2 = 55.7$, $df = 67$, $P < 0.0005$). Compared to the monsoon, road mortality was relatively low in all the habitats during summer. In both seasons, most roadkills were recorded mainly in tea ($n = 1402$), forest ($n = 948$), and forest-tea ($n = 287$) (Table 3) habitats. In tea, amphibians ($n = 641$) were most frequent in roadkills in both seasons, followed by molluscs ($n = 306$). However maximum mollusc roadkills occurred during monsoon ($n = 251$). Roadkills of reptiles ($n = 129$), earthworms ($n = 116$), millipedes ($n = 95$) and mammals ($n = 41$) were also considerable in tea. In the forest, amphibian roadkills were maximum ($n = 364$), followed by reptiles ($n = 226$) and millipedes ($n = 141$). The frequency of mammal roadkills was higher in the forest ($n = 78$)

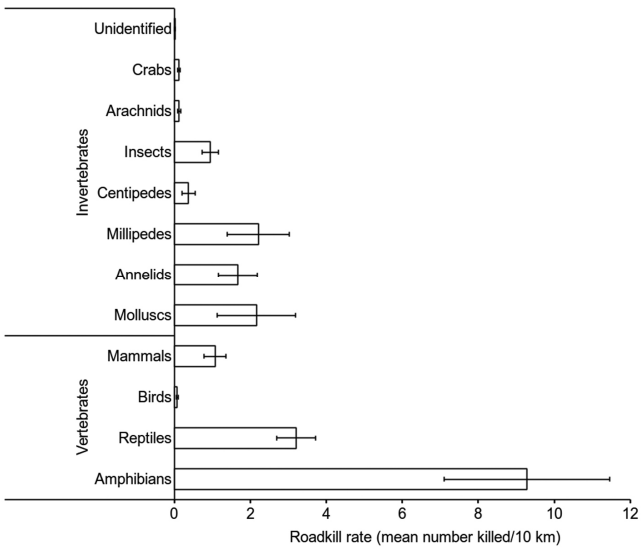

Figure 2. Average roadkill rate (error bars are SE) of various animal taxa along roads in Anamalai Tiger Reserve and Valparai plateau during the study.

Table 2. Seasonal differences in average roadkill rate (number killed/10 km) and frequency of various animal groups killed in the study landscape, Anamalai Hills

	Monsoon		Summer		Paired *t*-test (*df* = 10)	
Taxonomic group	Roadkill rate (SE)	Frequency (%)	Roadkill rate (SE)	Frequency (%)	*t*	*P*
Vertebrates						
Amphibians	11.8 (2.93)	917 (41.4)	5.9 (1.99)	390 (51.9)	2.133	0.059
Reptiles	4.2 (0.62)	324 (14.6)	1.9 (0.42)	114 (15.2)	6.064	<0.001
Birds	0.02 (0.01)	2 (0.1)	0.1 (0.06)	8 (1.1)	–1.921	0.084
Mammals	1.2 (0.36)	94 (4.2)	0.9 (0.24)	54 (7.2)	1.409	0.189
Invertebrates						
Molluscs	3.1 (1.41)	300 (13.5)	0.9 (0.54)	64 (8.5)	2.472	0.033
Annelids	2.9 (0.88)	218 (9.8)	0.03 (0.03)	2 (0.3)	3.186	0.01
Millipedes	3 (1.17)	210 (9.5)	1.1 (0.33)	66 (8.8)	1.922	0.084
Centipedes	0.6 (0.29)	39 (1.8)	0.04 (0.04)	2 (0.3)	2.087	0.063
Insects	1.1 (0.3)	86 (3.9)	0.7 (0.12)	44 (5.9)	1.683	0.123
Arachnids	0.1 (0.06)	12 (0.5)	0.1 (0.04)	5 (0.7)	0.788	0.449
Crabs	0.2 (0.05)	13 (0.6)	0.05 (0.03)	3 (0.4)	2.076	0.065
Unidentified	0.01 (0.01)	2 (0.1)	0 (0)	0 (0)	1.491	0.167
All taxa						
Overall roadkill	28.2 (5.32)	2217	11.7 (2.25)	752	4.048	0.002

