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Research article

# Wildlife-vehicular traffic collisions in the Ooty–Masinagudi–Moyar roads at Western Ghats Mudumalai Tiger Reserve, Southern India

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## Abstract

In a world increasingly fragmented by human infrastructure, it is becoming increasingly important to understand the drivers of collisions between wildlife and motor vehicles. We studied wildlife-vehicle traffic collisions in the Ooty–Masinagudi–Moyar roads at Mudumalai Tiger Reserve, southern India, and recorded 111 road kills between January and June 2024, that affected 29 species of invertebrates, reptiles, birds, and mammals. Birds were the most susceptible taxa (41.6%), followed by reptiles (24.9%), mammals (23.1%) including a golden jackal (*Canis aureus*), two spotted deer (*Axix axis*), two tufted grey langur (*Semnopithecus priam*), and invertebrates (9.5%) (ANOVA: F=0.057, df=5.965, p=0.819). The encounter rate of elephants was 1.4/km between the Sigur-Masinagudi road and 1.1/km between the Masinagudi-Moyar road and all opportunistic direct sightings were positively correlated with speed bumps in place (F=8.464, d.f. =2.545, p=0.074). The study found that birds and reptiles were slow to react to quick vehicle movements, and hypothetically drivers' inexperience in forest roads likely led to higher mortality among these species. The Masinagudi-Moyar road experienced higher collisions due to tourist safari vehicles, drivers' over-exhilaration, and wild animal feeding. To reduce wildlife road kills, we suggest regulating vehicle movements, implementing strict speed limits, controlling feeding, heightening speed bumps, and installing warning signboards along the roadside. This will help maintain a safer environment for wildlife movements.

**Keywords:** forest roads; animal feeding; roadkills; tourism; vehicle movements

## 1 | Introduction

Wildlife tourism, which accounts for 10.28% of India's GDP, is also liable for wildlife collisions caused by vehicles traveling through protected areas (Boominathan et al. 2008). Increasing infrastructural developments within and near the protected areas has led to a considerable increase in road kills, which pose a serious threat to free-ranging animal populations, natural habitats, and human safety (Baskaran & Boominathan 2010; Das et al. 2007; Newmark et al. 1996; Oldham & Swan 1991). The ecological effects of roads on the environment have been widely documented, with road kills being a significant cause of mortality for many free-ranging animals and potentially affecting population density and long-term survival and viability (Newmark et al. 1996). Linear features, such as roads and highways also affect fragment habitat and alter animal behaviour (Daniels 2005).

The most negative impact of roads on mammal populations may not be the direct mortality of individuals following collisions with vehicles, but rather the fragmentation of their habitat due to limitations on movements within their home ranges (Baskaran & Boominathan 2010). There is a serious risk that extensive areas of animal occurrence will be permanently cut off, resulting in isolated populations, endangering the long-term survival and viability of certain migratory species, especially large mammals (Fahrig & Rytwinski 2009). Animal road crossings are not evenly distributed throughout different spatiotemporal scales (Shwiff et al. 2007). Migratory species can be quite persistent in their use of crossing sites, a fact which should be considered when planning and constructing new roads (Seshadri et al. 2007).

Efforts to identify effective mitigation measures, such as fencing, warning reflectors, speed limits, driver awareness efforts, and over/under-passes, have been attempted, but no single technique can reliably eliminate road kills altogether (Burnett 1992). Factors such as traffic volume, speed, density of animal populations, driver awareness, time of year/month/day, road attractiveness, integration into the surrounding landscape, and roadside vegetation become relevant when selecting the best places to locate mitigation measures (Daniels 2005). Road kills are a growing and multifaceted problem in the Nilgiri Biosphere Reserve, important for safety reasons, biodiversity conservation, and economic costs. To better understand the factors influencing road kills and identify hotspots for future mitigation measures, more knowledge about the location and timing of road kills is required (Rosen & Lowe 1994). Therefore, the aim of our study was to understand the temporal dynamics of road kills in the Ooty-Masinagudi-Moyar road in Mudumalai Tiger Reserve at regular scales.