Table 3. Seasonal variation in frequency of the roadkills of various taxa in seven different habitats

	Coffee		Coffee-forest		Eucalyptus		Eucalyptus-tea		Forest		Forest-tea		Tea		
Groups	M	S	M	S	M	S	M	S	M	S	M	S	M	S	Total
Vertebrates															
Amphibians	116	5	22	8	13	0	20	7	292	72	79	32	375	266	1307
Reptiles	11	2	3	0	2	0	7	3	165	61	41	14	95	34	438
Birds	0	1	0	0	0	0	0	1	1	4	0	0	1	2	10
Mammals	2	3	2	1	0	0	0	2	49	29	18	1	23	18	148
Invertebrates															
Molluscs	4	0	8	0	0	0	6	1	13	6	18	2	251	55	364
Annelids	4	0	2	0	0	0	34	0	20	2	42	0	116	0	220
Millipedes	6	6	3	0	1	0	5	0	114	27	18	1	63	32	276
Centipedes	1	0	0	0	0	0	1	0	34	2	1	0	2	0	41
Insects	3	1	1	3	3	0	3	3	29	11	11	5	36	21	130
Arachnids	0	0	0	0	0	0	0	0	7	2	0	2	5	1	17
Crabs	1	0	0	1	0	0	0	0	8	0	0	1	4	1	16
Unidentified	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2
All taxa															
Total	148	18	41	13	19	0	76	17	732	216	229	58	972	430	2969

M, Monsoon; S, Summer.

compared to the other habitats surveyed. Among the seven categories of habitats, the proportion of amphibian roadkills was higher in coffee (78.4%) during monsoon, while in summer it was higher in the mixed forest-coffee (61.5%) habitat. For reptiles, a slightly larger proportion was killed in the forest during summer (28.2%) than monsoon (22.5%).

The average roadkill rate was higher during monsoon than in summer in 10 of 11 transects (Figure 3). In the Sholayar road transect, the summer average roadkill rate was higher due to a single episode of large mortality of amphibians. Average roadkill rate was highest in Puthuthottam, Old Valparai and Nallamudi during monsoon, and in Puthuthottam, Sholayar and Nallamudi in summer (Figure 3).

Discussion

This study recorded a large diversity of animal taxa ranging from small insects and herpetofauna to birds and

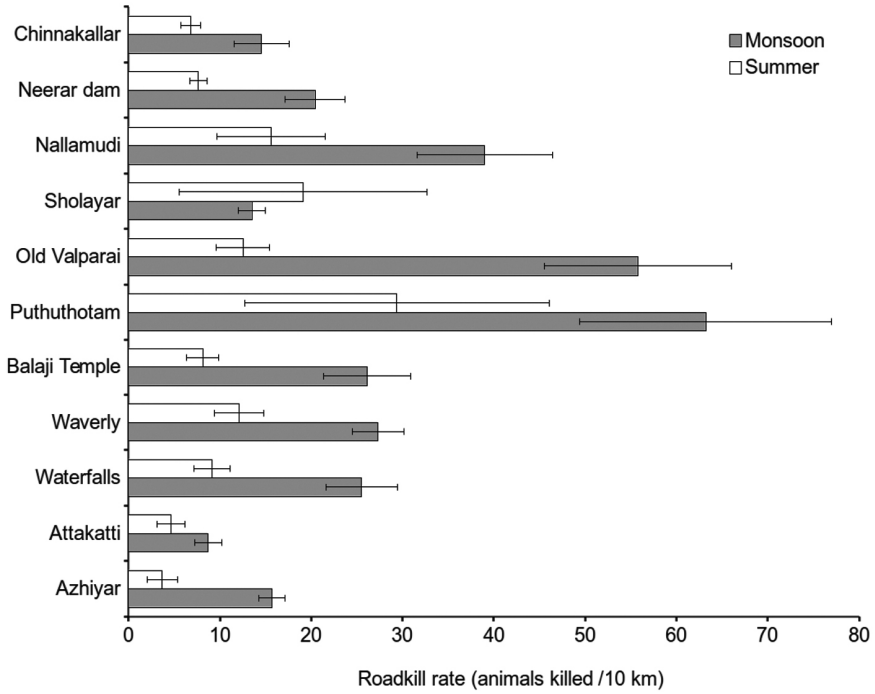

Figure 3. Average roadkill rate (error bars are SE) in summer and monsoon across the 11 transects along roads in Anamalai Tiger Reserve and Valparai plateau.

large mammals (e.g. sambar *Rusa unicolor*) killed on roads (Appendix 1), as noted in some earlier studies on the Western Ghats[12,21]. Most of the earlier roadkill studies in India have focused on particular taxa (mainly vertebrates) rather than recording all animals killed on the road and only a few studies focused on invertebrates[12,22,23]. In areas of high biological diversity, such as in the Western Ghats, roadkill surveys should ideally record all taxa killed on road to provide a comprehensive picture of impacts. These studies can help pinpoint direct research needed on the most vulnerable taxa and appropriate mitigation measures.

Our study shows that herpetofauna were the most frequently killed taxa, especially during monsoon. The preponderance of herpetofauna, particularly amphibians, has been noted in earlier multi-taxa roadkill surveys[10,12,21]. Among reptiles, most kills recorded were of snakes, particularly with mortality of uropeltids, endemic to the Western Ghats, being higher during monsoon as has been previously reported from this region[8,9]. The vulnerability of these taxa may be related to different life history or habitat attributes. Breeding and terrestrial overland movements of taxa such as anuran amphibians, caecilians and uropeltid snakes, during the monsoon, accentuated by their intrinsic slow mobility, may be responsible for their mortality while crossing roads[9]. The presence of streams or preferred microhabitats in proximity to the road coupled with inadequate structures (such as underpasses) to facilitate crossing below the road might increase the vulnerability of species such as amphibians, molluscs, crabs, snakes and turtles during dispersal. The maintenance of drains along roads, along with underpasses at regular intervals, can provide safe passages below roads and thereby reduce roadkills[3].

After herpetofauna, most roadkills during this study comprised of invertebrates, mainly millipedes, insects and molluscs. Among molluscs, snails were most frequently killed. However, samples from three bouts of roadkills in one particular transect (Nallamudi) contributed to much of the mollusc roadkill rate. It should be noted that rainfall prior to the specific survey days (24 August 2011, 9 September 2011, 28 April 2012) in this location, might have resulted in increased activity and mass movement of these animals due to which mass mortality may have occurred. The slow-moving nature of these animals would have increased their susceptibility to roadkill by the vehicles. Speeding vehicles may increase the likelihood of roadkills, even among more mobile invertebrates such as odonates and butterflies[22]. Studies have also noted that increased traffic volume, such as on weekends[22] or festival days[12] lead to a higher frequency of roadkills, although one study from Western Ghats found no correlation between traffic volume and herpetofaunal mortality[24]. A limitation of the present study is that the traffic volume was not measured on different roads. The results suggest that roadkill rates tend to be higher on some of the main roads with high traffic volume (Puthuthottam, Sholayar, Old Valparai, Nallamudi) including tourist traffic to locations such as Sholayar Dam and Nallamudi viewpoint. This aspect requires attention in future research.