## 2 | Materials and methods

### 2.1 | Study area

Mudumalai Tiger Reserve (MTR) is a critical conservation unit in India, located on the Northeastern and Northwestern slopes of the Nilgiris region (11°31'54.9″ and 11°42'18.5″ North and between 76°21'28.9″ and 76°45'21.5″ East) (Fig. 1) (Boominathan et al. 2008). It is situated at the junction of Kerala, Karnataka, and Tamil Nadu states, and is home to a rich and varied terrain, flora, and fauna (Daniels et al. 1995). MTR plays a pivotal role in biodiversity conservation, especially for large mammals, by providing habitat contiguity of about 3300 km$^2$ connecting three other protected areas such as Nagarahole–Bandipur National Parks, and Wayanad Wildlife Sanctuary, which support a large faunal assemblage, including a high abundance of threatened species like the Asian elephant *Elephas maximus* and Bengal tiger *Panthera tigris* (Gokula 1997). 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 (Champion & Seth 1968). The MTR was created in 1940 and has been enlarged multiple times, with a core zone of 321 km$^2$ and a buffer zone of 367.59 km$^2$. The Ooty–Masinagudi–Moyar road passes through the core & buffer zones of Mudumalai Tiger Reserve (Boominathan et al. 2008). Major threats to the area include highways fragmenting the key habitats, tourist smashing bottles in the forest fringes and roadside pressure - anthropogenic pressure from the ever-expanding human population, such as cattle grazing, cultivations, settlements, forest fires, fuelwood collection, non-timber forest products, invasive species invasion, and habitat degradation (Daniels et al. 1995).

### 2.2 | Selection of study roads

Biodiversity is declining globally due to human encroachment and overexploitation, particularly in tropical regions (Row et al. 2007). Deforestation, habitat fragmentation due to roads restricting free wildlife movements, and degradation are major drivers of defaunation, exacerbated by hunting (Drews 1995). Two public roads were selected for quantifying road kills within the MTR, between (i) Masinagudi–Sigur bridge and (ii) Masinagudi–Moyar (Fig. 1). The inter-state highway branches into a state highway at Teppakadu, leading to Udhagamandalam and beyond via Masinagudi. The inter-state highway sampling segment spanned 10.1 km between Sigur bridge to Masinagudi, while the secondary road sampling segment connected Masinagudi to Moyar spanning 8 km. Traffic intensity is high during summer and vacation times on these roads, which differ in their surrounding habitats and microhabitats but represent different networks of highways traversing the reserve.

### 2.3 | Quantification of road kills

The study aimed to assess the impact of roads on wildlife collisions, specifically amphibians, reptiles, birds, and mammals. Roads were systematically surveyed and photo-documented twice a week between 0600 to 0900 and 1600 to 1900 hrs from January and June 2024 using opportunistic sampling method, recording the species, number of road kills and their status (Baskaran & Boominathan 2010). The kills were classified into fresh (killed within the last 24 hours) and old (killed more than 24 hours) based on carcass condition. The carcasses were

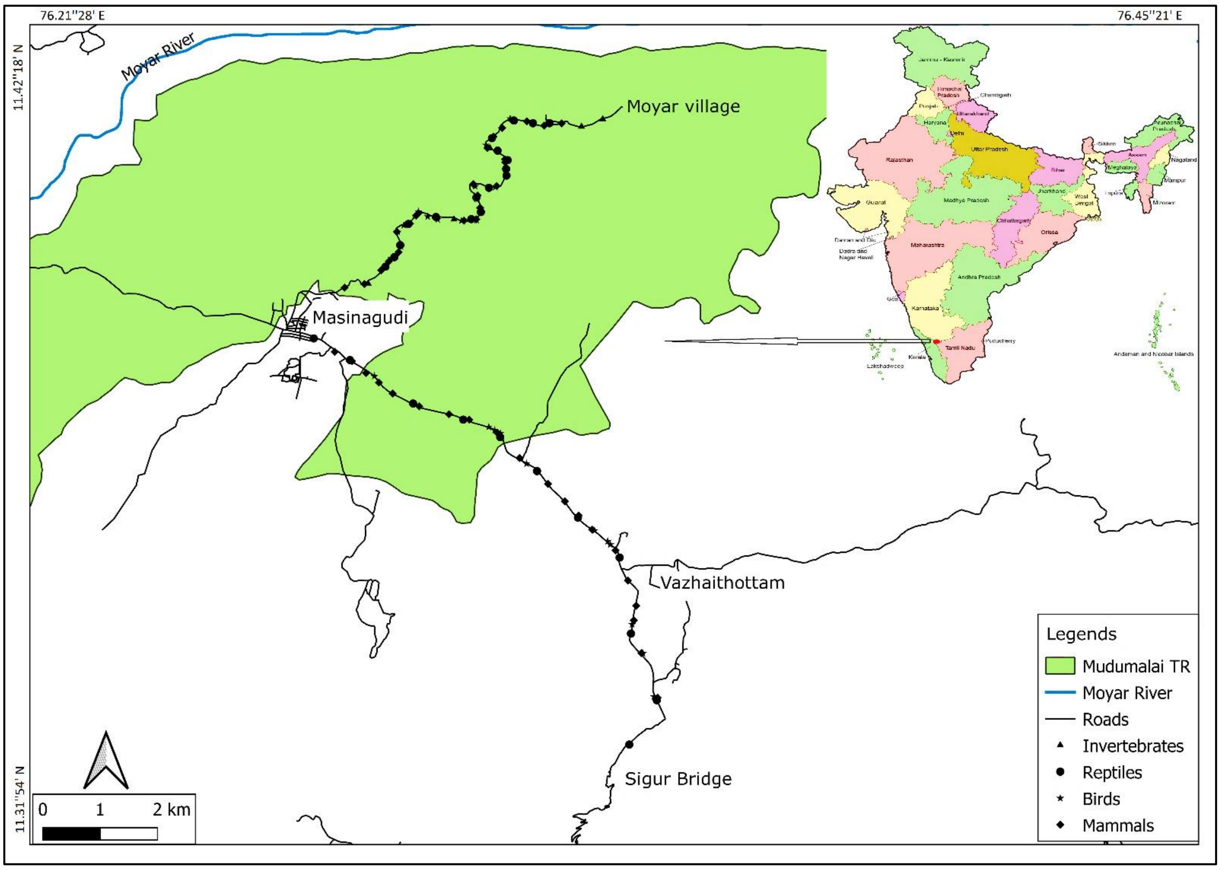


**Figure 1.** shows the wildlife-vehicle collisions in the Ooty-Masinagudi-Moyar roads and important landmarks at Mudumalai Tiger Reserve, Southern India between January and June 2024.

**Table 1.** List of species died due to wildlife-vehicle collision between January – July 2024 at Mudumalai Tiger Reserve, Southern India.