Appendix 1. Number of animals recorded as roadkill on transects and opportunistically during the study along roads in the Anamalai Tiger Reserve and Valparai plateau, Anamalai hills

Group/species	Road transects	Opportunistic	Group/species	Road transects	Opportunistic
Vertebrates			Invertebrates		
Amphibians			Molluscs		
Frogs	744	5	Snails	336	7
Toads	466	8	Slugs	28	0
Caecilians	87	2	Annelids		
Frog/Toad	10	0	Earthworms	220	0
Reptiles			Millipedes		
Snakes	210	4	Millipedes	225	0
Shieldtails	147	2	Pill millipedes	51	0
Skinks	39	4			
Calotes spp.	38	2	Centipedes		
Geckos	3	0	Centipedes	41	0
Agamids	1	0			
Indian rock python	0	1	Insects		
			Grasshoppers	31	0
Birds			Glow worms	24	0
Red-whiskered Bulbul	4	0	Unidentified insects	15	0
Unidentified birds	3	0	Butterflies	13	0
Red-vented Bulbul	1	0	Caterpillars	13	0
Indian Scimitar-Babbler	1	0	Praying mantis	9	0
White-throated Kingfisher	1	0	Beetles	7	0
Greater Coucal	0	1	Cockroaches	6	1
Nightjar sp.	0	1	Moths	4	0
Spotted Dove	0	1	Stick insects	4	0
			Crickets	2	0
Mammals			Damselfly	1	0
Mouse	102	0	Wasp	1	0
Rat	11	2	Cicada	0	1
Western Ghats striped squirrel	8	5			
Bat	7	0	Arachnids		
Shrew	7	0	Scorpions	9	0
Indian crested Porcupine	5	1	Spiders	8	0
Indian Palm Squirrel	3	0			
Black-naped Hare	2	0	Crabs		
Bonnet Macaque	2	1	Crabs	16	0
Brown Palm Civet	1	0			
Barking Deer	0	1	Unidentified	2	0
Sambar	0	1			
Indian Spotted Chevrotain	0	1			
Indian Giant Squirrel	0	1			
Small Indian Civet	0	1			
Common Palm Civet	0	2			
Lion-tailed Macaque	0	2			

Among mammals, murids and small squirrel species were most frequent in roadkills. These animals may become confused by vehicular movement, which may compromise their agility leading to a higher possibility of roadkill (P.J., personal observation). Most murids were killed on roads through forest stretches, most likely during night times. Bats may get killed when they try to catch the insects attracted to the lights of passing vehicles during the night time. Other mammals such as Indian porcupine, bonnet macaques, lion-tailed macaques, common palm civet, small Indian civet and sambar were killed perhaps while attempting to cross or because of food items offered[11] or thrown as debris by tourists along the roadside. It is also possible that especially for nocturnal mammals (from small murids to large sambar deer), continuous sidewalls without any gaps along the road would hinder their movement coupled with the confusion caused by dazzling vehicle headlights at night.

With the low sample size of bird roadkills (which may be due to the high mobility of birds), it is difficult to arrive at firm conclusions. However, it is interesting to note that their roadkill rates were more during summer than in monsoon. Since all the birds killed were resident birds it may be possible that they fly about more frequently during their breeding season (i.e. summer) near the road than during the monsoon.

Vijayakumar *et al.*[9] studied the impact of habitat on the herpetofauna in 1998 by surveying three transects of 2.5–3 km (Puthuthottam, Andiparai and Akkamalai) in the same study area. They found that amphibian roadkills were associated with coffee and forest habitat, while reptile roadkills were found only in forest habitat. It should be noted that their transects fell within our Puthuthottam and Waverly transects (Table 1) and we found more or less a similar pattern during our study. Overall, more roadkills were observed in tea habitat in our study, as probably this is the dominant form of land use on the Valparai plateau (9 of 11 transects). A large number of roadkills in forest habitat, despite its occupying a smaller fraction of the surveyed routes, which included numerous forest-dependent and endemic species, suggests that mitigation measures need to be prioritized for road stretches that abut or pass through forests. For arboreal animals like rainforest primates and squirrels, installation of canopy crossing structures and retention of natural overhead canopy connectivity[8] across the road are required to facilitate their safe movement. While a range of such wildlife crossing and roadkill mitigation structures and measures are now available and known to be effective if implemented scientifically[25], there has been little effort to design and integrate such mitigations along roads in the Western Ghats. Monitoring roadkill rates per kilometer, as in the present study, can serve as a useful index to compare over time, across sites and studies, and determine the placement and efficacy of appropriate mitigation measures.

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