| S. N. | Photo Plate # | Common name | Scientific name | No of collisions | DR (m) | IUCN Red List status |
|---|---|---|---|---|---|---|
| | **Mammals** | | | | | |
| 1 | 1, 10 | Spotted deer | *Axis axis* | 4 | 0 | LC |
| 2 | 3 | Black-napped hare | *Lepus nigricollis* | 3 | 0 | LC |
| 3 | 2 | Asian palm civet | *Paradoxurus hermaphroditu* | 1 | 2 | LC |
| 4 | 4,5,7,8,9,12,15 | Three-striped palm squirrel | *Funambulus palmarum* | 11 | 0 | LC |
| 5 | 11 | Unknown rodent | - | 2 | 0 | - |
| 6 | 13 | Spotted deer roadkill eaten by wild boar | *Sus scrofa* eat *Axis axis* | 1 | 2 | LC |
| 7 | 14 | Tufted grey langur | *Semnopithecus priam* | 2 | 1 | NT |
| 8 | 6 | Golden jackal | *Canis aureus* | 1 | 0 | LC |
| | **Birds** | | | | | |
| 9 | 16 | Blue-faced malkoha | *Phaenicophaeus viridirostris* | 1 | 0 | LC |
| 10 | 17, 20 | Asian koel | *Eudynamys scolopaceus* | 3 | 0 | LC |
| 11 | 18 | Black-rumped flameback | *Dinopium benghalense* | 2 | 0 | LC |
| 12 | 29 | Red-vented bulbul & Red-wattled lapwing | *Pycnonotus cafer* *Vanellus indicus* | 1 | 0 | LC |
| 13 | 24, 27, 30, 31 | Yellow-billed babbler | *Argya affinis* | 13 | 0 | LC |
| 14 | 25 | Common myna | *Acridotheres tristis* | 6 | 0 | LC |
| 15 | 23 | India robin | *Copsychus fulicatus* | 5 | 0 | LC |
| 16 | 26, 28 | Red-vented bulbul | *Pycnonotus cafer* | 6 | 0 | LC |
| 17 | 19 | Red-wattled lapwing | *Vanellus indicus* | 4 | 0 | LC |
| 18 | 22 | Changeable hawk-eagle | *Nisaetus cirrhatus* | 3 | 0 | LC |
| 19 | 32 | Black kite | *Milvus migrans* | 1 | 0 | LC |
| 20 | 21 | Indian stone-curlew | *Burhinus indicus* | 1 | 0 | LC |
| | **Herpetofauna** | | | | | |
| 21 | 35, 38 | Indian chameleon | *Chamaeleo zeylanicus* | 6 | 0 | LC |
| 22 | 34 | Monitor lizard | *Varanus bengalensis* | 5 | 0 | LC |
| 23 | 33, 37 | Common garden lizard | *Calotes versicolor* | 11 | 0 | LC |
| 24 | 36 | Bronzeback tree snake | *Dendrelaphis tristis* | 2 | 0 | LC |
| 25 | 39, 40 | Indian pond terrapin | *Melanochelys trijuga* | 4 | 0 | LC |
| 26 | 41 | Brahminy blind snake | *Indotyphlops braminus* | 1 | 0 | LC |
| | **Invertebrates** | | | | | |
| 27 | 43 | Common jezebel | *Delias eucharis* | 1 | 0 | - |
| 28 | 42 | Unknown crab | - | 2 | 0 | - |
| 29 | | Unknown moth | - | 8 | 0 | - |

**Note:** #- number, DR- distance from road; LC- Least Concern; NT- Near Threatened

removed from the road to prevent further smashing (Fahrig et al. 1995). The study covered an approximately 434 km of road travel by two-wheeler at the speed of 40 km/h, and we recorded the direct encounters of mammal species sightings during the road survey to estimate their encounter rate among these two roads (Gokula 1997). The study aimed to quantify the direct impact of roads on wildlife and calculate the encounter rate of mammals observed through opportunistic survey and direct sightings (Baskaran & Boominathan 2010).

## 3 | Results

On the two forest routes, 111 road kills were reported during a six-month period encompassing a 434 km road study. With 41.5% of the collisions, birds were the most impacted taxon, followed by reptiles (25.9%), mammals (23.1%), and invertebrates (9.5%) (Tables 1 & 2). The species groupings and the proportion of road crashes had an insignificant association, as shown by the Durbin-Watson linear fit correlation $R^2$= 0.0942; P= 0.064 (Fig. 2). This may be because there are not enough data available for each category. The most vulnerable animals were birds (12 species), next mammals (8 species), and reptiles (6 species). With nearly 30% of all road kills, the Yellow-billed Babbler was the most vulnerable bird species, followed by the common garden lizard among reptiles and the three-striped palm squirrel among mammal species (Photo plates 1, 2 & 3). Traffic killed canids included the golden jackal *Canis aureus*, primates the crested grey langur *Semnopithecus priam*, and an Asian palm civet *Paradoxurus hermaphroditus*. Table 1 lists the species of animals and birds found dead on these roads. Given that an unknown percentage of animals struck by cars either perish in the surrounding vegetation or are consumed by carrion eaters, these numbers are undoubtedly an underestimate.

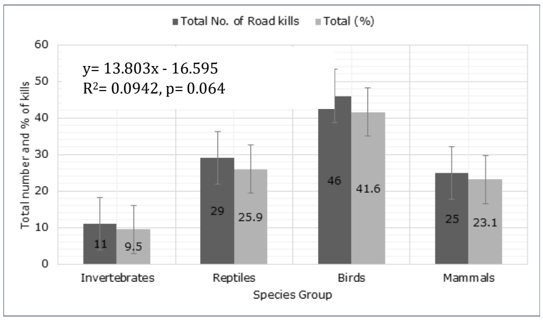


**Figure 2.** Linear fit of percentage of road collisions versus different species groups at Mudumalai Tiger Reserve between January and June 2024.

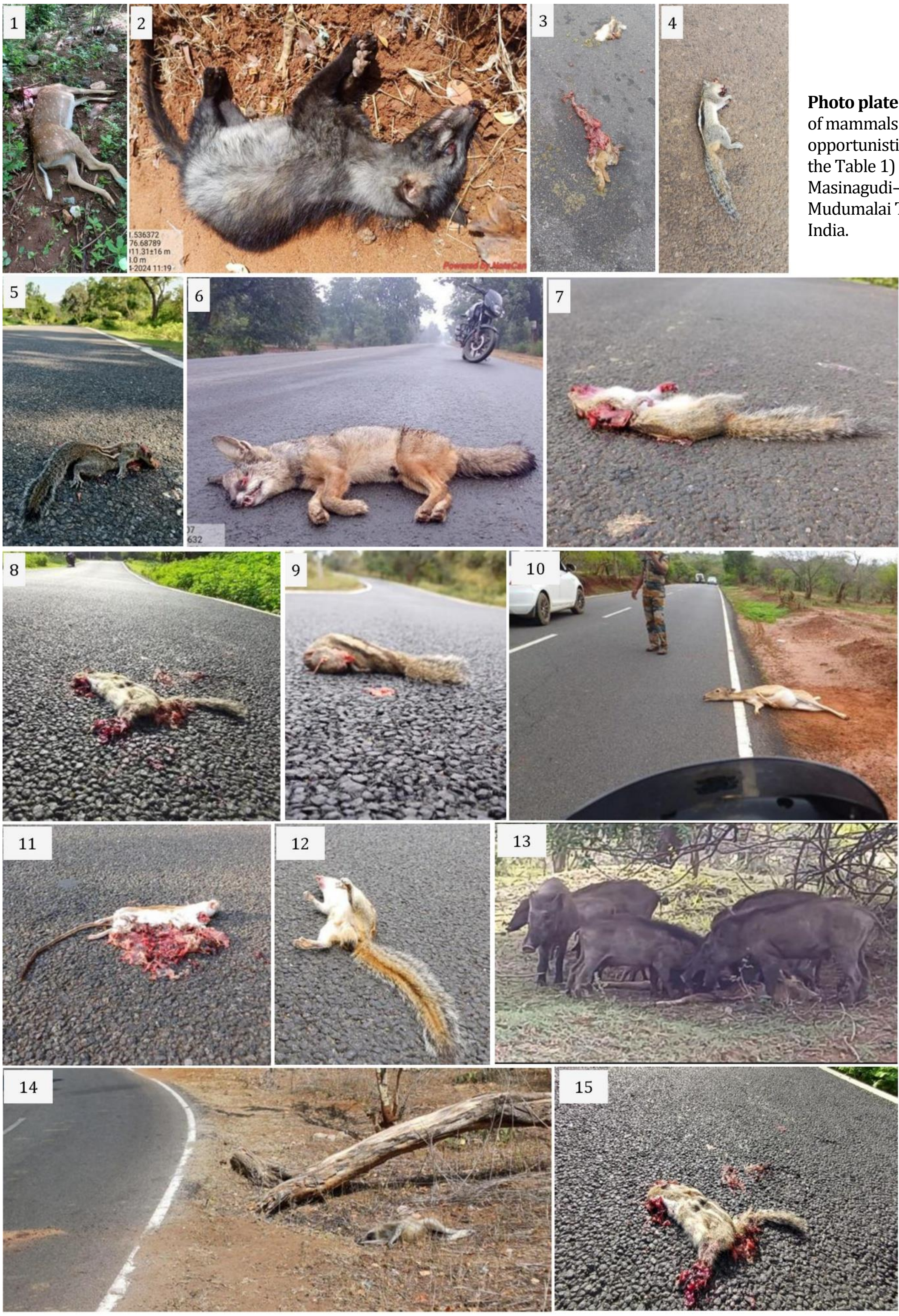

**Photo plate 1.** Road collision pictures of mammals taken during the opportunistic survey (Ref. no listed in the Table 1) between Sigur–Masinagudi–Moyar Roads at Mudumalai Tiger Reserve, Southern India.

**Table 2.** Estimated vehicle collision of wild animals recorded between January – July 2024 (A total of 109 km covered in opportunistic survey) at Mudumalai Tiger Reserve, Southern India.

| Sl. No | Species group | Total no of species | Total No. of roadkill | Total (%) | Encounter rate/km |
|---|---|---|---|---|---|
| **1** | Invertebrates | 3 | 11 | 9.5 | 0.02 |
| **2** | Reptiles | 6 | 29 | 25.9 | 0.06 |
| **3** | Birds | 12 | 46 | 41.6 | 0.11 |
| **4** | Mammals | 8 | 25 | 23.1 | 0.06 |
| | **Total** | **29** | **111** | **100** | **0.25** |


**Photo plate 2.** Road collision pictures of birds taken during the opportunistic survey (Ref. no listed in the Table 1) between Sigur–Masinagudi–Moyar Roads at Mudumalai Tiger Reserve, Southern India.

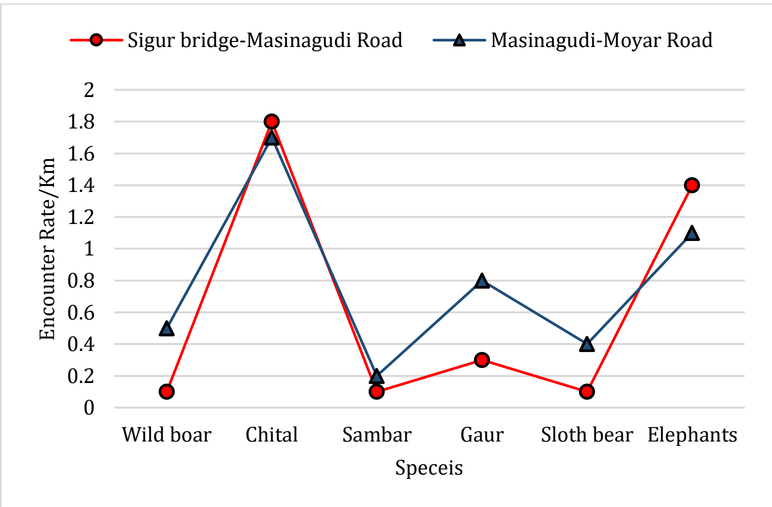


**Figure 3.** The encounter rate (/km) of mammals sighted in the two survey roads at Mudumalai Tiger Reserve between January and June 2024.

The bicycle surveys revealed that encounter rates with wild boar were the lowest at 0.1/km, followed by elephants at 1.4/km and spotted deer at 1.8/km along the Sigur-Masinagudi route. On the Masinagudi-Moyar route, the encounter rate with sloth bears was the lowest at 0.4/km, followed by elephants at 1.1/km and spotted deer at 1.7/km (Table 3 & Fig. 3). Speed calming devices (e.g., speed bumps) had a positive correlation with every interaction (F=8.464, df=2.545, p=0.07362). Road-related mortality among reptile species may have increased even though these animals were sluggish to respond to vehicle movements and the drivers' naïveté in forested areas respectively. Due to tourist safari vehicles' free access throughout the day, there are considerably more traffic accidents on Masinagudi—Moyar route (Fig. 4).

To comprehend the impact of roads, particularly those that run parallel to water sources, the number of road deaths reported in an 8-kilometer segment of a particular road that runs parallel to the Moyar canal was compared to a 10.1 km segment of the other road that travels away from waterbodies. According to the findings, the 8 km highway running next to water sources between Masinagudi and Moyar had 3.1 road deaths per kilometer, which is much higher than the 10.1 km sub-section of the second route that travelled away from water

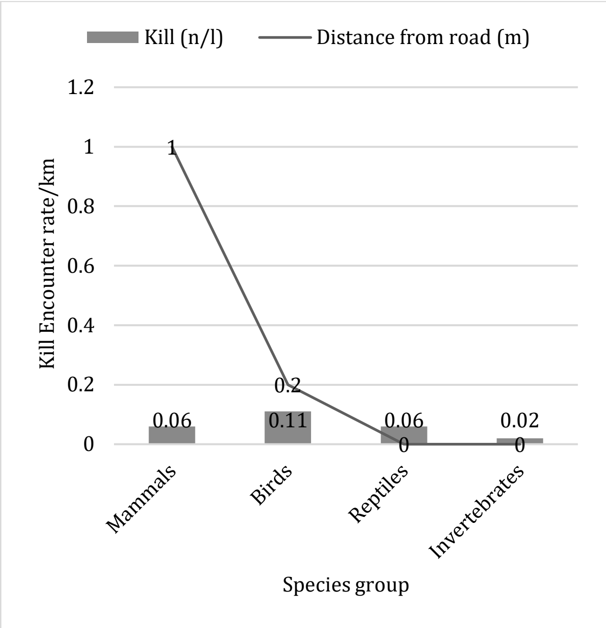


**Figure 4.** shows the encounter rate (/km) and proximity of road kills in the two survey roads at Mudumalai Tiger Reserve between January and June 2024.

bodies between Sigur bridge and Masinagudi. The reserve's 1.8 kills/km ($F = 4.00$, $df = 1$, $P < 0.05$) with no change in the taxonomic makeup are more harmful to wild animals than places free of water.

## 4 | Discussion

From a total survey effort of 434 km on the two forest roads, the research found 111 roadkill incidences. The most impacted species were birds, followed by mammals, reptiles, and invertebrates. This result is in line with earlier research conducted in Anamalai Hills and Mudumalai Tiger Reserve (Boominthan et al. 2008; Vijayakumar et al. 2001). When evaluating the barrier impact of a road, the size of the species, the speed of traffic, and its dispersion behaviour are all significant considerations (Montgomerg et al. 2012; Daniels 2005). The best highways to limit animal mobility are those with wide lanes and heavy traffic.

Birds comprised the highest fauna hit on these highways, with a count of 12 species. This may be related to the abundance of landing sites and shelter provided by shrubs and trees along the roads and they feast on insects near roadsides (Montgomerg et al. 2012), which could be due to their highly eurytopic and human commensal traits (Montgomerg et al. 2012). Yellow-billed Babbler was the most affected species, collected mostly on the road passing through shrub habitat. Mammals were affected second-most, with most road kills recorded in the study being diurnal species that could have been killed while crossing the roads (Vijayakumar et al. 2007). The Three-striped Palm Squirrel was observed in a considerable number of kills, possibly due to their habit of sunbathing regularly during early morning and late evening times (Baskaran & Boominathan 2010). Monitor lizard is a poikilothermic species with unique thermoregulation characteristics and was found only after rainfall and on sections of highway near water sources, such as streams and rivers (Daniels et al. 1995). The number of reptiles


**Photo plate 3.** Road collision pictures of reptiles and invertebrates taken during the opportunistic survey (Ref. no listed in the Table 1) between Sigur–Masinagudi–Moyar Roads at Mudumalai Tiger Reserve, Southern India.

**Table 3.** Details of mammals sighted during the opportunistic road survey in different roads (max. perpendicular distance recorded was 20 m) at Mudumalai Tiger Reserve, Southern India.

| Road Name | Encounter Rate/km | | | | | |
|---|---|---|---|---|---|---|
| | Wild boar | Spotted deer | Sambar | Gaur | Sloth bear | Elephants |
| Sigur bridge-Masinagudi Road | 0.1 | 1.8 | 0.1 | 0.3 | 0.1 | 1.4 |
| Masinagudi-Moyar Road | 0.5 | 1.7 | 0.2 | 0.8 | 0.4 | 1.1 |

killed on these two roads was higher in the dry season, possibly due to their generally higher activity during this period when temperatures are higher, and food availability is greater (Montgomerg et al. 2012). Moreover, abundant rainfall may flood reptile burrows, compromising their thermal regulation and forcing them to seek new, more reliable places to bask, such as hot asphalt on the roads. Snakes were also affected; Bronzeback Tree snake roadkill was recorded twice.

Common garden lizard (*Calotes versicolor*) was among the more susceptible reptiles (Gokula 1997; Boominathan et al. 2008). Many reptile species were found only after rainfall and on sections of road near water sources, such as canal/rivers. The number of reptiles killed on the roads was one-third higher in Mudumalai Tiger Reserve and xxx, possibly due to their generally higher activity during this period when temperatures are higher, and food availability is greater (Daniels 2005). The speed of the traffic, the size of the species, and its dispersal behaviour are also cited as important factors when assessing the barrier effect of a road (Desai & Baskaran, 1996). Wide roads with high traffic densities restrict animal movement most effectively.

The present study shows that highways have a severe impact on wildlife including Near Threatened tufted grey langur, reptiles, birds and mammals. We recommend long-term studies in vehicle movement collisions on wildlife studies to understand the various impacts of highways on wild animals. To minimise the impact of road kills on wildlife, we recommend increased size of speed breakers and situating them every 500 meters on straight-flat roads because the existing structures are not effectively slowing vehicular movements, installation of signboards along flat terrain roads with strict speed-limits and enforcement of those speed-limits, not upgrading roads, and clearing bushes near roadsides to reduce the impact of vehicular collision on animals. Strict regulation or interdict of tourist vehicles movement in the Masinagudi-Moyar roads is mandatory. Long-term studies are needed to understand the full extent of these impacts.

## 5 | Conclusions

Roadkill observation is a crucial single wildlife observation and sampling approach for ecology. It expands knowledge across various ecological research areas and aids investigations to reduce road effects on wildlife populations. The development of tools is essential for wildlife protection and sustainable transport infrastructure development, complementing other negative effects of roads.

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## Authors' contributions

K.N. conceptualized and designed the study. G.P. collected field data; K.N. analysed the data and wrote the manuscript.

## Conflicts of interest

The authors declare no conflict of interest.

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